Acta Veterinaria Scandinavica

BioMed Central

Oral presentation

Open Access

High risk pregnant mare

Mats HT Troedsson

Address: Department of Large Animal Clinical Sciences, College of Veterinary Medicine, University of Florida, Gainesville, FL, 32610-0136, USA

Email: Mats HT Troedsson - troedssonm@vetmed.ufl.edu

from Perinatal Death In Domestic Animals: The 20th Symposium of the Nordic Committee for Veterinary Scientific Cooperation (NKVet) Reykjavik, Iceland. 26–27 April 2007

Published: 12 December 2007

Acta Veterinaria Scandinavica 2007, **49**(Suppl 1):S9 doi:10.1186/1751-0147-49-S1-S9

This abstract is available from: http://www.actavetscand.com/content/49/S1/S9

Introduction

Improved diagnostic techniques and advances in the understanding of equine reproductive physiology and pathology have resulted in increased pregnancy rates in mares. In contrast, the incidence of pregnancy loss has remained fairly constant at a rate of 10–15% [1]. Pregnancy losses during late gestation (>5 months) represent an even greater problem for the equine breeding industry. Affected mares will not only fail to produce a foal, but will often have a lower conception rate during the next breeding season.

Pregnancy losses during late gestation could be the result of fetal illness, placental dysfunction, or maternal illness (see Table 1). Pre-partum disorders of the mare are easy to diagnose, but identifying conditions that affects the fetus and the placenta may be more difficult. Monitoring of the fetus and the placenta during late gestation is routinely performed in human pregnancies, but has only recently gained recognition in equine veterinary medicine.

Fetal evaluation

Indications for examination of the fetus include early lactation, vaginal discharge, maternal systemic illness, larger than normal abdominal size, suspected twinning, overdue pregnancy and a previous poor outcome of parturition [2-5].

Transabdominal ultrasonography of the equine fetus can be performed reliably after 90 days of gestation. At this time, the uterus drops over the pelvic brim and is visible from the ventral abdomen. The assessment of fetal well being is obtained through measurement of heart rate, size, movement and tone of the fetus. The thickness of the fetal membranes, echogenicity and quantity of the allantoic and amniotic fluids, and the number of fetuses provide information to evaluate the fetus.

The fetus is visible in the inguinal area and between the mammary glands in early gestation [5]. As pregnancy progresses the fetus is found progressively more cranial. It is necessary to apply alcohol or to clip the hair on the abdomen to obtain a diagnostic image of the fetus. In late gestation, the mare should be examined from the mammary glands to the xyphoid extending to the level of the stifles on both sides of the abdomen.

Variable gestational length, size and body type of the mare and position of the fetus will affect the choice of transducer. The highest frequency transducer that will penetrate to the desired depth should be chosen. Generally a 2.5 or 3.5 MHz transducer is required to image the fetal heart in late gestation since a depth of 30 cm is often required [5,6]. A second higher frequency transducer (7.5–10 MHz) should be used to image the uteroplacental unit [6]. Either a curvilinear or sector scanner is preferred because they produce a pie-shaped image that allows an increasingly larger field of view in the deeper section of the image. Sedation of the mare will affect the heart rate, tone and movement of the fetus and should be avoided if possible. The ventral abdomen of the mare should be scanned in the sagittal and transverse plane.

The entire uterus should be scanned to determine the number of fetuses and the position of the fetus. The fetus should be lying in the sagittal plane in cranial position

Table 1: Conditions causing high risk pregnancies

Maternal conditions	Fetal conditions	Placental conditions
Colic	Twins	Placentitis
Endotoxemia	Dystocia	Twisted umbilical cord
Abdominal tunic rupture	Congential defects	Fescue toxicity
Prepubic tendon rupture	Hydrops	
Dystocia		
Uterine inadequacy		
Uterine torsion		
Hyperlipemia		

[5,6]. In late gestation the head of the fetus is near the brim of the pelvis. Orbital diameter can usually only be obtained by transrectal scanning [7,8]. The fetus is in dorsal recumbency with the vertebrae closest to the ventral abdominal wall [6]. To determine fetal orientation, the uterus should be scanned in a sagittal section. The thorax of the fetus can be localized by the recognizable striped pattern (see Figure 1). The heart is found in the cranial aspect of the thorax. The fetal heart rate has been suggested to be used as an indicator of fetal well being [9]. A poor outcome of parturition was associated with bradycardia or tachycardia in the fetus. Heart rate of the fetus peaks at 3 months of gestation to a mean of 196 beats per minute and then gradually decrease throughout pregnancy [10]. The decrease in fetal heart rate is a result of increasing parasympathetic tone to the heart [2]. The average fetal heart rate in a fetus greater than 300 days gestation is 75 ± 7 bpm [9]. Fetal heart rate slows by approximately 10 bpm at greater than 330 days gestation.

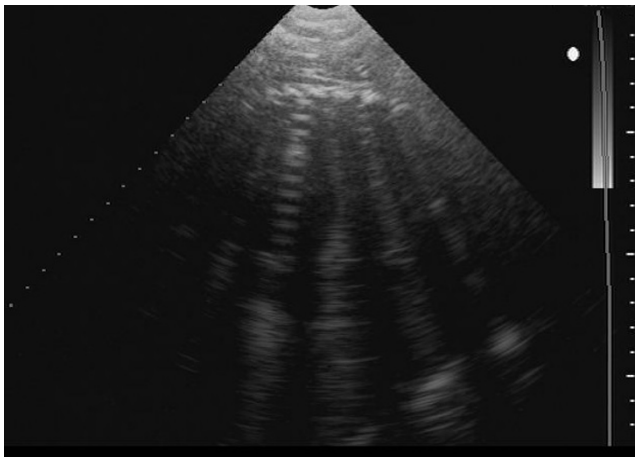

Figure 1
Transabdominal ultrasound image of the fetal thorax obtained with a 2.5 MHz sector scanner transducer. The shadows are caused by the vertebrae and ribs. Ventral is the top of the image and dorsal is at the bottom.

Fetal heart rates vary with activity level which should be considered when examining a mare. Consistently low or high fetal heart rates are associated with fetal stress. Serial examinations should be performed to verify fetal well being or distress. Mares considered "at risk" for pregnancy loss are often examined on a daily basis. Fetuses experiencing distress are often evaluated several times a day. This is particularly true when determining if fetal distress is significant enough to prompt intervention such as induction of parturition.

Fetal heart rate can be obtained either by using a stopwatch while monitoring the B mode image or utilizing M-mode. M-mode displays movement at a fixed position of the transducer. The M-mode cursor is moved so that it intersects the heart. The M mode image is activated. The image displayed will show movement of the heart over time (see Figure 2). The heart rate is automatically calculated by measuring the time between 2 cardiac cycles. M-mode analysis is more accurate in assessing the fetal heart rate than the stopwatch method.

Aortic diameter has been shown to correlate to maternal weight and is a good indicator of fetal size during late gestation [6]. The aorta is visualized as it exits the heart and courses dorsally in the fetus adjacent to the vertebrae. The aorta is measured at the caudal border of the heart. Normal aortic diameter obtained in 32 light breeds of mares with normal pregnancies ranged from 18.5–27 mm [6]. A smaller than normal aortic diameter has been associated with abnormal foals with low birth weight [10]. Fetal tone should be present. A flaccid fetus that floats in the fluids is an indication of a weak or dead fetus. The normal healthy fetus should exhibit movement during the ultrasound scan. Movement may be extension or flexion of the limbs or rotation on the fetal long axis [5,6]. As the fetus ages, it will display more complex movements [3].

The amniotic membrane is seen as a thin hyperechoic structure floating within the fetal fluids. The membrane is thin in the normal pregnancy although cysts may be seen [3]. In regions of the uterus where the foal is making contact with the uteroplacental unit the amnion is rarely dis-

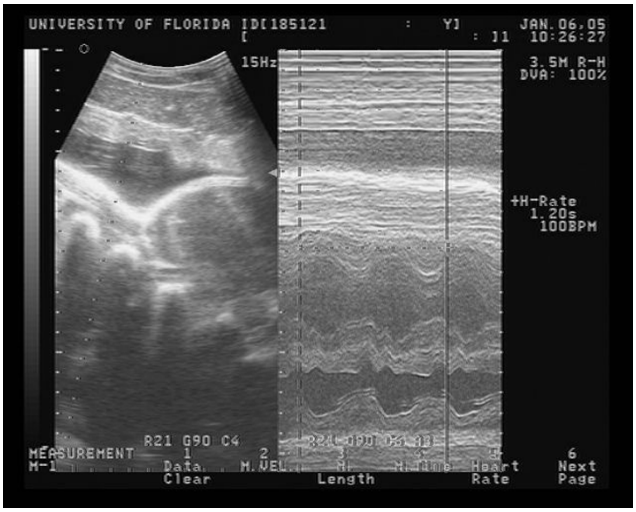

Figure 2
Transabdominal ultrasound image of the fetal heart obtained with a 2.5 MHz curvilinear scanner transducer. The B-mode image is at the left of the picture. The M-mode image is at the right of the picture. The cursor marks delineate two cardiac cycles. The calculated heart rate is 100 bpm.

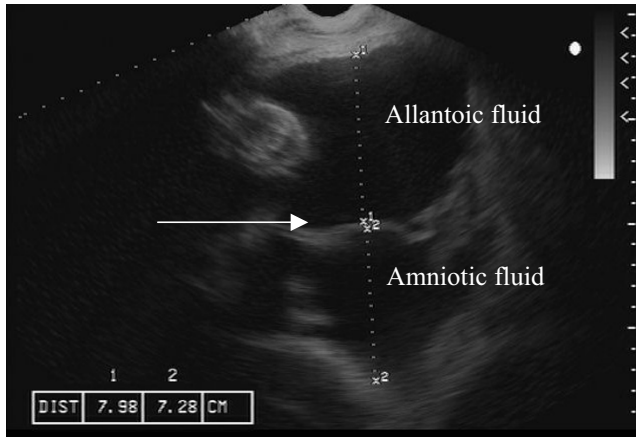

Figure 3
Transabdominal ultrasound image of the allantoic and amnionic fluid pockets obtained with a 5.0 MHz curvilinear transducer. The amnionic membrane divides the 2 pockets (arrow).

cernable. The amount of fetal fluids should be assessed in 4 areas within the uterus (right and left cranial and caudal). Generally the largest fluid depths are located around the fetal thorax in the region of the elbow (see Figure 3) [6]. The depth of the allantoic and amniotic fluids is used to assess total volume of fetal fluids. The normal mean for maximal allantoic and amniotic fluids is 13.4 ± 4.4 cm and 7.9 ± 3.5 cm, respectively. The allantoic and amniotic fluids should contain a moderate amount of particles. Echogenic free-floating particles are normal from month 4 to the end of gestation [6,11]. The hippomane may be seen floating within the allantoic fluid. It has an oblong shape with a layered or onion appearance to the more echogenic center.

Evaluation of mammary secretion to assess fetal maturity

Measurement of the concentration of sodium, potassium and calcium in mammary secretions of mares before foaling can provide information about impending foaling and fetal maturity [12]. In the late pregnant mare, the electrolytes are reflecting concentrations in serum. Between 2 and 3 days before parturition, the sodium concentrations in mammary secretion decline and the potassium concentrations rise, resulting in an inversion of the electrolyte concentrations. In addition, the calcium concentrations in mammary secretion increase within a day before parturition. Analysis of milk electrolytes in high risk pregnant mares can be helpful in providing information on fetal maturity. Occationally, an inversion of sodium and potassium milk concentrations may occur prior to fetal maturity. It is therefore important to use mammary secretion electrolyte data in conjunction with gestational length and other clinical data.

Placental evaluation

The equine placenta consists of the allantochorion, the allantoamnion, and the umbilical cord. The chorionic part of the allantochorion is attached to the endometrium through microcotyledons, which integrate the endometrium throughout the uterus with exception of a small area at the internal os of the cervix, the so-called cervical star. The allantochorion supports the fetus in utero. It provides respiratory and nutrient exchange between the mare and the fetus, and it is an endocrine active organ with hormone synthesis and metabolism of importance for maintenance and normal development of the fetus. The "free floating" allantoamnion allows the fetus to move freely within the uterus. It is not attached to the allantochorion with exception of a small area at the umbilical stalk. The only attachment between the fetus and the allantoamnion is at the umbilicus. The umbilical cord has an amniotic portion and an allantoic portion. The umbilicus contains two umbilical arteries, one umbilical vein, and the urachus. The length of the cord, and the length of the allantoic and amniotic portions can vary, but is normally 50 to 100 cm long. A cord length of >80 cm has been reported to predispose to abnormal twisting of the cord and fetal death [13].

Evaluation of the equine placenta is routinely performed after parturition. A thorough examination of the placenta post partum provides valuable information on disease

processes or dysfunctions that could have affected the well being of an aborted fetus, or potentially cause illness in the neonatal foal. However, this examination does not aid the clinician in decisions that are aimed to prevent abortion or neonatal diseases of the foal. Evaluation of the placenta in the mare can be performed by the use of ultrasonography and endocrine tests.

Ultrasonographic evaluation of the placenta

Transabdominal ultrasonography

Ultrasonographic examinations of the placenta in mares that are considered to be at risk for abortion during late gestation are routinely performed by a transabdominal approach [10,14,15]. Using a 5–7.5 MHz transducer, normal values for the combined thickness of the uterus and the placenta (CTUP) has been established (see Figure 4) [10,11,14]. Reef and co-workers recommended to examine four quadrants of the placenta; right cranial, right caudal, left cranial, and left caudal [6]. Using this technique, they suggested that mares with normal pregnancies should have a minimal CTUP of 7.1 ± 1.6 mm, and a maximum CTUP of 11.5 ± 2.4 mm. In a subsequent study, it was observed that mares with an increased CTUP often delivered abnormal foals [10]. A CTUP of >17.5 mm has been suggested to be consistent with placentitis [16]. Renaudin *et al*, examined the monthly variations of the CTUP in mares with normal pregnancies [11]. Their study confirmed previous studies, but showed a significant difference in the CTUP between pregnancy months. However, the CTUP did not increase consistently, and the reliability of measuring CTUP by a transabdominal approach was questioned. Nevertheless, placental thickening and partial separation of the allantochorion from the endometrium may be observed by the use of transabdominal ultrasonography in mares with placentitis originating from hematogenous infection (see Figure 5). In addition, a pocket of hyperechoic fluid can be seen at the base of the lowest area of the uterus in mares with the *Nocardia* form of placentitis [17,18].

Mares grazing endophyte-infected fescue often experience premature separation of the allantochorion, increased allantochorion weight and thickness, and retained placenta. A significant increase in uteroplacental thickness and premature separation of the allantochorion has been demonstrated on transabdominal ultrasonographic examination of endophyte-infected mares. However, the thickness was not observed until an average of 8 hours before the onset of labor [19].

Transrectal ultrasonography

Although a transabdominal approach provides excellent image of the fetus and most of the uterus and placenta, the caudal portion of the allantochorion cannot be imaged by this approach, resulting in difficulties to diagnose early stages of ascending placentitis. However, transrectal ultrasonography of the caudal allantochorion in late gestational mares provides an excellent image of the placenta close to the cervical star (see Figure 6). Renaudin *et al*, examined normal pregnant mares monthly during gestation, starting at 4 months of pregnancy until parturition [11]. A 5–7.5 MHz linear transducer should be positioned 1–2 inches cranial of the cervical-placental junction, and then moved laterally until a uterine vessel is visible at the ventral aspect of the uterine body [11]. The CTUP should then be measured between the vessel and the allantoic fluid (see Figure 6). It is important to obtain all CTUP measurements from the ventral aspect of the uterine body, since physiological edema of the dorsal aspect of the allantochorion has been noted in normal pregnant mares (see Figure 6) [11]. In addition, care should be exercised to be certain that the amniotic membrane is not adjacent to the allantochorion, since this may result in a false increased CTUP. When possible, three measurements should be taken and averaged. Normal values for CTUP have been established (see Table 2) [11,20]. Increases in CTUP have been associated with placental failure and pending abortion [20,21] In some cases of placentitis, hyperechoic fluid (purulent material) can be noticed separating the uterus and the placenta. Measurements in these cases are meaningless as one is no longer measuring the combined unit.

Additional parameters that can be evaluated using transrectal ultrasonography include changes in the amniotic

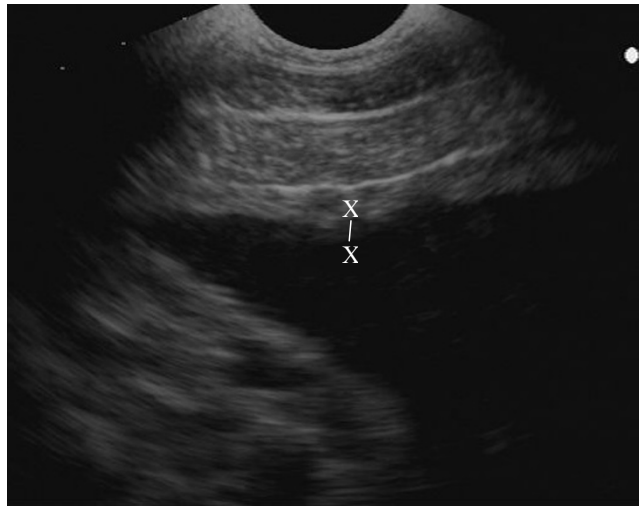

Figure 4
Transabdominal ultrasound image of the uteroplacental unit in a normal mare at 320 days of gestation. The image was obtained with a 7.5 MHz curvilinear array transducer. The X marks the thickness of the uteroplacental unit.

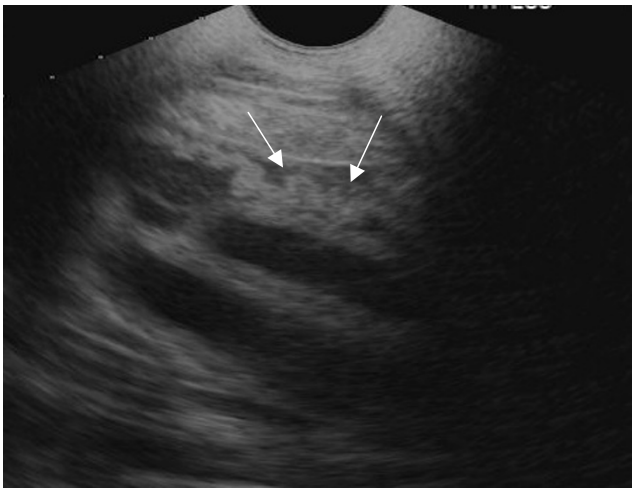

Figure 5
Transabdominal ultrasonography of the placenta in a mare during 9th month of gestation. The arrow points to the area of placental separation.

membrane and fluid character. Amniotic thickening, which occurs in some cases of placentitis, can be identified using transrectal ultrasonography. Changes in allantoic and amniotic fluid character can also be identified using transrectal ultrasonography. In normal mares, allantoic fluid is commonly hypoechoic with some specular

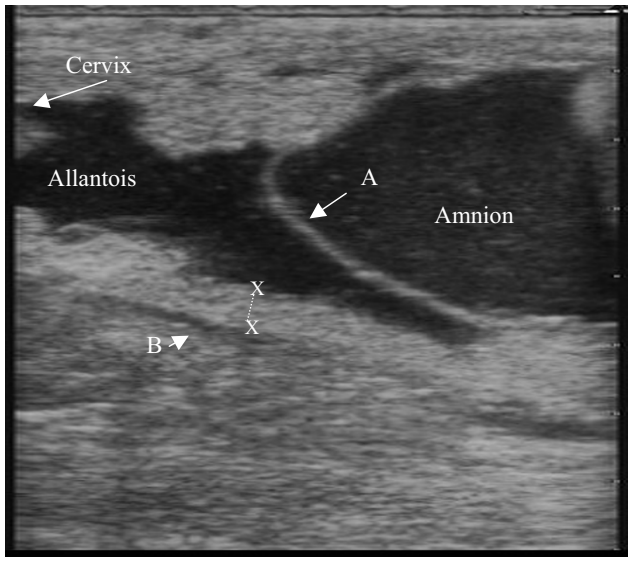

Figure 6
Transrectal ultrasonography of the caudal part of the placenta in a late gestational mare. A = amniotic membrane; B = uterine blood vessel; x---x = CTUP.

material, while amniotic fluid is frequently a shade more hyperechoic (gray) than allantoic fluid [11,14]. Marked changes in these fluid characteristics suggest placental infection or stress to the fetus.

While transrectal and transabdominal ultrasonographic examination of the placenta is useful to detect early signs of some placental pathology, it is important to keep in mind that placental changes resulting in periparturian problems can be subtle and may not readily be detected on ultrasonographic examination. For example, a correlation between both endometrial fibrosis and angiosis, and poor chorionic villous development has been reported [22,23]. These changes can of course not be evaluated by the use of ultrasonography, but would require other techniques.

Endocrine monitoring of the placenta

Progesterone

The equine placenta is part of an endocrine fetal-placental interaction, which synthesizes and metabolizes progestagens [24] This endocrine function of the placenta is important for maintenance of pregnancy after the endometrial cups and the secondary corpora lutea disappear around day 120 – 150 of gestation. Fetal-placental progesterone is rapidly metabolized to 5α-pregnanes. Mares with placental pathology may have increased plasma concentrations of progestagens as a result of stress to the fetal placental unit [25]. Unfortunately, 5α-pregnanes are not readily assayed in a commercial setting, so diagnosis of placental disease using 5α-pregnane concentrations is not possible. There is cross-reactivity between 5α-pregnanes and progesterone using some commercial radioimmunoassays for progesterone. In recent studies [26,27] using an experimental model to induce placentitis, it was found that mares that develop a chronic form of placentitis responded with increased plasma progesterone concentrations. Conversely, mares that developed acute placentitis and abortion soon after infection experienced a rapid drop in plasma progesterone concentrations. It was suggested that measurement of repeated samples of plasma progestin concentrations in mares with placentitis might be a useful method to identify mares that may abort or deliver prematurely [26]. Furthermore, sensitivity of progesterone assays can be improved when combined with evidence of placental thickening as detected using transrectal ultrasonography [27].

Estrogen

Estrone sulfate in maternal serum has been used to monitor fetal well being [28]. However, this test has not consistently been useful to detect early signs of placentitis [29].

Table 2: Normal upper limits for the combined thickness of the uterus and the placenta (CTUP) during late gestation [11, 20].

Gestation length	Normal CTUP
151 – 270 days	<7 mm
271 – 300 days	<8 mm
301 – 330 days	<10 mm
331 –	<12 mm

Relaxin

Relaxin is produced by the equine placenta, and can be detected in peripheral blood plasma from day 80 of gestation and throughout the pregnancy [30]. The role of relaxin during pregnancy is not fully understood, but there is some evidence that placental relaxin production is compromised in mares at risk of aborting their fetuses [31,32]. Ryan and co-workers observed subnormal plasma relaxin concentrations in mares with abnormal pregnancies [32]. Mares with clinical signs of placentitis and mares exhibiting signs of fescue toxicosis had suppressed plasma relaxin concentrations. There is currently no commercial test available for equine relaxin, and more research need to be performed to evaluate the usefulness of plasma relaxin as a clinical tool to diagnose placentitis and to monitor the efficacy of treatment strategies.

Management and treatment of high risk mares

General considerations

High risk pregnant mares should be monitored for fetal and placental well-being. Progestin therapy is currently being implemented in humans to halt preterm labor. Presumably, the anti-prostaglandin effect of progestins contribute to reduced myometrial activity by interfering with upregulation of prostaglandin and oxytocin receptors [33]. Without receptor formation, gap junction formation would be inhibited and uterine contractility prevented. Treatment with progestins has long been advocated to promote uterine quiescence in mares with uterine pathology. Daels and co-workers showed that supplementation of mares with the synthetic progestin altrenogest (0.088 mg/kg SID) was able to prevent prostaglandin-induced abortion [34].

A variety of tocolytic agents have been used in women with preterm labor including: magnesium sulfate, β sympathomimetic agents (ritodrine, terbutaline), prostaglandin synthesis inhibitors (indomethacin, suldinac, ibuprofen, aspirin), calcium channel blockers (nifedipine) and oxytocin antagonists (atosiban) [35] Tocolytic agents have not been shown to significantly prolong pregnancy or improve neonatal outcome when used alone. Historically, tocolytics prolong pregnancy for up to 48 hours during which time glucocorticoids can be administered to the mother in an effort to expedite fetal maturation. Clenbuterol, a β sympathomimetic agent, has been used in clinical equine practice. The effects of clenbuterol administration on uterine tone and maternal and fetal heart rates were examined by Card and Wood [36]. Clenbuterol was administered intravenously (300 μg) to four pregnant mares throughout gestation until parturition. Uterine relaxation occurred within 3 minutes of drug administration and persisted up to 120 minutes. The authors concluded that clenbuterol was effective in causing uterine relaxation throughout gestation, and that the side effects were minimal and transient. A more recent study reported the effects of clenbuterol when administered to 29 mares late in gestation [37]. These authors concluded that clenbuterol was not effective in preventing the onset of myometrial contractions in normal foaling mares at term. Treated mares in this study actually foaled earlier in the evening than untreated mares. The authors speculated that the relaxant effects of clenbuterol may have promoted cervical relaxation and subsequent parturition. Based on side effects detected when clenbuterol is administered to pregnant mares, and lack of effect for delaying normal parturition, the authors suggest that this agent has limited usefulness in horses.

Management of selected high risk pregnancy conditions

Colic

The risk of postoperative abortion in mares undergoing surgery for colic is surprisingly low, and not related to stage of gestation or type of lesion. In a retrospective study, Santschi and co-workers found that 18% of surviving mares that underwent colic surgery experienced pregnancy loss [38]. Half of the abortions occurred long after the resolution of the disease, and may have been unrelated to the surgery or colic. Hypoxia and endotoxemia were identified as risk factors associated with death of the fetus. Abortions were associated with a PaO_2 <80 mm Hg when surgery occurred during the last two months of gestation.

Uterine torsion usually presents as a mild colic during the last trimester of pregnancy. Diagnosis is based primarily on rectal palpation of the broad ligaments. When the uterus is torsed, the mare is at risk for uterine rupture. Options for correction include rolling the mare, or surgical correction. Rolling may be an alternative to surgery early in the third trimester, but should not be tried in mares close to term due to increased risk of uterine rupture. Surgical correction is the most effective treatment for uterine torsion, and was found to result in the highest survival rate of foals [39]. Furthermore, the prognosis for mares and foals is best when uterine torsion occurs at <320 days of gestation [39].

Abdominal tunic and prepubic tendon rupture

Ruptures of the abdominal tunic or prepubic tendon are painful and result in varying degree of edema of the ventral abdomen. Mares with a rupture of the prepubic tendon have an abnormal position of the pelvis and mammary glands. The tuber coxae is tipped up and the tuber ischii tipped down. The mammary gland is displaced because of the loss of caudal attachment of the abdominal wall [40]. The prognosis for mare and foal is poor in mares with a complete rupture. Stall confinement, anti-inflammatory drugs, and abdominal support should be implemented. The progression of the condition of abdominal muscle and tendon, and the fetal well-being should be monitored by ultrasonography. Parturition should be induced and attended when the fetus is ready for birth. Measurement of milk secretion electrolytes are helpful in determining when it is safe to induce parturition.

Hydrops

Hydrops is the accumulation of excessive fluid within the amniotic or allantoic cavity. The condition is uncommon in mares, and the prognosis for pregnancy is considered poor. Presenting signs include a history of rapid abdominal enlargement over 10–14 days after the 7th month of gestation. Mares will be depressed and uncomfortable with labored breathing, ventral edema, and possibly difficulty walking. Risk of uterine rupture, abdominal hernia, or prepubic tendon rupture are all increased. To save the mare, termination of the pregnancy is often recommended. However, sudden removal of abdominal fluid associated with termination of the pregnancy or foaling may result in blood pooling in the abdominal vasculature, leading to hypovolemic shock and death of the mare. Therefore supportive fluid therapy is needed at the time of foaling or termination of pregnancy to maintain blood pressure. If possible, fluid should be drained gradually prior to removing the fetus. A case of successful management of a mare with hydrops amnion, resulting in the birth of a live foal was recently reported from the University of Florida Veterinary Medical Center [41]. The mare was closely monitored for integrity of the abdominal wall, degree of abdominal extension, and the abdomen was supported with a girdle-like device. The pregnancy was supported medically to prevent preterm labor, and the mare produced a live foal at a normal gestational time.

Placentitis

Placentitis in mares poses a significant threat to fetal and neonatal viability. Placentitis is commonly caused by bacteria ascending through the vagina. The most frequent bacterial pathogens implicated in equine placentitis are *Streptococcus equi* subspecies *zooepidemicus*, *Escherichia coli*, *Klebsiella pneumonia*, and *Pseudomonas aeruginosa* [42]. While bacterial infection initiates disease, recent work from an experimental model of ascending placentitis in pony mares showed that premature delivery may occur secondary to inflammation of the chorion rather than as a consequence of fetal infection [43,44]. It was suggested that these inflammatory processes may result in prostaglandin production (PGE_2 and $PGF_2\alpha$) and stimulation of myometrial contractility, thus resulting in preterm delivery. However, in some chronic cases of placentitis, foals will experience accelerated fetal maturation. These foals will be delivered prematurely, but will be mature enough to survive in the extrauterine environment. In humans, it is thought that indirect stimulation of the fetal hypothalamic-pituitary-adrenal axis by pro-inflammatory cytokines is responsible for precocious fetal maturation [45,46]. If this phenomenon is also true for equine fetuses, then delaying premature labor long enough to allow accelerated fetal maturation to occur may improve foal survival rates. To achieve this goal, it is necessary to promptly diagnose and effectively treat the disease. The most common signs of placentitis in mares are premature udder development (± streaming of milk) and vulvar discharge. Transrectal and transabdominal ultrasound, combined with endocrinological assays, provide additional tools for early diagnosing and monitoring progression of placentitis in mares. Pregnant mares with signs of placentitis should be treated with systemic broad spectrum antibiotics and anti-inflammatories. Using *in vivo* microdialysis to detect concentrations of commonly used drugs in allantoic fluid of pregnant pony mares, Macpherson and co-workers at the University of Florida found that penicillin (22,000 IU/kg, q 6 h), gentamicin (6.6 mg/kg, q 24 h) and trimethoprim sulfamethoxazole (30 mg/kg, BID) resulted in inhibitory concentrations (MIC) of these drugs in allantoic fluid and placental tissue [47,48]. Preliminary experimental data and clinical observations suggest that long term therapy with a combination of antibiotics, altrenogest (regumate; 0.088 mg/kg), flunixin meglumine (1.1 mg/kg BID), and pentoxifylline (8.4 mg/kg BID) can positively impact pregnancy outcome with delivery of healthy foals in mares with placentitis [49].

Acknowledgements

Portions of this article are adapted from Troedsson M and Sage AM. Fetal/Placental Evaluation in the Mare. In: Ball B.A. (Ed.), *Recent Advances in Equine Reproduction*. Ithaca: International Veterinary Information Service http://www.ivis.org, 2001; Document No. A0203.0501.

References

1. Roberts SJ: *Veterinary obstetrics and genital diseases (Theriogenology)* 3rd edition. Edited by: *Roberts SJ. North Pomfret, Vt*; 1986:38-50.
2. McGladdery AJ: **Ultrasonographic diagnosis and management of fetal abnormality in the mare in late pregnancy.** *Pferdeheilkunde* 1999, **15:**618-621.
3. Reef VB: **Fetal ultrasonography.** In *Equine diagnostic ultrasound* Edited by: *Reef VB. Philadelphia: WB Saunders Co*; 1998:425-445.
4. Sertich PL, Reef VB, Oristaglio-Turner RM, Habecker PL, Maxon AM: **Hydrops Amnii in a mare.** *J Amer Vet Med Assoc* 1994, **204:**1481-1482.

5. Pipers FS, Adams-Brendemuehl CS: **Techniques and applications of transabdominal ultrasonography in the pregnant mare.** *J Amer Vet Med Assoc* 1984, **185:**766-771.
6. Reef VB, Vaala WE, Worth LT, *et al.*: **Ultrasonographic evaluation of the fetus and intrauterine environment in healthy mares during late gestation.** *Vet Rad and Ultrasound* 1995, **36:**533-541.
7. Turner RM, McDonnell SM, Feit EM, *et al.*: **Real-time ultrasound measure of the fetal eye (vitreous body) for prediction of parturition date in small ponies.** *Theriogenology* 2006, **66:**331-337.
8. Turner RM, McDonnell SM, Feit EM, Grogan EH, Foglia R: **How to determine gestational age of an equine pregnancy in the field using transrectal ultrasonographic measurement of the fetal eye.** *Proc Am Assoc Eq Pract* 2006, **52:**250-255.
9. Curran S, Ginther OJ: **M-mode ultrasonic assessment of equine fetal heart rate.** *Theriogenology* 1995, **44:**609-617.
10. Reef VB, Vaala WE, Worth LT: **Ultrasonographic assessment of fetal well being during late gestation: development of an equine biophysical profile.** *Equine Vet J* 1996, **28:**200-208.
11. Renaudin C, Troedsson MHT, Gillis C, King VL, Bodena A: **Ultrasonographic evaluation of the equine placenta by transrectal and transabdominal approach in pregnant mares.** *Theriogenology* 1997, **47:**559-573.
12. Ousey JC, Dudan F, Rossdale PD: **Preliminary studies on mammary secretions in the mare to assess fetal readness for birth.** *Eq Vet J* 1984, **16:**259-263.
13. Whitwell KE, Jeffcott LB: **Morphological studies on the fetal membranes of the normnal singleton foal at term.** *Res Vet Sci* 1975, **19:**44-55.
14. Adams-Brendemuehl C, Pipers FS: **Antepartum evaluations of the equine fetus.** *J Reprod Fert (suppl)* 1987, **35:**565-573.
15. Vaala WE, Sertich PL: **Management strategies for mares at risk for periparturient complications.** *Vet Clin North Am: Eq Pract* 1994, **10:**237-265.
16. Schott HC II: **Assessment of fetal well-being.** In *Equine Reproduction* Edited by: *McKinnon AO, Voss JL. Philadelphia: Lea & Febiger*; 1991:964-975.
17. Donahue JM, Williams NM: **Emergent causes of placentitis and abortion.** *Vet Clin Morth Am, Eq Pract* 2000, **16:**443-456.
18. Christensen BW, Roberts JF, Pozor MA, Giguere S, Sells SF, Donahue JM: **Nocardioform placentitis with isolation of Amycolatopsis spp in a Florida-bred mare.** *J Am Vet Med Assoc* 2006, **228:**1234-1239.
19. Brendemuehl JP, Boosinger TR, Bransby DI, *et al.*: **Effects of short-term exposure to and removal from the fescue endophyte *Acremonium coenophialum* at 300 days of gestation on pregnant mares and foal viability.** *Biol Reprod Monograph Series 1: Equine Reprod VI* 1995, **1:**61-67.
20. Troedsson MHT, Renaudin CD, Zent WW, Steiner JV: **Transrectal ultrasonography of the placenta in normal mares and in mares with pending abortion: a field study.** *Proc Am Assoc Eq Pract* 1997, **43:**256-258.
21. Renaudin CD, Liu IKM, Troedsson MHT, Schrenzel MD: **Transrectal ultrasonographic diagnosis of ascending placentitis in the mare: a report of two cases.** *Equine Veterinary Education* 1999, **11:**69-74.
22. Bracher V, Mathias S, Allen WR: **Influence of chorionic degenerative endometritis (endometrosis) on placental development in the mare.** *Eq Vet J* 1996, **28:**180-188.
23. Schoon D, Schoon H-A, Klug E: **Angiosis in the equine endometrium: pathogenesis and clinical correlations.** *Pferdeheilkunde* 1999, **15:**541-546.
24. Pashen RL: **Maternal and Fetal Endocrinology During Late Pregnancy and Parturition in the Mare.** *Equine Veterinary Journal* 1984, **16:**233-238.
25. Rossdale PD, Ousey JC, Cottrill CM, Chavatte P, Allen WR, McGladdery AJ: **Effects of placental pathology on maternal plasma progestagen and mammary secretion calcium concentrations and on neonatal adrenocortical function in the horse.** *J Reprod Fertil Suppl* 1991, **44:**579-590.
26. Stawicki RJ, Ruebel H, Hansen PJ, Sheerin BR, LJ O'Donnell, Lester GD, *et al.*: **Endocrinological findings in an experimental model of ascending placentitis in the mare.** *Theriogenology* 2002, **58:**849-852.
27. Sheerin PC, Morris S, Kelleman AA, Stawicki R, Sheerin BR, LeBlanc MM: **Diagnostic efficiency of transrectal ultrasonography and plasma progestin profiles in identifying mares at risk for premature delivery.** *Am Assoc Eq Pract, Focus in Equine Reproduction* 2003, **1:**22-23.
28. Stabenfeldt GH, Daels PF, Munro CJ, Hughes JP, Lasley BL: **An oestrogen conjugate enzyme immunoassay for monitoring pregnancy in the mare: limitation of the assay between Days 40 and 70 of gestation.** *J Reprod Fert (Suppl)* 1991, **44:**37-43.
29. Santschi EM, LeBlanc MM: **Fetal and placental conditions that cause high-risk pregnancy in mares.** *Comp Cont Educ Pract Vet* 1995, **17:**710-720.
30. Stewart DR, Stabenfeldt GH, Hughes JP, Meagher DM: **Determination of the source of equine relaxin.** *Biol Reprod* 1982, **27:**17-24.
31. Stewart DR, Addiego LA, Pascoe DR, Haluska GJ, Pashen R: **Breed differences in circulating equine relaxin.** *Biol Reprod* 1992, **46:**648-652.
32. Ryan P, Bennet-Wimbush K, Vaala WE, Bagnell CA: **Relaxin as a biochemical marker of placental insufficiency in the horse: A review.** *Pferdeheilkunde* 1999, **15:**622-626.
33. Garfield RE, Kannan MS, Daniel ME: **Gap junction formation in the myometrium: Control by estrogens, progesterone and prostaglandins.** *Am J Physiol* 1980, **238:**C81-C89.
34. Daels PF, Besognet B, Hansen B, Mohammed H, Odensvik K, Kindahl H: **Effect of progesterone on prostaglandin F-2 alpha secretion and outcome of pregnancy during cloprostenol-induced abortion in mares.** *Am J Vet Res* 1996, **57:**1331-1337.
35. Ramsey PS, Rouse DJ: **Therapies administered to mothers at risk for preterm birth and neurodevelopmental outcome in their infants.** *Clin Perinatology* 2002, **29:**725-743.
36. Card CE, Wood MR: **Effects of acute administration of clenbuterol on uterine tone and equine fetal and maternal heart rates.** *Biol Reprod Mono 1* 1995, **1:**7-11.
37. Palmer E, Chavette-Palmer P, Duchamp G, Levy I: **Lack of effect of clenbuterol for delaying paturition in late pregnant mares.** *Theriogenology* 2002, **58(2–4):**797-799.
38. Santschi ES, Slone DE: **Maternal conditions that cause high-risk pregnancy in mares.** *Comp Cont Ed Pract Vet* 1994, **16:**1481-1488.
39. Chaney KP, Holcombe SJ, LeBlanc MM, Hauptman JG, Embertson RM, Mueller POE, Beard WL: **Effect of uterine torsion on mare and foal survival: A retrospective study 1985–2005.** *Proc Am Assoc Eq Pract* 2006, **52:**402-403.
40. Santschi EM: **Prepartum conditions.** In *Current Therapy in Equine Medicine 4* Edited by: *Robinson NE. WB Saunders Company, Philadelphia, PA*; 1997:541-546.
41. Christensen BW, Troedsson MHT, Murchie TA, Pozor MA, Macpherson ML, Roberts GD, Estrada AH, Langois J: **Management of hydrops in a Thoroughbred mare resulting in successful foaling.** *J Am Vet Med Assoc* 2006, **228:**1228-1232.
42. Acland HM: **Abortion.** In *Equine Reproduction* Edited by: *McKinnon AO, Voss JL. Philadelphia: Lea & Febiger*; 1993:554-561.
43. Leblanc MM, Giguere S, Brauer K, Paccamonti DL, Horohov DW, Lester GD, *et al.*: **Premature delivery in ascending placentitis is associated with increased expression of placental cytokines and allantoic fluid prostaglandins E-2 and F-2 alpha.** *Theriogenology* 2002, **58:**841-844.
44. Mays MBC, LeBlanc MM, Paccamonti D: **Route of fetal infection in a model of ascending placentitis.** *Theriogenology* 2002, **58:**791-792.
45. Gravett MG, Hitti J, Hess DL, Eschenbach DA: **Intrauterine infection and preterm delivery: Evidence for activation of the fetal hypothalamic-pituitary-adrenal axis.** *Am J Obst Gyn* 2000, **182:**1404-1410.
46. Besedovsky HO, delRey A: **Immune-neuro-endocrine interactions: Facts and hypotheses.** *Endocrine Reviews* 1996, **17:**64-102.
47. Murchie TA, Macpherson ML, LeBlanc MM, Luznar SL, Vickroy TW: **A microdialysis model to detect drugs in the allantoic fluid of pregnant pony mares.** *Proc Am Assoc Eq Pract* 2003, **49:**118-119.
48. Rebello SA, Macpherson ML, Murchie TA, LeBlanc MM, Vickroy TW: **The detection of placental drug transfer in equine allantoic fluid.** *Theriogenology* 2005, **64:**776-777.
49. Troedsson MHT, Zent WW: **Clinical ultrasonogaphic evaluation of the equine placenta as a method to successfully identify and treat mares with placentitis.** In *Proc Workshop on the Equine Placenta Volume 1. UK Agricultural Experimental Station, SR-2004-1*; 2004:66-67.