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Case Reports

Airway Management on Placental Support (AMPS)—The Anaesthetic Perspective

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SUMMARY

Neonatal airway obstruction has been reported to have a high mortality. Antenatal diagnosis of this condition is now possible. Anaesthetic and surgical techniques have been developed that allow neonatal airway obstruction to be managed at delivery, while the fetus remains oxygenated via the placental circulation. Three case studies are presented, and the anaesthetic issues for mother and fetus/neonate are discussed with reference to previously published cases of airway management on placental support. In particular, techniques for uterine relaxation and maintenance of placental circulation are explored. The history of these procedures and issues of planning and logistics are also discussed.

Key Words: AIRWAY: obstruction; anaesthesia, obstetric. PLACENTA: support, EXIT, OOPS

The fetal airway can be obstructed by a neck mass[1], or by absence of normal airway development[2]. The fetus may then die at delivery when placental gas exchange ceases. With the advent of antenatal ultrasound scanning in the 1970s, prenatal diagnosis of such conditions became possible[3]. Surgical and anaesthetic techniques can maintain fetoplacental gas exchange during delivery, to allow time for airway examination and any interventions which may be required to secure the airway. Interventions include endotracheal intubation at laryngoscopy or rigid bronchoscopy, and tracheostomy. Early descriptions involved complete delivery of the infant from the uterus (by caesarean section or vaginal delivery) with the umbilical cord unclamped, and the placenta left in utero[4,5]. The longest reported procedure of this kind was 14 minutes[6]. Longer procedure times (over one hour)[7] have been reported where the fetus was delivered by caesarean section only as far as the shoulders or thorax, thus leaving the cord entirely in utero (Figure 1).

This practice has been described as "OOPS" (operation on placental support)[8], but was later termed "EXIT procedure". In its first usage EXIT stood for ex-utero intrapartum tracheoplasty[9], but was renamed ex-utero intrapartum treatment to reflect the diverse procedures which may be performed[7]. Perhaps "AMPS"—airway management on placental support—would be a useful, unequivocal term to describe any airway procedure during which fetal oxygenation is allowed to continue via the placental circulation, without specifying how fully the fetus is delivered.

The keys to successful AMPS procedures are:

—Planning and logistics

—Preventing uterine contractions that impair fetal oxygenation and cause placental separation

—Providing fetal anaesthesia transplacentally to

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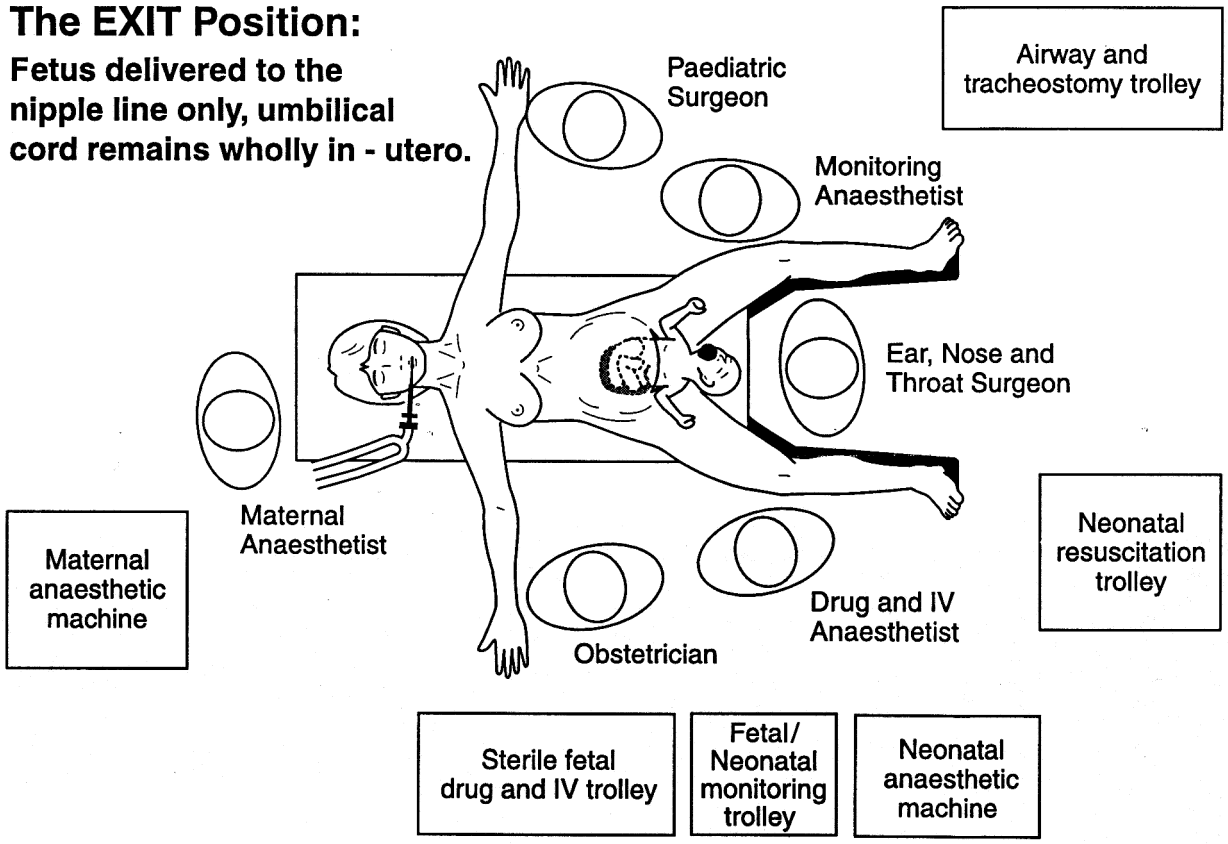

FIGURE 1

facilitate airway procedures and help maintain the fetal pattern of circulation
—Maintaining maternal homeostasis
—Fetal/neonatal anaesthesia care which may include resuscitation and subsequent tumour resection.

CASE REPORTS

This review was prompted by three cases of AMPS in which the authors were involved in the last three years. In each case the airway obstruction was prenatally diagnosed, prompting the formation of a multidisciplinary team to plan the AMPS procedure. The procedure was rehearsed preoperatively. The airway was managed along the lines of the algorithm seen in Figure 2 and umbilical lines were placed immediately post-separation. The adjacent theatre was prepared for further airway procedures and/or tumour resection. Brief descriptions follow:

Case 1 (Sydney, Australia) was a 38-year-old with polyhydramnios in a singleton 34 week pregnancy. Ultrasound and magnetic resonance imaging (MRI) showed a tumour filling the fetal naso- and oropharynx. Elective AMPS was planned but premature labour required the procedure be done urgently. Anaesthesia was maintained with propofol by infusion at 6 to 10 mg/kg/h, along with sevoflurane at 1% end-tidal concentration and remifentanil infusion at 0.4 reducing to 0.25 μg/kg/minute. The fetus was delivered to the EXIT position and given intramuscular pancuronium and vitamin K. A paediatric ENT specialist, unable to intubate at direct laryngoscopy, passed a rigid bronchoscope and placed a 3mm diameter endotracheal tube over a bougie within eight minutes. Surfactant (6 ml) was administered. After the initiation of ventilation, in the EXIT position, a left tension pneumothorax occurred, which was decompressed with a cannula. The fetus was delivered and after tube thoracostomy, the tumour (mature teratoma) was resected. Resection was complicated by large blood loss and recurrent tension pneumothorax.

Case 2 (Wellington, New Zealand) involved a term singleton fetus with an anterior neck mass on ultrasound and no polyhydramnios. The mother came to

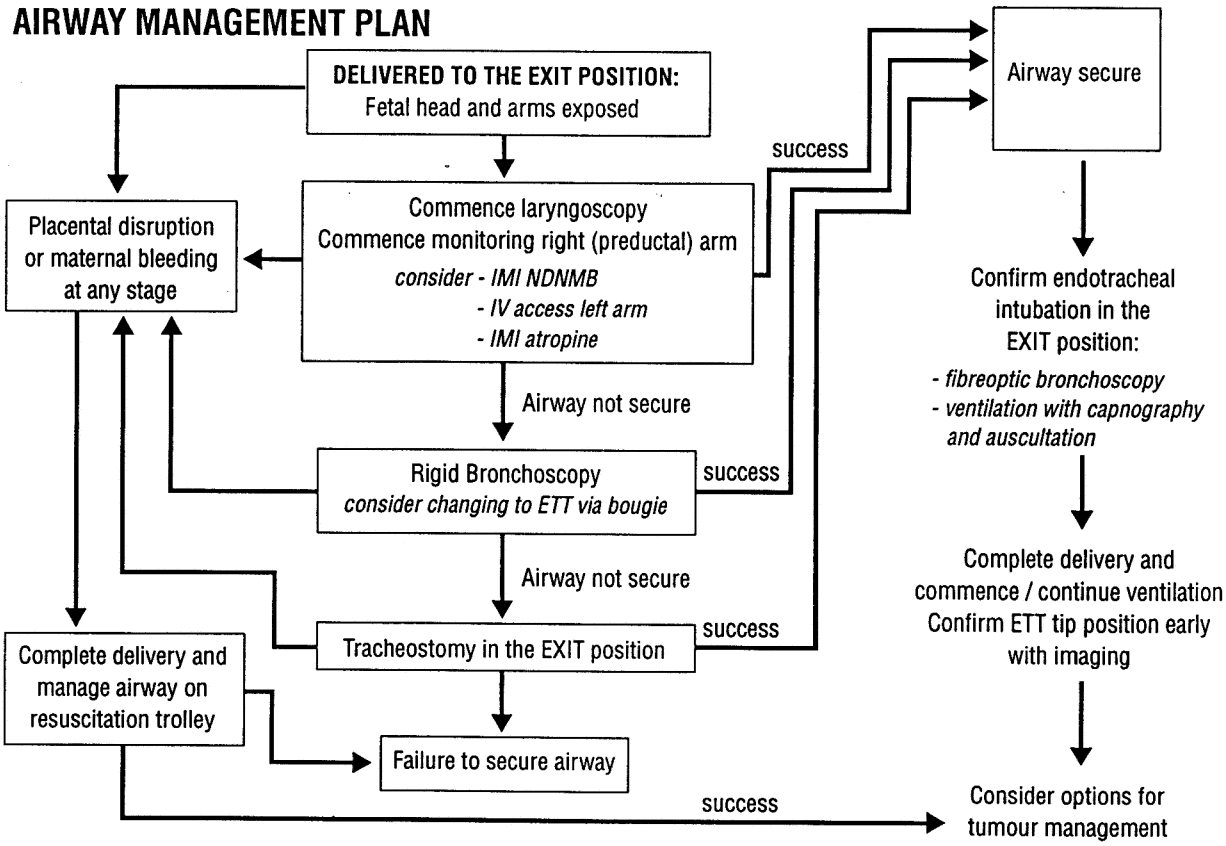

FIGURE 2

elective AMPS. Anaesthesia was maintained with isoflurane and 200 μg of fentanyl. Glyceryl trinitrate (GTN) was used to prevent uterine contraction. To preserve the potential for spontaneous ventilation the fetus was not paralysed. At direct laryngoscopy by an anaesthetist the larynx was slightly displaced by tumour and obscured by amniotic fluid from the stomach. Initial attempts at intubation were performed with only the head delivered. Delivery to the EXIT position allowed optimal positioning and successful oral intubation by direct laryngoscopy less than 12 minutes after hysterotomy. The lesion was a cystic hygroma.

In Case 3 (Sydney, Australia) a large complex neck mass, without polyhydramnios, was seen in a term, presenting (leading) twin. Elective AMPS was performed. Anaesthetic maintenance consisted of sevoflurane at end-tidal value above 4% in an air/oxygen mixture. Remifentanil infusion ran at 0.5 μg/kg/minute. The fetus was delivered to the EXIT position. An anaesthetist administered pancuronium and vitamin K to the fetus intramuscularly, and inserted a 24 gauge cannula to the left cubital fossa while an ENT surgeon achieved endotracheal intubation via a laryngoscope in 2 minutes. The lesion was a cystic hygroma. After twin 1 was delivered the inspired sevoflurane concentration and the remifentanil infusion were decreased. The second twin was delivered 10 minutes after the first and was intubated on a resuscitation trolley. This baby was extubated after 18 minutes.

Aetiology and Prognosis of Neonatal Airway Obstruction

The incidence and mortality of neonatal airway obstruction are difficult to estimate as the lesion may go unreported if the fetus is stillborn[1] and prognosis varies with the site and nature of the lesion and the degree of airway obstruction. Conditions which may cause neonatal airway obstruction[1,10, 11,12] are listed in Table 1.

Jordan and Gauderer[13] reviewed and classified cervical teratomas. Their first group (12% of fetuses with this lesion) were stillborn or died at birth from

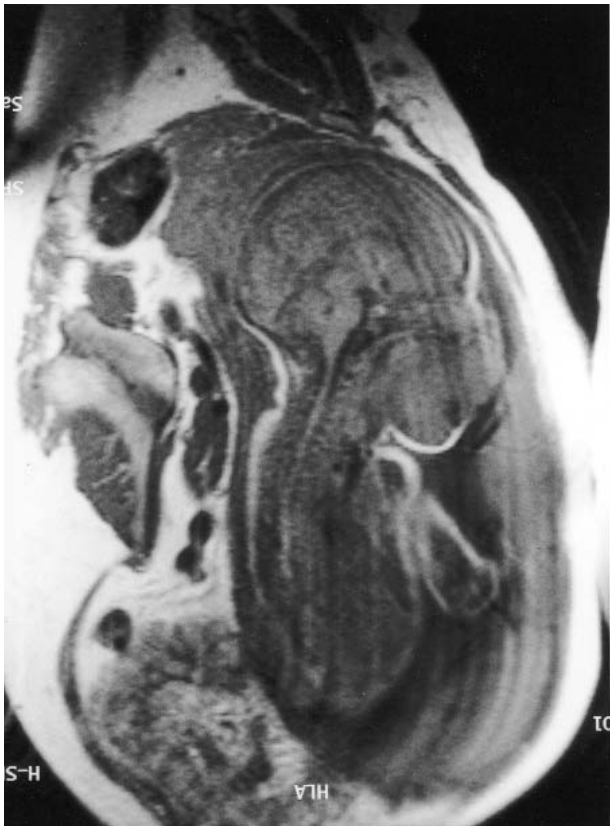

PHOTO 1: Antenatal MRI scan for patient from Case 1 showing tumour mass filling upper airway.

TABLE 1
Causes of neonatal airway obstruction

Teratoma
Cystic hygroma
Haemangioma
Branchial cyst remnants
Congenital thyroid goitre
Neuroblastoma
Neural tube defects
Hypoplastic craniofacial syndromes
Hydrocephalus
Vallecular cyst
Airway atresias
Fetal tracheal clip

severe respiratory distress or apnoea. Their second group, comprising 46% of live newborns with cervical teratomas, was a group with respiratory distress at birth and had a mortality rate of 43%. Other authors[4] report 30% mortality for neonates with cervical teratoma, and 21% for oropharyngeal teratoma. Mortality rates of 80 to 100% have also been reported[14].

Developmental abnormalities such as laryngeal atresia and tracheal stenosis can cause congenital high airway obstruction syndrome, or "CHAOS"[2]. These patients should be distinguished from those with airway obstruction by neck masses, as CHAOS is associated with renal and cardiac abnormalities, oesophageal atresia and hydrocephalus[15,16]. Before AMPS, CHAOS mortality was extremely high[2,17,18].

Prenatal Diagnosis of Potential Neonatal Airway Obstruction

Antenatal diagnosis of teratoma was first made in 1978[3]. The first report of airway rescue in the delivery room (not AMPS) prompted by prenatal diagnosis of airway obstruction was in 1985[19]. Modern ultrasound machines can sometimes estimate the degree of airway obstruction by the amount of amniotic fluid streaming through the trachea with fetal breathing movements. In one case an airway mass was found antenatally but the volume of fluid flow seen on ultrasound was such that AMPS was not performed[20]. MRI presents a means to more fully outline the lesion's substructure and nature. It may define the degree of impingement on fetal airway and vessels and reveal other anomalies such as CNS defects[21,22].

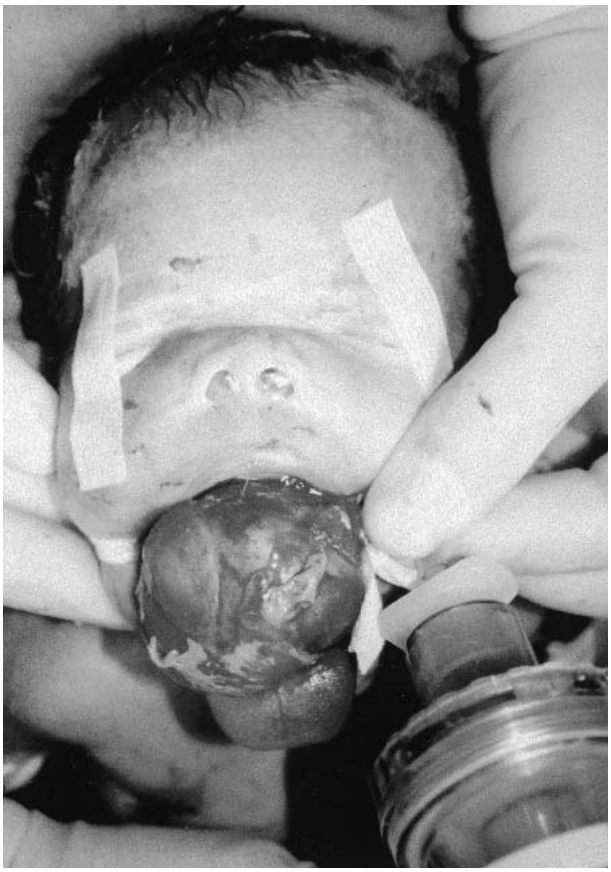

PHOTO 2: Post-intubation photo of Case 1 showing tumour mass in mouth and nose causing protrusion of the tongue.

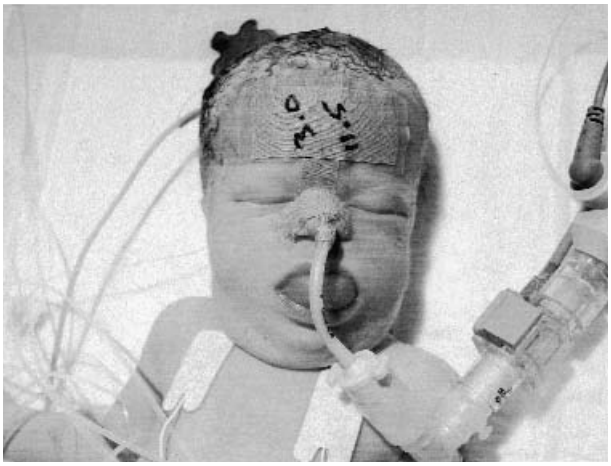

PHOTO 3: Patient from Case 3 in Children's Intensive Care Unit post-intubation.

The History of AMPS

In their work on fetal surgery in primates, Harrison and colleagues pioneered contemporary management of AMPS[23]. They used transplacental fetal anaesthesia (with halothane), perioperative tocolysis (with non-steroidal anti-inflammatory drugs, beta-adrenergic agonists and halothane) and hysterotomy with haemostatic auto-stapling devices. They aggressively treated maternal hypotension with fluids and ephedrine.

In 1985 Holinger and colleagues provided perhaps the first description of the mobilization of airway experts to the operating theatre for caesarean delivery of a fetus with expected airway obstruction[24]. Few details are provided and it is unclear whether the airway was managed on placental support.

In 1989 Norris and co-workers described the management of a fetus with a neck mass, which included details such as deliberate use of high-dose halothane anaesthesia (2-2.5% inspired concentration) to provide maternal and fetal anaesthesia as well as tocolysis[25]. It is unclear whether the infant was fully or partially delivered, but rigid bronchoscopy and tracheostomy were attempted on placental support. The infant's condition deteriorated in five minutes, although the umbilical cord (which by this time had been exposed) continued to pulsate. The infant died when an airway could not be established.

In 1990 the first successful AMPS was published[4]. The infant was fully delivered (i.e. not to the EXIT position) and the intact cord packed in warm gauze allowing time for direct laryngoscopy and intubation of the child. The anaesthetic technique was not described.

The first successful intubation in the EXIT position was reported in 1992[26].

Over 50 cases of AMPS have been published. Airway pathologies have included iatrogenic airway obstruction when the fetal trachea had been occluded in utero with a clip to treat diaphragmatic hernia[9]. Intubation on placental support is also performed for non-airway indications, e.g. for congenital diaphragmatic hernia[28]. Gaiser[27] reports performing over 25 cases of AMPS, but only some of these have been published in detail.

Planning for AMPS

Preoperative concerns include development and communication of plans for the procedure. The team includes anaesthetic, obstetric, radiology and social work staff[11] for the mother, airway experts from anaesthesia and ENT and paediatric surgeons for the fetus, and postoperative neonatal intensive care. The large number of personnel in the operating room makes logistics difficult, especially for multiple pregnancies. Plans for the positioning of staff[12] and rehearsal of the procedure in the prepared operating room are necessary. Radiology, blood bank, and pathology (for urgent histology) are involved from the planning stage. Staff should be available out-of-hours.

We had a designated team-leader/timekeeper (the neonatologist) with the power to make intraoperative decisions in the event of a crisis such as placental failure or maternal haemorrhage. This person had no hands-on role until fetal separation.

Drawing up an algorithm for airway management was useful, especially in guiding decisions under the stress of AMPS conditions. In planning for Case 1 above, we drew an algorithm to help guide management (Figure 2) and subsequently became aware of other algorithms[29,30].

All neonatal anaesthetic equipment needs to be sterilized because airway manipulation occurs within the surgical field. This includes equipment for ventilation, monitoring and intravenous access, as well as pre-diluted drugs[8,29] for muscle relaxation, resuscitation and surfactant instillation. Fetal weight can be estimated by ultrasound[31]. We prepared colloid in a sterile syringe and had O-negative, CMV-negative, irradiated packed red cells available in case of fetal blood loss.

Sterile airway equipment includes a range of direct laryngoscopes, rigid bronchoscopes, bougies, endotracheal tubes and a tracheostomy set-up. Trach-lite (Laerdal Medical Corporation, Amonk, New York,

U.S.A.), laryngeal mask airway, bag and facemask with Guedel's airway have also been tried[11], and, along with a flexible intubating bronchoscope, may be useful in some cases. Extracorporeal membrane oxygenation (ECMO) via umbilical vessels has been suggested but is untried[5]. Dissection of the cord for ECMO access may terminate placental support and defeat the purpose of AMPS. An open-care bed with overhead warmer and light should be available for ongoing resuscitation or airway management.

Fetal gestational age is important in planning the timing of AMPS. It may be useful to delay delivery as long as possible, as fetal lung maturity is important in avoiding respiratory distress syndrome (RDS). Steroids may be used, as in Case 1, to hasten fetal lung maturation. If tumour growth is faster than fetal growth the airway may become more obstructed with time[32]. Worsening of fetal hydrops in CHAOS cases is a relative indication for earlier operation to prevent intrauterine death[33], although it can resolve[34]. In CHAOS, the obstruction can prevent egress of lung fluid, so amniotic fluid markers of lung maturity may be inaccurate[2]. In polyhydramnios, premature labour often intervenes (Case 1). Early elective caesarean section increases the chance of in-hours delivery.

How Far to Deliver the Fetus?

At caesarean section, in choosing between AMPS with the entire fetus and umbilical cord delivered, or AMPS with delivery to the mid-thorax only (EXIT position), the main considerations are duration of placental support, and neonatal heat and water loss. Complete delivery of the fetus will increase evaporative losses of heat and water[38]. Exposure of the umbilical cord to cold[39] and dry air causes prostaglandin synthesis resulting in vasoconstriction, decreasing blood flow. Vaginal delivery is potentially dangerous as the cord will be exposed. Vaginal delivery also risks tumour dystocia, and trauma to the tumour, causing haemorrhage and neonatal hypotension or further intubation difficulties[26].

For AMPS at caesarean section O'Callaghan[35] chose full delivery rather than EXIT position as there were concerns that the EXIT position would limit access to the baby's airway. He reported that the umbilical cord stopped pulsating three minutes after delivery. In another case of AMPS with full delivery[25], the infant could only be maintained in good condition for five minutes, while in other cases the duration of placental support is unclear[34]. It seems the longest duration of placental support after full delivery has been 14 minutes, by which time the umbilical cord was very thin and neonatal Apgar scores were poor[6].

By contrast, placental support in the EXIT position has frequently lasted more than 20 minutes[7,17,36,37,38], with no reports of placental failure. It seems this is the superior procedure for AMPS, allowing more time for airway management, up to 60 minutes[7] or more. If the neonate is fully delivered, it should be kept at placental height until the cord is clamped to avoid placental transfusion[12,35].

Goals of Anaesthesia

In addition to the usual considerations of anaesthesia for the obstetric patient (especially maintaining maternal blood pressure) there are special considerations pertaining to AMPS procedures: maintaining fetoplacental circulation by profound uterine relaxation; and achieving fetal anaesthesia for airway manipulation. Fetal anaesthesia may also have a role in maintaining fetoplacental circulation by preventing the first breath.

Uterine Relaxation

Tocolysis is a vital part of AMPS as the gravid uterus in humans is sensitive to handling, and hysterotomy will stimulate contractions[23], which may shear the placenta off the uterine wall causing fetal hypoxia and maternal haemorrhage. Contractions may also cause fetal desaturation by compromising uterine blood flow[40]. Most tocolytic agents also cause vasodilatation and the agent of choice for AMPS has not been elucidated in a clinical trial.

Drugs that decrease uterine contractility include the anaesthetic agents halothane, enflurane, isoflurane, sevoflurane and desflurane, as well as glyceryl trinitrate, beta-adrenergic agonists, magnesium, non-steroidal anti-inflammatory drugs (NSAIDS) and nifedipine. Also, propofol reduces uterine contractility in vitro at higher dose-ranges (unpublished observations from our laboratory).

Sevoflurane use in AMPS has not been widely reported. Its in vitro dose-response curve for isolated gravid human myometrium has been determined and as a tocolytic it has similar potency to desflurane, and probably isoflurane, at equianaesthetic doses[41]. Its low blood-gas solubility[42] makes for more rapid changes in blood tension. Studies have shown no difference between the volatile agents in terms of fetal blood-gas values, acid-base status, lactate levels or in Neurologic and Adaptive Capacity scores[43-45]. Sevoflurane may produce less cardiovascular instability[42], and be removed more quickly in the event

of relative overdose[46] than other volatiles. At routine caesarean section sevoflurane had no advantage over isoflurane in rate of maternal recovery[45] although this may not be the case for longer anaesthesia times (Case 1 above took 42 minutes from incision to delivery). For these reasons, sevoflurane at high inspired concentrations may have a small theoretical advantage as the volatile/tocolytic agent of choice for AMPS.

The tocolytic effect of the volatiles is dose-dependent[47]. Although many AMPS have required no other tocolytics[8,30,37,48,49] uterine activity has been seen despite end-tidal volatile agent concentrations well in excess of one MAC (minimum alveolar concentration). Several AMPS procedures using 2-3% end-tidal isoflurane have required additional tocolysis with terbutaline or glyceryl trinitrate[7,50]. No uterine activity was detected in our cases using sevoflurane (Cases 1 and 3 above). In Case 2, using isoflurane, additional GTN was needed (boluses of 300, 100 and 100 μg, plus infusion at 16 μg/min). High concen trations of volatile agent may cause maternal hypotension and placental hypoperfusion as well as direct fetal cardiovascular depression, so volatile agent dose should be titrated to effect. The obstetrician can palpate the uterus to detect any contractions throughout the airway procedure.

Glyceryl trinitrate (GTN) has been the subject of recent review[51]. Anecdotally it is useful in 50-100 microgram boluses with rapid onset and offset of action. The main side-effects are hypotension and pulmonary ventilation/perfusion mismatch. Uterine blood flow can fall after GTN administration, and although this is usually well tolerated, it may be cause for concern during a long procedure like AMPS. Mild hypotension following GTN use has been reported during AMPS and also occurred in Case 2[7,11,50]. Studies regarding dose regimens and demonstration of efficacy when used alone and with volatile agents are awaited, but due to its favourably rapid kinetics our approach is to have it prepared for urgent use if required. A simple dilution is to add a 50 mg ampoule to a 1000 ml bag of crystalloid, giving 50 μg/ml. This can be drawn up in a syringe for 1 to 2 ml boluses.

The beta-adrenergic agonists have been used in AMPS[7,29]. Their side-effects include tachycardia and hypotension (both seen in AMPS cases), dysrhythmias, pulmonary oedema, acidosis and hypokalaemia. Their onset of action is rapid and although their β half-life is relatively long, their redistribution half-life is short[53] and IV boluses may be a useful adjunct to sevoflurane/GTN for tocolysis.

Magnesium sulphate is used for threatened premature labour[53]. It has been used in one case of AMPS under epidural block in combination with GTN[11]. The dose was not reported. Uterine contraction occurred promptly at discontinuation of infusion, and maternal blood loss was 1000 ml. Its main problem is hypotension when given rapidly intravenously[52]. The enhancement of neuromuscular blockade and toxic effects in overdose (reflex suppression, respiratory depression and cardiovascular collapse) need to be considered.

NSAIDs have not been used for AMPS at all, probably because of concern over their anti-platelet effects, neonatal renal effects and premature closure of the ductus arteriosus[53]. No report has been made of the use of nifedipine for AMPS procedures. Propofol may not convey any clinical tocolytic benefit over volatile agents and its use for anaesthetic maintenance adds complexity.

The return of uterine tone is usually, but not always, readily achieved. The weaning or cessation of volatile agent, or other tocolytic, is probably the most important step. Oxytocin has been used for many cases of AMPS, and is frequently the only uterotonic required[7,8,25,36,38]. Uterine relaxation due to ritodrine and isoflurane has been reversed with intravenous methergine and intramyometrial PGF2α, but whether this was in response to marked uterine atony is unclear. Maternal blood loss was 800 ml[29]. One group used isoflurane to 2.8% end-tidal, and required 200 μg of methyl ergonovine IMI to overcome atony that persisted despite prophylactic methyl ergonovine, carboprost methinine, and oxytocin by infusion[37]. In this case maternal blood loss was not reported. The approach in our three cases was to use oxytocin by bolus and infusion. Ergometrine was not required.

Some groups have maintained intrauterine volume with saline amnioinfusion to prevent uterine contraction, placental separation and umbilical cord compression[33,48].

Maternal Homeostasis

Uterine (and fetal) oxygen delivery can be maximized by avoiding hyperventilation[54], increasing maternal inspired oxygen concentrations[55], maintaining uterine perfusion pressure and by using uterine displacement. At AMPS uterine blood flow is at additional risk from the side-effects of tocolytics, vasodilatation and hypotension and potentially from maternal blood loss.

In general, we felt that frequent non-invasive measurements of blood pressure were appropriate

but in Case 3 (twins) we used an arterial line due to perceived increased risks of supine hypotension and maternal haemorrhage, and to more closely guard against compromise of the second twin. In Case 1, in which sevoflurane/propofol/remifentanil were used, two doses of ephedrine (6+3 mg) were needed. In Case 2 (isoflurane/fentanyl) 12 mg of ephedrine was needed after GTN infusion was commenced, whilst in Case 3 (sevoflurane/remifentanil) an ephedrine infusion (total dose 9 mg) was used. There is some evidence that ephedrine may cause fetal acidosis[56], probably through its beta-agonist effects. This may explain the pH of twin 2 in Case 3 which was 7.21. Even if maternal hypotension resolves with ephedrine, acidosis can persist[57]. Prophylactic infusion of vasopressors such as angiotensin II has been used in AMPS[37]. Both angiotensin II[58] and phenylephrine[59] have been shown to cause little neonatal acidosis, and may be better choices for AMPS, although further data is required, especially about their relative effects under general anaesthesia.

Usually after delivery, the uterus is empty and contracted, but during AMPS, with the fetus only partially delivered, the uterus is full and atonic, potentially increasing the risk of maternal haemorrhage. An important and effective surgical technique to minimize blood loss[23] is opening of the uterus with a stapling device (US Surgical Corp., Norwalk, Connecticut, U.S.A.). This device makes the incision at the same time as placing a double row of steel staples over the cut edges, decreasing haemorrhage. Maternal blood loss is not detailed in many AMPS case reports. In their early case, Norris and colleagues[25] estimated 1200 ml blood loss. In one series of eight cases, mean maternal blood loss was reported to be 925 ml[17]. Another series of five cases had a minimal maternal blood loss of 930 ml[36]. These are in the range normally associated with caesarean section[60]. Maternal blood loss was 400 and 600 ml in our first two cases, and 800 ml in the case involving twins.

Polyhydramnios, which probably results from impairment of fetal swallowing[2,24], is often present and can cause difficulty in locating the placental edge on ultrasound scanning. Some authors advocate routine amnio-reduction immediately prior to the hysterotomy so that the placental edge can be imaged and avoided[36].

In the three cases reported above, acute haemodilution was used to decrease maternal haemoglobin loss during surgery. Three, two and two litres of crystalloid were given in Cases 1, 2 and 3 respectively. We placed two large-bore IV cannulae for each case. The immediate availability of cross-matched blood for the mother should be considered.

Neuraxial versus General Anaesthesia

There are two case reports of AMPS under epidural block[6,11]. In one case GTN was given transdermally and intravenously, along with magnesium sulphate[11]. The total dose-rate of GTN was 3400 μg/hour to achieve uterine relaxation, and after four and a half minutes in the EXIT position umbilical arterial blood gas values were pH 7.31 and base deficit 5.2. Uterotonics used were oxytocin by infusion, and ergometrine 0.075 mg in three doses over 30 minutes. Maternal blood loss was estimated at 1000 ml. No comment was made about fetal/neonatal movement or anaesthesia. In the second case, tocolysis and fetal anaesthesia are not detailed, and the fetus was moving during airway procedures. Only two reports do not permit useful comparison with AMPS under general anaesthesia. Both babies born of AMPS under epidural block died, but death was not seemingly associated with anaesthetic technique.

A single case report also exists of AMPS under spinal anaesthesia[61], but here the baby cried immediately at delivery and thus fetal circulation was immediately curtailed.

The advantages of regional anaesthesia include maternal involvement and satisfaction, lower risk of aspiration and intubation difficulties in the mother, and possibly better uterine contraction post-delivery as all tocolytics can be discontinued. Volatile anaesthetic agents have been reported to increase blood loss at caesarean section[62], although perhaps not in clinically significant amounts[63].

There are several disadvantages of regional anaesthesia for AMPS. Fetal anaesthetic agents must be given directly to the fetus by intravenous or intramuscular routes to avoid maternal sedation. Single-shot spinal anaesthesia is not ideal as the procedure may outlast the block. Some authors suggest that regional anaesthesia be avoided due to its potential to worsen the effects of hypovolaemia[64]. Also, uterine relaxants must be administered in addition to regional anaesthesia. General anaesthesia with volatile agents and opioid can provide maternal and fetal anaesthesia as well as tocolysis and has been used for the majority of published AMPS procedures.

Fetal Anaesthesia

The decision about whether to allow a trial of spontaneous ventilation must be made prior to AMPS operation. A spontaneous breath will induce transition-pattern circulation and placental circulation will diminish. Placental support may then be unavailable

if the airway is later lost. Also, airway interventions may be easier if the fetus is still. Therefore there is an argument in favour of anaesthetizing the fetus to prevent the lungs from inflating until the airway is completely secure. Some groups deliver additional analgesia and/or muscle relaxation by the intramuscular route[5-7,12,36,65-67] to achieve this. The stimuli for the first breath may include hypercapnia and a fall in body temperature[67], hypoxia[69], and sensory stimuli such as cold air on the face and umbilical cord occlusion[70].

The opposing argument is that spontaneous ventilation is traditionally promoted as being safer for patients with a threatened airway who require anaesthesia. This teaching, however, pertains to self-ventilating patients, not to a fetus whose oxygenation is currently provided by the placenta. There is no clear indication of how to make this decision. In general terms we consider that if severe airway obstruction is expected, the neonate's first breath should be prevented until the airway is secured and airway security is confirmed by return of carbon dioxide with ventilation in the EXIT position.

The use of high concentrations of volatile agents will result in fetal anaesthesia as these drugs cross the placenta[71]. Fetal MAC is lower than maternal MAC by as much as 50%[72]. Since high maternal MACs are commonly used for AMPS, fetal anaesthesia is likely if time for equilibration is allowed. Deliberately long induction-to-incision times have been used for this[6,12,66,67]. Others have intentionally avoided fetal anaesthesia when aiming to achieve effective spontaneous neonatal respiration[35].

Muscle relaxants do not cross the placenta to an important degree[73], so they must be administered to the fetus intramuscularly or intravenously. Some groups give these drugs only if the fetus is moving[7]. Atropine has been used in addition to these agents[36,67]. We gave IMI pancuronium in cases 1 and 3 prophylactically. In Case 2 we elected to leave the fetus unparalysed as the degree of airway obstruction was unclear preoperatively. The fetus did not move or attempt to breathe prior to intubation in any of the three cases.

For many AMPS procedures, opioids are administered to the mother as part of a balanced anaesthetic technique. Fentanyl has been used successfully for this[10] (Case 2). Remifentanil is an ultrashort-acting fat-soluble narcotic. It causes profound narcosis and rapidly crosses the placenta in significant amounts, at least in the presence of epidural blockade[74]. We used it in Cases 1 and 3 to assist in maternal and fetal analgesia and anaesthesia, and to oppose the onset of spontaneous neonatal ventilation. Its rapid offset aids emergence from anaesthesia for the mother and fetus, which is useful if spontaneous ventilation for the fetus becomes desirable, however this requires that it be given by infusion through a secure IV line.

The neonate's first breath by positive-pressure ventilation may require the use of very high inflation pressures due mainly to surface tension effects in the alveoli. Transpulmonary pressures in spontaneous ventilation may reach 100 cmH_2O[75]. If present, surfactant deficiency will contribute to poor pulmonary compliance. Surfactant can be given prophylactically to premature infants (as in Case 1) to try to prevent pulmonary barotrauma and respiratory distress syndrome[6,7,18,36,67] Respiratory distress syndrome is common after AMPS, and sometimes fatal[5,18,30,36,49,76]. Despite surfactant, initial pressures were up to 100 cmH_2O.

Several AMPS, including Case 1 above, have been complicated by pneumothorax[76,77]. In Case 1 there was concern that pressure on the fetal thorax from the maternal abdominal wall while in the EXIT position had contributed to the high pressures required. The use of a bougie to change from a ventilating bronchoscope to an ETT or possible endobronchial intubation may also have contributed.

In order to minimize this risk in Case 3, the first breaths were delivered by mechanical pressure-limited ventilator, and this was effective in avoiding pneumothorax. Peak pressures of 45 cmH_2O were required for good chest wall movement.

An airway mass can produce a circuitous path from lips to carina, such that the correct depth of ETT insertion is increased by an unknown amount. At the same time, endobronchial intubation must be avoided. A sterile stethoscope may aid in confirmation of endotracheal intubation prior to division of the umbilical cord[29], and in the diagnosis of endobronchial intubation. In Case 3, flexible fibreoptic bronchoscopy was performed to try to confirm correct ETT position prior to terminating placental support, but the view was extremely poor due to amniotic fluid. Return of CO_2 from a pressure-limited ventilated breath in the EXIT position can be used to confirm intubation prior to termination of placental support. Early confirmation of ETT tip position by portable X-ray is important.

Tracheostomy or tumour resection, if required to establish an airway in the EXIT position, may cause fetal haemorrhage. Intravenous access in the left arm of the fetus was therefore attempted in both Cases 1 and 3, for transfusion of fluids or blood and also for administration of other drugs if required.

TABLE 2
Fetal monitoring for AMPS

Monitoring Technique	Advantages	Disadvantages
1. Clinical assessment e.g. pulse rate, volume, capillary refill	No special equipment	Changes may be late sign of placental failure
2. Auscultation for heart rate and breath sounds	Inexpensive Helps confirm ETT placement	Need sterilized stethoscope Not audible to all staff
3. Umbilical cord palpation	No special equipment	Cord should not be on view May cause cord failure Pulsation does not equate to good perfusion
4. Cutaneous ECG	Readily available, inexpensive, audible to all staff	Can be unreliable due to poor adherence Need access to appropriate sites
5. Needle ECG	Better signal pickup than adhesive electrodes Audible to all staff	Invasive Less readily available
6. Scalp electrode	Readily available Inexpensive	Equipment often bulky Invasive
7. Praecordial ultrasound	Reliable with little interference Audible to all staff	Praecordial access may be crowded
8. Adult pulse oximeter	Readily available Inexpensive Audible to all staff More information than ECG	Unreliable at low SpO_2 Adherence can be problematic Need right arm access
9. Fetal pulse oximeter	Calibrated for low SpO_2 Audible to all staff More information than ECG	Adherence can be problematic Need right arm or brow access Not readily available Expensive

Fetal Monitoring

It is vital to monitor the fetus during AMPS to detect failure of placental support[11] or cardiorespiratory compromise such as the pneumothorax in Case 1.

Table 2 lists a number of monitoring options that have been used in AMPS. Techniques 2-7 give an indication of heart rate alone, while clinical assessment and pulse oximetry also give some measure of perfusion and oxygenation. ECG and oximetry have the advantage of an audible signal that informs all staff in the theatre of changes in fetal parameters. Palpation of the cord[37] (which may risk placental insufficiency by stimulating cord vasoconstriction[77]) may not give accurate information about fetoplacental flow as in one case the infant deteriorated despite continuing pulsation[25]. Cutaneous ECG may be difficult to keep in place[7]. Scalp probes have been successfully used[17]. Doppler or cardiac echo probe gives a reliable indication of the fetal heart rate, without interference from vernix, blood or amniotic fluid[7,29,67], but a mass can interfere if it extends over the praecordium[11].

Pulse oximetry has been used in many AMPS procedures[6,7,10,17,36,38,49]. Common pulse oximeters are calibrated for oxygen saturations of 70 to 100%[78]. A fetal pulse oximeter is more accurate as mean fetal preductal SpO_2 in normal labour is around 46.9% to 50%[80,81]. There is a wide natural variation in fetal SpO_2, two standard deviations below the mean being 33%[82]. A fetal SpO_2 of 30% may be well tolerated during labour for up to 10 minutes[80]. At AMPS, reported SpO_2 has ranged from 38% to 95%[17]. Any fall in fetal SpO_2, especially below 33%, may be an indication for intervention to maximize fetoplacental flow or expedite airway security. The transition from fetal to neonatal patterns of circulation will see a large change in SpO_2. We used both adult and fetal oximeters in Cases 1 and 3 above, as we were not certain that the fetal oximeter (a reflectance-type usually used per vaginum during labour) would work well in these circumstances. The fetal oximeter on the right arm did not give dependable readings, possibly due to vernix caseosa[37], poor contact or interference from ambient light[67]. As improvements continue to be made in fetal oximetry it may become easier to use in AMPS[81]. We feel praecordial Doppler and pulse oximetry would be the ideal combination.

In Case 3, the fetus requiring AMPS was the presenting twin (Twin 1). Twin 2 was continuously monitored from anaesthetic induction until delivery of twin 1 by transabdominal Doppler ultrasound. Fetal compromise was not detected and the procedure did not have to be interrupted. We believe this is the first AMPS procedure performed for a leading twin[10].

Definitive Tumour Resection

The difficulty of the endotracheal intubation may influence the decision to proceed immediately to tumour resection, as accidental extubation may prove fatal[26]. The type of tumour, risk of haemorrhage if left untreated and the existence of other problems requiring urgent attention (e.g. cardiac abnormalities) are also relevant.

CONCLUSION

Airway management on placental support can improve the prognosis for fetuses with neck masses or airway atresia[77]. Antenatal diagnosis is now possible. A team approach, preparedness for urgent operation and rehearsal in the operating theatre are important. The obstetric anaesthetist has the unusual goals of profound uterine relaxation to allow continuing placental support as well as fetal anaesthesia. Although many tocolytics have been used, sevoflurane's rapid kinetics may convey benefits in this instance. Delivery to the mid-thorax only, with the umbilical cord remaining in utero, may increase the duration of placental support while minimizing fetal heat and water loss. Fetal anaesthesia will prevent spontaneous ventilation that may prematurely terminate fetal-pattern circulation, and can be administered transplacentally and/or directly to the fetus. Fetal monitoring is by clinical assessment, heart rate monitoring and pulse oximetry. Placental support is terminated only when a secure airway can be guaranteed.

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