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Advances in obstetric anesthesia: anesthesia for fetal intrapartum operations on placental support

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Abstract
Fetal intrapartum operations on placental support (OOPS), also known as ex-utero intrapartum treatment (EXIT) procedures, are very rare (and often challenging) surgical techniques designed to allow partial delivery (cesarean section) of a fetus with a potentially difficult airway, with subsequent management of the neonatal airway (direct laryngoscopy, fiberoptic bronchoscopy, or tracheostomy) while oxygenation is continuously maintained via the placenta (on placental support). The peripartum management of pregnant women and their fetuses undergoing OOPS is very complex and multidisciplinary, and differs greatly from that of standard cesarean sections. The goal of this article is to review the current recommendations for the peripartum anesthetic management of pregnant women carrying fetuses with fetal congenital malformations undergoing OOPS.

Key words Cesarean section · Obstetric anesthesia · Fetal surgery · Operations on placental support (OOPS) · Ex-utero intrapartum treatment (EXIT) procedure

Introduction

Recent advances in the prenatal diagnosis (and treatment) of fetal congenital malformations (including abnormalities of the fetal airway) have led to the development of fetal intrapartum operations on placental support (OOPS), which primarily focus on the management of the potentially difficult fetal airway before the severing of the umbilical cord [1–5]. These very rare procedures are also known as ex-utero intrapartum treatment (EXIT) procedures on the fetus/neonate [4,6]. OOPS are performed in conjunction with an elective cesarean delivery.

The peripartum anesthetic management, which usually requires general anesthesia, of pregnant women undergoing OOPS is very different from that of standard cesarean sections [1–19]. These differences can be summarized as follows (Table 1) [1–19]. First, deep volatile anesthesia (often exceeding 2 minimal alveolar concentration [MAC]) with isoflurane or sevoflurane (often in conjunction with continuous intravenous infusion of nitroglycerine) is required to maintain full uterine relaxation. Second, unlike a standard cesarean section, there is no need to limit induction of anesthesia or skin incision to delivery time. Third, the maintenance of maternal intraoperative cardiac output (CO) and blood pressure (BP) might at times necessitate continuous intravenous infusions of dopamine. The fetus is only partially delivered from the uterus with maintenance of placental support for the duration of time needed to secure the potentially difficult neonatal airway (direct laryngoscopy, fiberoptic bronchoscopy, or tracheostomy) [1–19].

Historical perspective

OOPS were initially developed for the management of tracheal occlusions in fetuses with congenital diaphragmatic hernias (CDH) [18]; however, over time, these procedures have been widely adapted to treat a variety of other fetal congenital abnormalities [2,5,7,11,17]. Current indications for OOPS include the peripartum management of fetuses with large fetal neck masses (e.g., lymphangiomas and teratomas), and fetuses with a wide variety of congenital syndromes (e.g., Treacher-Collins syndrome), among many other extremely rare

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Table 1. Summary of major requirements in OOPS that differ from those of standard cesarean section

1. Deep volatile anesthesia (e.g., above 2 MAC) is often employed
2. Continuous infusion of nitroglycerine may be required to maintain uterine relaxation
3. There is no need to limit induction of anesthesia or skin incision to delivery time
4. Maintenance of maternal hemodynamics might necessitate infusions of dopamine
5. The fetus is only partially delivered, with maintenance of placental support
6. Direct fetal anesthesia for airway management might be necessary

Table 2. Reported indications for OOPS

1. Congenital diaphragmatic hernias (CDH)
2. Fetal neck masses (e.g., lymphangiomas and teratomas)
3. Fetal lung masses
4. Treacher-Collins syndrome
5. Congenital high airway obstruction syndrome (CHAOS)
6. Congenital cystic adenomatoid malformation of the lung (CCAM)
7. Unilateral fetal pulmonary agenesis
8. Thoracoomphalopagus conjoined twins
9. Large fetal intra-oral cyst
10. Cystic hygroma of the neck and oropharynx
11. Benign fetal mediastinal tumors
12. Malignant fetal mediastinal lymphoma
13. Congenital giant ranula
14. Cervical fetus in-fetu syndrome
15. Fetal laryngeal stenosis/atresia

conditions (Table 2) [1–19]. It is well established that all these abnormalities are associated with a high likelihood of difficult airway control at birth following routine modes of delivery [5]. The antenatal diagnosis (usually by ultrasound) of these conditions allows the primary care physician (usually the obstetrician) sufficient time to assemble a multidisciplinary team of experts for the *special* delivery (OOPS) of these high-risk fetuses and establishment of the neonatal airway while on placental bypass (on placental support) [19]. Hedrick et al. [17] recommended that indications for OOPS should be expanded to include any fetal anomaly in which resuscitation of the neonate may be compromised. The current indications for OOPS reported in the literature are listed in Table 2.

The multidisciplinary approach

OOPS are by their very nature a multidisciplinary effort and require meticulous advanced planning and preparation. At the University of California, San Diego, a preoperative meeting (case conference) with the participation of representatives from several specialties/subspecialties, including obstetrics and gynecology, perinatology, obstetric anesthesia, neonatology, pediatric otolaryngology, and nursing, among many others, occurs several weeks prior to each of these procedures. Members of each specialty/subspecialty develop a detailed specialty-specific perioperative protocol that is carefully coordinated and meticulously carried out on the day of surgery. The successful and safe perioperative management of pregnant women undergoing OOPS requires the multidisciplinary team of experts to understand and consider the unique changes in anatomy and physiology that take place during pregnancy (Table 3) [20–22]. An outline of the anatomical and physiological changes in pregnancy is discussed in the following section of this review [22].

Anatomy and physiology of pregnancy

Marked changes in anatomy and physiology occur in women during pregnancy (Table 3) [22]. Many of these changes require alterations in perioperative anesthetic techniques.

The cardiovascular changes that take place during pregnancy may complicate the evaluation of intravascular blood volume and the assessment of blood loss during cesarean section, and even more so during OOPS [20,22]. Maternal hemodynamic measurements may not accurately reflect the status of the uteroplacental circulation. It is important to remember that pregnancy maximally dilates the uterine vasculature, so that autoregulation is absent, and uterine blood flow is entirely dependent on maternal mean arterial blood pressure (MAP).

The coagulation system is significantly altered during pregnancy, with changes in both blood clotting and fibrinolysis. Pregnancy represents a state of accelerated but compensated intravascular coagulation, which has both advantages and disadvantages for the pregnant woman [22]. Increased levels of coagulation factors may improve hemostasis following surgery; however, at the same time, parturients remain at increased risk for thromboembolic complications during periods of immobilization (e.g., in the postpartum period, and particularly after surgery). Because buffering capacity during pregnancy is diminished, pregnant women rapidly develop metabolic acidosis during periods or hypoxia and hypoperfusion.

Table 3. Physiological changes of pregnancy with anesthetic significance/implications

System affected	Change: ("+" increase or "–"decrease)
Central nervous system	
Minimal alveolar concentration (MAC) for inhaled anesthetic agents	–40%
Cardiovascular system	
Peripheral vascular resistance (PVR)	–15%
Heart rate (HR)	+15%
Stroke volume (SV)	+30%
Blood volume (BP)	+35%
Cardiac output (CO)	+40%
Plasma volume	+45%
Pulmonary system	
Functional residual capacity (FRC)	–20%
HCO_3	–15%
$PaCO_2$	–15%
PaO_2	+10%
Respiratory rate (RR)	+15%
Oxygen consumption	+20%
Tidal volume (VT)	+40%
Minute ventilation (MV)	+50%
Hematological system	
Hemoglobin (Hgb)	–20%
Clotting factors	+50% to 200%
Renal system	
Glomerular filtration rate (GFR)	+50%

The mean body weight increases in pregnancy. It is not uncommon for the pregnant woman to gain 20 kg or more during pregnancy. Weight gain and uterine enlargement lead to decreased functional residual capacity (FRC) of the lungs, which hastens the onset of hypoxemia during periods of hypoventilation or apnea [22–24]. Pregnancy results in a significant increase in breast size. In the supine position the enlarged breasts tend to fall back against the neck, which can interfere with insertion of the laryngoscope and intubation. Therefore, the use of a short-handled laryngoscope has been widely recommended in obstetric patients [24]. In addition, placing the patient in the sniffing position helps keep the laryngoscope handle away from the breasts.

Vascular engorgement of the respiratory tract during pregnancy leads to edema of the nasal and oral pharynx, larynx, and trachea [23,24]. These changes in the nasal mucosa may result in bleeding at the time of airway manipulation or nasogastric tube placement. Laryngeal edema may inhibit the passage of a standard-size endotracheal tube (despite adequate vocal cord visualization at laryngoscopy) and a smaller internal-diameter tube size may be required. Furthermore, tongue enlargement may make it difficult to retract the tongue into the mandibular space during direct laryngoscopy.

Increased maternal metabolic requirements combined with fetal metabolic needs and increased maternal respiratory requirements result in increased maternal oxygen consumption. In approximately 12%–15% of parturients at term, the gravid uterus may compress the vena cava and aorta when the patient is in the supine position, causing decreased venous return, decreased cardiac output, decreased blood pressure, and decreased uterine blood flow. Therefore, pregnant women should not be allowed to assume the supine position [22–24].

Pregnant women have an elevated gastric acid content, with decreased pH, and reduced function of the gastro-esophageal sphincter secondary to the mechanical and hormonal effects of pregnancy. Consequently, all parturients should be assumed to have full stomachs and are at increased risk for aspiration of the gastric contents [24]. General anesthesia should always be induced with cricoid pressure in order to decrease the risk of regurgitation of the gastric contents in the pharynx. Lung denitrogenation with the administration of 100% oxygen is mandatory before rapid-sequence induction of general anesthesia.

Monitoring

The overall goal of anesthetic management of a pregnant woman undergoing cesarean section and OOPS is to maintain the mother and her fetus (until the umbilical cord is severed) in the best possible physiological condition [20–23]. This requires that we effectively monitor the mother and the fetus in the perioperative period. Essential maternal monitoring includes blood

Table 4. Perioperative monitoring during OOPS

1. Blood pressure
2. Heart rate
3. Respiratory rate
4. Electrocardiogram
5. Oxygen saturation
6. End-tidal carbon dioxide
7. Fetal heart rate

pressure (BP), pulse rate, electrocardiogram (ECG), respiratory rate, temperature, pulse oximetry, and end-tidal CO_2 ($ETCO_2$, Table 4) [22]. As OOPS may be associated with significant blood loss, continuous intra-arterial BP monitoring, in addition to standard anesthesia monitors, is indicated.

Aorto-caval compression must be prevented with a left uterine displacement device, such as a wedge [20,21,23]. Hyperventilation should be avoided; maternal respiratory alkalosis is easy to produce, as resting $ETCO_2$ is already reduced to 32 mmHg and FRC is reduced by approximately 20% during pregnancy (Table 3) [22]. Respiratory alkalosis shifts the oxyhemoglobin dissociation curve to the left and thus may impair transfer of oxygen across the placenta. Umbilical blood flow is also decreased with alkalosis. Continuous $ETCO_2$ monitoring may help to avoid both over- and underventilation [22].

Fetal heart rate (FHR) monitoring (either by Doppler technique or by fetal pulse oximetry) may prove useful at identifying intraoperative conditions leading to impaired uteroplacental blood flow and fetal oxygenation prior to delivery [23]. A normal FHR is between 120 and 160 beats per min, with 3 to 7 beats variability. Variability is decreased by hypoxia and by sedatives and other anesthesia drugs.

Premedication

The goals of routine preanesthetic medications typically are as follows: first, to dry secretions; second, to prevent vagal activity; third, to provide anxiolysis; fourth, to ensure analgesia for uncomfortable anesthetic procedures (e.g., arterial line placement prior to induction of anesthesia); and fifth, to provide a basal level of analgesia for surgery [22]. Sedative drugs are usually avoided in pregnancy, and verbal reassurance may often suffice for the patient undergoing cesarean section under general anesthesia.

In selected cases, it is not unreasonable to administer an anticholinergic agent, which decreases secretions and lessens the likelihood of bradycardia during anesthesia. Atropine readily crosses the placenta and results in an increased FHR, with decreased beat-to-beat variability. In contrast, glycopyrrolate does not readily cross the placenta, and it is the anticholinergic agent of choice [22]. Unfortunately, the use of anticholinergic agents results in decreased lower esophageal sphincter tone [22,23]. Moreover, most patients dislike the mouth dryness that follows the administration of an anticholinergic agent. When an anticholinergic agent is indicated, glycopyrrolate may be given intramuscularly 30 to 60 min before the induction of anesthesia, or intravenously just before the administration of anesthesia.

Metoclopramide is a procainamide derivative that is a cholinergic agonist peripherally and a dopamine receptor antagonist centrally. A 10-mg intravenous dose of metoclopramide increases lower esophageal sphincter tone, has an antiemetic effect, and reduces gastric volume by increasing gastric peristalsis. Metoclopramide can have a significant effect on gastric volume in as little as 15 min. Metoclopramide crosses the placenta, but studies have reported no significant effects on the fetus [22,23]. The mother should also receive 30 ml of sodium bicitrate orally prior to the induction of general anesthesia for cesarean section and OOPS, to reduce gastric acidity [17,18].

Drugs for anesthesia

Although the overall use of general anesthesia has been steadily declining in obstetric patients [20], in selected cases (e.g., an emergent cesarean section, or OOPS), it may still be preferred, indicated, and/or necessary [1,2,8,11]. The following section reviews the drugs most commonly employed for the administration of general anesthesia in pregnant women.

Volatile halogenated agents

Potent inhalational halogenated agents in adults are usually administered for the maintenance phase of general anesthesia [25]. Those in use today include sevoflurane, isoflurane, and desflurane. Potent inhalational halogenated agents can affect the fetus indirectly, by causing maternal hypotension and/or hypoxia, or directly, by depressing the fetal cardiovascular or central nervous system [22]. Studies in an animal model (gravid ewes) have shown minimal maternal and fetal effects with the administration of moderate (e.g., 0.75–1.0 MAC) concentrations of volatile halogenated agents. However, higher concentrations of inhalational agents (e.g., 2.0 MAC), which are frequently used for OOPS (to maintain uterine relaxation), when combined with prolonged exposure (e.g., prolonged manipulation of the difficult neonatal airway on placental support), may cause maternal hypotension and decreased uteroplacental blood flow, and may affect the fetus (e.g., fetal hypoxia and acidosis) [22,23].

Nitrous oxide

The uptake and elimination of nitrous oxide are rapid, primarily as a result of its low blood-gas partition coefficient. It produces some analgesia, and in concentrations greater than 60% may produce amnesia. Because of its high solubility compared to oxygen, nitrous oxide may diffuse into the cuff of an endotracheal tube and lead to a marked increase in cuff pressure, which could result in significant airway management complications (e.g., high cuff pressure-related ischemia of the tracheal mucosa) [26]. This may be particularly important in pregnant patients because of the physiological changes of pregnancy, which include narrowing of the airway secondary to edema.

Opioids

Fentanyl, sufentanil, alfentanil, and remifentanil are the most popular opioids used in the modern practice of obstetric anesthesia when general anesthesia is necessary [20,22]. Their primary effect is analgesia. Therefore, they are used to supplement other (e.g., potent inhalational and/or intravenous) anesthetic agents during the induction and/or maintenance of general anesthesia for cesarean sections. Opioids and induction agents decrease FHR variability and fetal depression; possibly to a greater extent than inhalational agents [22].

Intravenous induction agents

When choosing an induction agent for general anesthesia, the primary goals are [20]: to preserve maternal BP, CO, and uterine blood flow; (2) to minimize fetal depression; and (3) to ensure maternal hypnosis and amnesia [22].

Propofol

Propofol allows a rapid, smooth induction of anesthesia. It has no analgesic properties. The drug produces dose-dependent decreases in CO and arterial blood pressure. Propofol attenuates the cardiovascular response to laryngoscopy and intubation more effectively than does thiopental [22]. Some studies have noted that the administration of propofol results in a greater decrease in BP than does thiopental [20,22]. Decreased BP results in decreased uteroplacental perfusion.

Propofol is a lipophilic agent with a low molecular weight, and it rapidly crosses the placenta. Propofol does not offer significant advantages over thiopental during rapid-sequence induction of general anesthesia in most obstetric patients. However, propofol blunts the hypertensive response to laryngoscopy and intubation more effectively than the other induction agents.

Barbiturates

Thiopental is the barbiturate most commonly used for the induction of anesthesia in obstetrics. It is very short-acting and produces unconsciousness in one arm-to-brain circulation time (30 s). Recovery from the induction dose occurs in approximately 5–9 min as a result of this drug's high lipid solubility and rapid redistribution. Thiopental decreases arterial BP and CO in a dose-dependent manner [21].

Extensive published data have confirmed the safety of thiopental for the induction of anesthesia in obstetric patients. Thiopental provides prompt, reliable induction of anesthesia; it has few adverse effects on airway irritability; its pharmacokinetics is well understood; and it results in a smooth emergence from anesthesia [20–23]. Thiopental rapidly crosses the placenta, and it can be detected in umbilical venous blood within 30 s of administration. The umbilical venous blood concentration peaks in 1 min.

Ketamine

Ketamine is usually employed as an induction agent; in 30–60 s after an intravenous induction dose, it produces unconsciousness which may last for 15–20 min [20]. Ketamine is a very useful induction agent in obstetric patients [20,22]. It has a rapid onset of action, it provides both analgesia and hypnosis, and it reliably provides amnesia. In addition, its sympathomimetic properties are advantageous in patients with asthma or modest hypovolemia. Ketamine rapidly crosses the placenta, and it reaches a maximum concentration in the fetus approximately 1–2 min after administration [23].

Etomidate

Etomidate is commonly used for the intravenous induction of general anesthesia [20]. Etomidate is an intravenous induction agent that has been used in obstetric anesthesia practice since 1979. Etomidate produces a rapid onset of anesthesia in one arm-to-brain circulation time. It undergoes rapid hydrolysis, which results in a rapid recovery period. It produces a dose-dependent decrease in the respiratory rate and tidal volume.

Etomidate causes little cardiovascular depression; thus, it is an excellent choice in patients with hemodynamic instability. Intravenous injection of etomidate may result in pain and myoclonus, which can be severe [22].

Neuromuscular blocking drugs

A small dose of a nondepolarizing muscle relaxant may be given 3 to 5 min before the induction of general anesthesia to prevent fasciculations after the administration of succinylcholine [20,22,23]. Alternatively, such a small dose may serve as a priming dose if a non-

depolarizing agent is to be used to achieve muscle relaxation.

Succinylcholine
The depolarizing agent succinylcholine remains the muscle relaxant of choice for the obstetric patient. This dose provides complete muscle relaxation and optimal conditions for laryngoscopy and intubation within approximately 45 s of intravenous administration [22]. Succinylcholine is highly ionized and water-soluble, and only small amounts cross the placenta. Maternal administration of succinylcholine rarely affects fetal neuromuscular function. The anesthesiologist should confirm the return of neuromuscular function before giving additional doses of a muscle relaxant.

Rocuronium
Rocuronium is a suitable alternative to succinylcholine when a nondepolarizing agent is preferred for rapid-sequence induction of general anesthesia [20,22]. Magorian et al. [27] demonstrated that a larger dose of rocuronium [0.9 or 1.2 $mg \cdot kg^{-1}$) resulted in an onset of paralysis similar to that provided by succinylcholine, but that the duration of action was prolonged.

Regardless of the choice of muscle relaxant, laryngoscopy and intubation should not be attempted until adequate muscle relaxation has occurred [22]. The use of a nerve stimulator allows an objective assessment of the onset of paralysis and also guides the administration of additional doses of muscle relaxant. Only very small amounts of the nondepolarizing muscle relaxants cross the placenta; thus, the fetus rarely is affected. In most cases, the anesthesiologist should not attempt ventilation before insertion of the endotracheal tube [20,22].

Principles of anesthesia care

The major considerations for providing successful and safe anesthesia care for pregnant women undergoing OOPS should consist of the following principles (Table 5) [22]: (1) understanding the anatomical and physiological changes of pregnancy; (2) maintaining an adequate uteroplacental blood flow until fetal delivery; (3) avoiding and promptly treating hypotension; (4) avoiding aorto-caval compression; (5) selecting anesthetic drugs and techniques with a good record for safety; (6) selecting anesthetic drugs (e.g., nitroglycerine) and agents (e.g., sevoflurane) with rapid titratability; (7) providing adequate fetal surveillance until delivery; (8) making appropriate adjustments in technique (e.g., the depth of anesthesia) as guided by the results (e.g., BP, CO); (9) preventing placental separation following partial delivery of the fetus; (10) maintaining the fetoplacental circulation by profound uterine relaxation following partial delivery of the fetus; and (11) providing fetal anesthesia (if needed) for fetal airway manipulations [1–19,22].

Obstetric considerations

Following rapid-sequence induction of general anesthesia with cricoid pressure, a low-transverse abdominal skin incision is usually carried out. A transverse lower-segment uterine incision (as this will allow future vaginal births after the cesarean section) is performed unless anterior placentation is present (sterile ultrasonography is usually employed to map the exact position of the placenta), which might require alterations in the surgical technique. A single-use uterine surgical stapling instrument (e.g., Auto Suture Premium Poly CS-57; Norwalk, CT, USA) is typically employed for hysterotomy to maintain alignment of the tissue layers and to minimize intraoperative bleeding (A. Hull, personal communication).

The fetal head, neck, and upper part of the chest is then delivered, with the rest of the torso remaining in the uterine cavity. It is important to minimize intraoperative fetal heat loss and the loss of amniotic fluid. Maintenance of adequate amniotic fluid volume (to prevent umbilical cord compression) is supported by the continuous infusion of warm crystalloid solutions (e.g., Lactated Ringer's) through rapid fluid/blood infusion

Table 5. Anesthetic principles for pregnant women undergoing OOPS

1. Understanding the anatomical and physiological changes of pregnancy
2. Maintaining an adequate uteroplacental blood flow
3. Avoiding and promptly treating hypotension
4. Avoiding aorto-caval compression
5. Selecting anesthetic drugs and techniques with a good record for safety
6. Selecting anesthetic drugs and agents with rapid titratability
7. Providing adequate fetal surveillance until delivery
8. Making appropriate perioperative adjustments in technique as guided by the results
9. Preventing placental separation following partial delivery of the fetus
10. Maintaining the fetoplacental circulation following partial delivery of the fetus
11. Providing fetal anesthesia for fetal airway manipulations

systems (e.g., a level 1, Pressure Infusion System, Smiths Medical ASD, Rockland, MA, USA) [18,19]. Fetal hemodynamics (as expressed by FHR and partial pressure of oxygen [PaO_2]) are continuously monitored using a specially designed fetal pulse oximeter (specifically designed probe). Although the fetus is usually sufficiently anesthetized as a result of the transplacental transfer of drugs given to the mother [28], in some cases (e.g., tracheotomy), direct fetal anesthesia and muscle relaxation might be required. The duration of the placental support, the mode of fetal airway control (nonsurgical versus surgical) and time from skin incision to the delivery of the fetus depends on the type and nature of the fetal congenital abnormalities. The time on placental bypass from uterine incision to umbilical cord clamping (based on currently available case reports and case series) ranges from 8 to 66 min. Prematurity is not a contraindication to OOPS [5].

The most common significant maternal complication of OOPS is post-OOPS uterine atony. Therefore, we believe that the use of stapling instruments is essential to control uterine bleeding during OOPS.

The neonatal airway

Upper airway obstruction in a neonate at delivery constitutes an emergency [5]. When it appears possible to secure the fetal airway with direct laryngoscopy this is the first-choice technique of airway management, which should be employed. Distorted anatomy of the fetal airway should be strongly suspected in fetuses with large neck masses (e.g., lymphangiomas and teratomas) [18]. When direct laryngoscopy is difficult and endotracheal intubation not possible, other techniques (e.g., surgical tracheostomy), as deemed necessary by the otolaryngologist and/or pediatric anesthesiologist, are carried out (by the pediatric surgeon). Once the fetal airway is established (and confirmed by the $ETCO_2$), and the positive-pressure ventilation is satisfactory, the umbilical cord is severed and the neonate is fully delivered from the uterus. As most of these neonates require additional resuscitative efforts (e.g., administration of surfactant) they are subsequently taken to the neonatal intensive care unit (NICU) for further stabilization. OOPS are well tolerated by the mothers and their fetuses, and the reported perioperative morbidity rates remain low.

Goals of anesthesia

The prevention of uterine contractions and placental separation, and the preservation of uterine and placental blood flow following hysterotomy and partial delivery of the fetus are the hallmarks of OOPS [2,4,8,11]. These goals are accomplished through the maintenance of profound uterine relaxation achieved with deep levels of general anesthesia with potent inhalational agents (e.g., sevoflurane or isoflurane) [2,18,19]. Sevoflurane is usually the preferred potent inhalational anesthetic agent because of its rapid titratability [9]. General anesthesia with a high concentration of inhalational agents is believed to serve three principles: first, to provide surgical anesthesia for the mother; second, to provide tocolytic effects on the gravid uterus; and third, to provide intraoperative anesthesia for the fetus [2,5]. Additional uterine relaxation (if needed) may be obtained with tocolytic drugs, such as beta-adrenergic agonists, and/or smooth-muscle relaxants, such as nitroglycerine. Nitroglycerine is especially potent and has the added benefit of being easily titratable and short-acting.

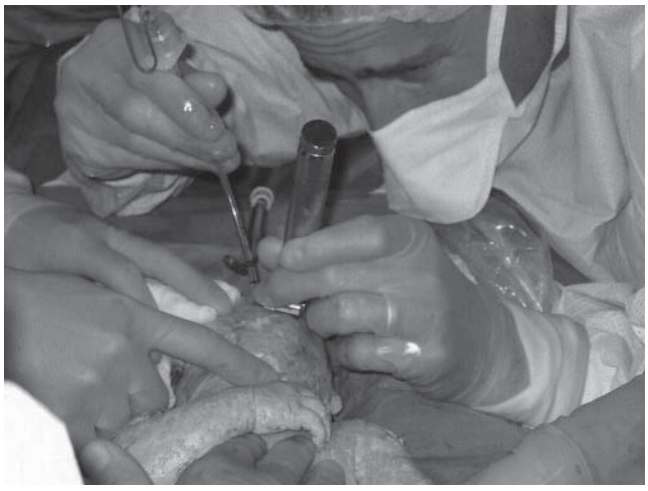
Although prior case reports describe intramuscular paralysis of the fetus [11], this author does not find this routinely necessary. Many of the maneuvers indicated to enhance uterine relaxation potentially decrease maternal BP and uteroplacental perfusion. At the University of California, San Diego, we employ aggressive volume expansion, as well as a dopamine infusion, to maintain maternal arterial BP, which is directly monitored via an intraarterial catheter. Dopamine is easily titratable and improves blood flow to the kidneys and viscera, presumably also increasing uterine blood flow.

The prolonged duration of OOPS coupled with uterine relaxation can result in significant bleeding. Furthermore, the high concentration of inhalational anesthetic agents combined with tocolytics can lead to uterine atony and continued hemorrhage post-partum. It is imperative that anesthesia providers be prepared for large amounts of blood loss and be prepared to use replacement blood products if necessary. Post-delivery oxytocin and carboprost in conjunction with uterine massage may be needed to facilitate uterine contraction.

Although it has become a standard of practice at most centers performing OOPS to use a deep level of general anesthesia (with potent inhalational agents) in order to accomplish adequate uterine relaxation [2,5,6,8,11,18,19], it has been reported (T. Okutomi, personal communication) that potent inhalational anesthetic agents used in much lower—routine for standard cesarean sections (e.g., 0.5–1.0 MAC) concentrations—combined with intravenous infusions of nitroglycerine, might offer a reasonable and safe alternative strategy to deep levels of inhalational agents for the anesthetic management of parturients undergoing these procedures.

Conclusion

OOPS are uncommon surgical procedures indicated for fetal lesions with the potential to cause life-threatening



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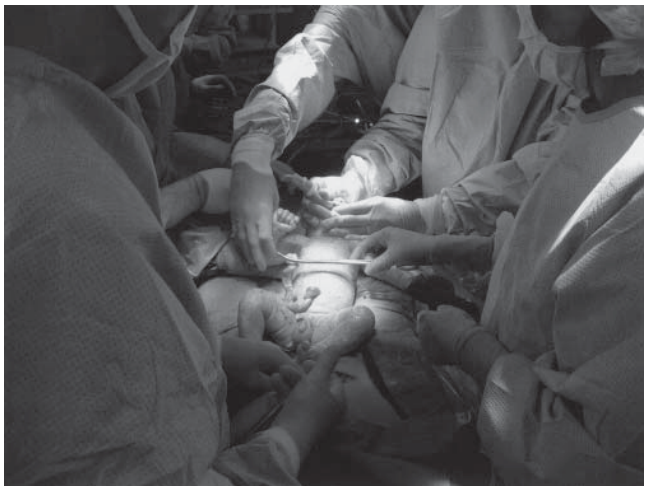

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Fig. 1a,b. Management of the potentially difficult neonatal airway on placental support during Operations on placental support (OOPS). **a** Laryngoscopy and endotracheal intubation of the partially delivered fetus; **b** delivery of the fetus after the airway has been secured

airway obstruction immediately after delivery [1–19]. By maintaining the uteroplacental circulation, the fetal airway can be evaluated and secured prior to delivery. The anesthetic goals for OOPS differ significantly from those for a routine cesarean delivery, and include profound uterine relaxation, fetal anesthesia, and maintenance of the maternal-fetal circulation (Table 5). As planning for elective cesarean section in conjunction with OOPS constitutes a complex and multidisciplinary effort, it requires meticulous advance planning and preparation. To facilitate this process, 6 years ago, at the University of California, San Diego, we established a High-Risk Obstetric Anesthesia Clinic [29], where all high-risk pregnant patients (including pregnant women with fetal congenital abnormalities) can be evaluated several weeks prior to their date of confinement. Figure 1A,B depicts the management of a potentially difficult neonatal airway on placental support during an OOPS procedure recently conducted at the University of California, San Diego, in San Diego, California, United States.

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