Anesthesia Case of the Month

@History

A 15-year-old 564-kg (1,240-lb) Quarter Horse mare was referred to the University of Georgia Veterinary Teaching Hospital for evaluation of colic of 36 hours’ duration. The mare was 10 months pregnant and had a history of colic during previous pregnancies; it was pawing intermittently upon arrival. Physical examination revealed tachycardia (68 beats/min), increased expiratory effort, and a markedly distended abdomen. No gastrointestinal sounds were auscultated. Xylazine (0.27 mg/kg [0.12 mg/lb], IV) was administered for analgesia and to provide sufficient sedation to allow a rectal examination and nasogastric tube placement. A large fetus and a firm gastrointestinal structure on the right side of the abdomen were palpated per rectum. Three liters of net reflux was obtained from the nasogastric tube. An abdominocentesis was performed, and analysis of the abdominal fluid revealed a nucleated cell count of 2,700 cells/µL and protein concentration of 3.1 g/dL. Results of a CBC and serum biochemistry profile were unremarkable, except for mild hyperfibrinogenemia (500 mg/dL; reference range, 100 to 400 mg/dL), mild hyperproteinemia (7.1 g/dL; reference range, 4.9 to 7 g/dL), mild hyperchloremia (107 mmol/L; reference range, 95 to 104 mmol/L), moderately high creatine kinase activity (1,233 U/L; reference range, 91 to 343 U/L), and mildly to moderately high creatinine concentration (2.9 mg/dL; reference range, 0.3 to 1.8 mg/dL).

On admission, the mare was administered 10 L of isotonic crystalloid solution† IV and 20 mL of 0.22% altrenogest PO. The working diagnosis at this time was cecal or large colon impaction. Several hours later, the mare developed signs of increasing pain and was treated with detomidine (0.009 mg/kg [0.004 mg/lb], IV), butorphanol (0.009 mg/kg, IV), and flunixin meglumine (0.89 mg/kg [0.40 mg/lb], IV). The mare continued to have signs of colic, and the decision was made to perform an exploratory laparotomy.

@Question

What are the expected anesthetic complications in this patient? What is the prognosis for the mare and fetus?

@Answer

Expected anesthetic complications for any equine patient with colic include hypoxemia and hypotension, both of which are exacerbated by the normal physiologic changes associated with pregnancy. For horses positioned in dorsal recumbency, the weight of the uterus causes compression of the abdominal great vessels as well as pulmonary atelectasis and ventilation-perfusion mismatching. Hypotension or hypoxemia in the mare leads to decreased oxygen delivery to the fetus. Sedative and anesthetic drugs have effects on uterine blood flow, uterine tone, and fetal development.

There does not appear to be an increased risk of death in pregnant mares undergoing colic surgery, compared with nonpregnant control mares. The postoperative abortion rate in this population is likely to be between 20%1,2 and 46%.3

@Treatment and Outcome

The patient was premedicated with xylazine (0.53 mg/kg [0.24 mg/lb], IV) and butorphanol (0.02 mg/kg [0.009 mg/lb], IV). Anesthesia was induced with ketamine (2.1 mg/kg [0.95 mg/lb], IV) and midazolam (0.05 mg/kg [0.023 mg/lb], IV), and an endotracheal tube (internal diameter, 26 mm) was placed with the mare in sternal recumbency. Oxygen was administered through a demand valve and an additional dose of xylazine (0.14 mg/kg [0.06 mg/lb], IV) was given before the horse was hoisted to the surgery table. The mare was positioned in dorsal recumbency on a padded surgery table angled to a mild (3° to 5°) head-up position. Anesthesia was maintained with isoflurane administered in oxygen via a circle system. Intermittent positive-pressure ventilation began immediately with a respiratory rate of 10 breaths/min, tidal volume of 9 mL/kg (4.1 mL/lb), PIP of 40 cm H2O, and PEEP of 10 cm H2O. Electrolyte solution† was administered at a rate of 13 mL/kg/h (5.9 mL/lb/h), IV. An initial bolus of lidocaine (0.9 mg/kg [0.41 mg/lb]) was administered IV over 5 minutes, followed by a constant rate infusion of lidocaine (2.7 mg/kg/h [1.2 mg/lb/h]).

Monitored parameters included arterial blood pressure (measured directly), end-tidal partial pressure of carbon dioxide, inspired and expired isoflurane concentrations, tidal volume, peak inspiratory pressure, respiratory rate, heart rate, and oxygen satu-
ration (determined by means of pulse oximetry); an ECG was also monitored. The initial mean arterial pressure was 60 mm Hg, but within 5 minutes, mean arterial blood pressure was > 70 mm Hg and remained > 70 mm Hg for most of the procedure. Dobutamine (0.3 to 2 µg/kg/min [0.14 to 0.9 µg/lb/min], IV) and ephedrine (0.04 mg/kg [0.018 mg/lb], IV, once) were used to maintain mean arterial blood pressure > 70 mm Hg. Heart rate was slightly high (37 to 51 beats/min) throughout the procedure with a sinus rhythm. End-tidal partial pressure of carbon dioxide was maintained between 28 and 33 mm Hg, and end-tidal isoflurane concentration ranged from 1% to 1.3%. Tidal volume was maintained at 9 mL/kg, and PIP ranged from 28 to 41 cm H2O. Positive end-expiratory pressure was instituted at 10 cm H2O once the horse was connected to the breathing circuit. One hour after the start of surgery, PEEP was decreased to 7 cm H2O and was decreased further to 5 cm H2O 10 minutes before the end of anesthesia. Oxygen saturation remained 99% to 100% throughout the anesthetic period.

An arterial blood sample was analyzed 35 minutes after induction of anesthesia (Table 1). Mild respiratory acidosis (pH, 7.291; PaCO2, 48.6 mm Hg) was present with normal arterial oxygen content (465 mm Hg; fraction of inspired O2, 98%). Bicarbonate, ionized calcium, glucose, sodium, and potassium concentrations and Hct were within reference limits.

Anesthesia lasted for approximately 2 hours 40 minutes, with a surgical time of 2 hours. The surgical diagnosis was right dorsal displacement of the large colon and sand impaction of the right dorsal colon and pelvic flexure. A pelvic flexure enterotomy was performed, and the colon was emptied of ingesta. Two additional doses of butorphanol (0.02 mg/kg [0.009 mg/lb], IV) were given during anesthesia to provide additional analgesia. The lidocaine constant rate infusion was discontinued 20 minutes before the patient was disconnected from the breathing circuit. A bolus of xylocaine (0.09 mg/kg [0.041 mg/lb], IV) was given after the mare was moved to the recovery stall, and 100% oxygen was administered, initially via a demand valve and then by insufflation (13 L/min) into the trachea while the mare was intubated or nares after the mare was extubated. Anesthetic recovery was rough overall, with severe ataxia and multiple attempts to stand, despite the assistance of head and tail ropes. Analysis of a venous blood sample obtained during the recovery period revealed marked lactic acidosis and moderate hyperkalemia, which were attributed to strenuous muscle activity associated with multiple attempts to stand (Table 1). Severe forelimb lameness was evident after the mare had recovered from anesthesia, and the mare went into premature labor approximately 36 hours after surgery.

**Discussion**

Major physiologic adaptations during late pregnancy present challenges for successful anesthetic management of equine patients. Although there is little information on pregnant horses, it is reasonable to assume that the physiology of mares is similar to that of other mammalian species. The effects of pregnancy on the cardiovascular and respiratory systems necessitate management techniques unique to pregnant patients. These effects add to the cardiovascular and respiratory compromise that occurs in equine patients with colic.

During pregnancy, the cardiovascular system must compensate for fetal oxygen demands. In pregnant women, cardiac output is increased as a result of a 20% to 30% increase in stroke volume and 20% increase in heart rate. A 40% to 50% increase in blood volume results in increased preload, and afterload is decreased as a result of a 20% to 30% decrease in systemic vascular resistance. These changes decrease the ability of patients to compensate for the decreases in heart rate, contractility, and vascular resistance that occur secondary to the administration of anesthetic drugs. There can be an increase in abdominal volume of > 50% in mares in late-stage pregnancy. This additional volume may cause aortocaval compression when the mare is positioned in dorsal recumbency for surgery, decreasing preload and cardiac output. Aortocaval compression in late-term pregnant women is well described, and positioning in a supine position is avoided for this reason. A late-term fetus may cause respiratory compromise in the mare. Pressure on the diaphragm, which is exacerbated by dorsal recumbency, may result in ventilation-perfusion mismatching and hypoxemia. In pregnant women, the oxygen requirements of the fo-
junct drugs such as lidocaine may be used to decrease the
on the basis of serum ionized calcium concentration. Ad-
deriving sympathomimetic drugs such as dobutamine and
delivered inhalation anesthetic concentration, or admin-
istering crystalloid or colloid fluids IV, decreasing the
most importance in optimizing fetal health during an-
esthesia. Oxygen delivery is dependent on cardiac out-
put and arterial oxygen content. Because cardiac output is
difficult to measure, arterial blood pressure is often
used as an estimate of cardiac output, and the current
recommendation is that mean arterial blood pressure be
maintained > 70 mm Hg during anesthesia in pregnant
mares. Blood pressure support may be achieved by ad-
ministering crystalloid or colloid fluids IV, decreasing the
delivered inhalation anesthetic concentration, or admin-
istering sympathomimetic drugs such as dobutamine and
ephedrine. Calcium should be administered as needed
on the basis of serum ionized calcium concentration. Ad-
ject drugs such as lidocaine may be used to decrease the
minimum alveolar concentration of inhalation anesthet-
ics, allowing lower concentrations to be delivered and
possibly decreasing the associated vasodilation and nega-
tive inotropy. Pregnancy decreases the minimum alveolar
concentration of inhalation anesthetics in other species, so
close attention to clinical signs of anesthetic depth is
Critical. In women, arterial oxygen content increases to
102 to 106 mm Hg during pregnancy, which facilitates oxygen
transfer to the fetal circulation. Although hypox-
emia in anesthetized pregnant mares has been defined as
Pao_2 < 80 mm Hg, it seems prudent to maintain Pao_2
> 100 mm Hg to optimize fetal oxygenation. Maintaining
maternal oxygenation may be achieved by administering supplemental oxygen during anesthetic induction and recovery (eg, by use of a demand valve or insufflation) and by use of techniques such as PEEP during intermittent positive-pressure ventilation. However, maintaining a PEEP will increase the negative cardiovascular effects associated with intermittent positive-pressure ventilation. Therefore, the positive effects of PEEP on oxygenation must be balanced with the negative effects on blood pressure. Anecdotally, applying a slight head-up tilt to the surgery table may allow lower peak inspiratory pressures and improve ventilation-perfusion matching by decreasing pressure on the diaphragm.

Anesthetic drugs may cause specific deleterious ef-
fects in a fetus. The anesthetic protocol chosen for a pregnant mare should not cause uterine contraction, increase uterine vascular tone, or lead to hypoxemia. If a cesarean section is not planned, anesthetic-induced respiratory depression of the delivered foal is of less concern. It does appear that anesthetic drugs have an effect on the neurologic system of the developing fetus, depending on the time of exposure. Isoflurane anes-
thesia in pregnant rats may cause learning disabilities in the adult offspring. Administration of α_2-adrenoceptor agonists causes an increase in uterine pressure in preg-
nant goats and decreases delivery of oxygen to bovine fetuses. In addition, α_2-adrenoceptor agonists have been shown to cause increases in intrauterine pres-
sure in nonpregnant mares; however, multiple seda-
tion episodes with detomidine in the last trimester of pregnancy did not result in abortion in 1 study. In humans, ketamine causes an increase in intrauterine pressure when given in the first trimester of gestation; this is of unknown clinical importance in mares. Weak bases such as lidocaine may accumulate in the fetal circu-
lation, which typically has a pH approximately 0.1
lower than the maternal plasma pH; this effect is in-
creased with fetal acidosis. Systemically administered
lidocaine is recommended as an antiarrhythmic agent in pregnant women, but the effects of lidocaine on anesthetized equine fetuses are unknown. Most anes-
thetic drugs (eg, propofol, barbiturates, opioids, and local anesthetics) are considered safe to use in pregnant humans. Although NSAIDs are generally not recom-
pended for pregnant women, flunixin meglumine does
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undergoing colic surgery.

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There is little information on the effects of sympa-
thomimetic drugs on equine fetuses. In humans, hypo-
tension secondary to vasodilation during spinal anes-
thetia for cesarean section is a common problem and
there is extensive research comparing ephedrine and phenylephrine treatment. A recent meta-analysis con-
cluded that phenylephrine produced less fetal acidosis, compared with ephedrine. It is difficult to generalize
this information to anesthetized equine patients that
have hypotension but do not necessarily have vasodi-
lation. The mare of the present report did not appear
to have vasodilation; therefore, dobutamine was chosen
for its positive inotropic effect. Both dopamine and do-
butamine produce a decrease in uterine blood flow in
pregnant sheep, although animals in that study were
not anesthetized or hypotensive. Dobutamine was used
to maintain blood pressure in pregnant mares during
colic surgery in 1 retrospective study (use of sympa-
thomimetic drugs was not described in other studies). In
that study, there was no difference in abortion rate
between mares undergoing surgery (with or without
dobutamine) and those treated medically.

Complications associated with anesthetic recovery in pregnant mares are similar to those encountered in
nonpregnant horses. Muscle weakness secondary to
hypocalcemia or anemia may lead to a poor recovery. Pregnancy causes dilutional anemia, so preanesthetic
values should be considered before treating a low Hct.
Pregnant mares may require extra assistance to stand,
depending on the size of the fetus and fitness of the
patient. Head and tail ropes may be used, considering the temperament of the mare and personnel preference
and training. Equine anesthetic recovery in general has
a high risk of injury, including catastrophic fracture or
luxation.

The risk of abortion in pregnant mares following
colic surgery appears to be between 20% and 46%. The

There may be an increased risk of abortion in mares that have surgery, although earlier studies did not demonstrate a difference in abortion rate between colic patients treated surgically versus medically. Risk factors for abortion may include hypotension and anesthesia for > 3 hours or hypoxemia in the last 60 days of gestation. There was no difference in short-term survival rate between pregnant mares and nonpregnant controls undergoing colic surgery. In the most recent retrospective study, the anesthetic protocol was not described for fetuses treated surgically versus medically. Risk factors demonstrate a difference in abortion rate between colic surgery in pregnant mares and nonpregnant controls undergoing colic surgery. The mare of this report had a rough anesthetic recovery and management strategies may be used successfully.

The primary goals during anesthesia of pregnant mares should include maintaining cardiac output and arterial oxygen content. There are few absolute contraindications in these cases, and multiple pharmaceutical and management strategies may be used successfully. The mare of this report had a rough anesthetic recovery for no identifiable medical reason. The resulting severe lameness likely caused physiologic stress, possibly increasing abortion risk.

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**References**


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