Physiological events during parturition and possibilities for improving puppy survival: a review

G. Kredatusova, J. Hajurka, I. Szakallova, A. Valencakova, B. Vojtek

Small Animal Clinic, University of Veterinary Medicine and Pharmacy, Kosice, Slovak Republic

ABSTRACT: Clinical examination and emergency care in newborn puppies is difficult, due to their different physiological characteristics and needs from those of adult dogs. This paper reviews the physiological events during parturition and the influence of parturition on puppy health.

Keywords: parturition; puppies; Apgar; lactate; acid-base

Contents

1. Introduction

Delivery of healthy offspring is the ultimate goal of a breeding program (Buczinski et al., 2007). As veterinary care has advanced, so too has the demand for assisted reproductive technologies in dogs, including management of pregnancy and whelping (Smith, 2007). Consequently, there are considerable efforts being made to develop methods to optimise the outcome for each puppy and bitch (Miranda and Domingues, 2010).

For the neonate, labour represents the most critical phase contributing to the first minutes after birth (Indrebo et al., 2007). Early recognition of foetal distress and dystocia are crucial to the successful management of labour and for optimal neonatal health. The total length of parturition and the time required for puppy expulsion are commonly considered the most important parameters affecting neonatal viability (Groppetti et al., 2010).

2. Physiological events (changes) during parturition

Significant changes occur in physiological parameters during parturition because of pain, anxiety and uterine contraction (Song et al., 2004). During normal parturition, uterine contractions induce an increase in circulating blood volume as blood restricted to the uterus is released into the general circulation, and as parturition nears completion, there is reduced compression of the caudal vena cava which allows an increase in cardiac output and arterial blood pressure (Chamchad et al., 2007).

A high heart rate is a result of the combination of stress and contractions (uterine and abdominal) during parturition.

Obstetrical interventions may increase the stress and pain of parturition and may induce further haemodynamic or vascular changes (Lucio et al., 2009).

2.1. Effects of labour pain on the neonate

Labour induces a massive catecholamine surge in the foetus, which helps to preserve blood flow to the brain, heart and adrenal glands and to promote post-natal adaptive circulatory changes. While this foetal stress response is favourable to the foetus, unmodified 'natural' labour induces maternal changes that may be detrimental. Maternal hyperventilation in response to pain has adverse foetal effects. It leads to: (a) Respiratory alkalosis and a left shift in the oxygen dissociation curve (potentially disadvantageous to placental transfer of oxygen); (b) compensatory metabolic acidosis, which becomes progressively more severe as labour advances and is also conveyed to the foetus; (c) episodes of hypoventilation, leading to haemoglobin desaturation, between contractions; (d) uterine vasoconstriction.

The stress of labour also leads to the release of maternal cortisol and catecholamines, which may prolong labour and impair placental flow. Stress hormones also bring about lipolysis with the release of free fatty acids (readily transferable across the placenta) and hyperglycaemia, which will exacerbate foetal hypoxia. All these changes tend to intensify foetal metabolic acidosis, which indeed becomes progressively more severe as labour advances (Reynolds, 2010).

2.2. Asphyxia and acidosis

Asphyxia characterised by hypercapnia and hypoxaemia is a life – threatening condition in newborn animals. Foetal asphyxia, which results from inadequate oxygenation of the foetus via the umbilical cord, is differentiated from neonatal asphyxia, which is the result of inadequate respiratory gas exchange due to the immaturity of the lungs or the respiratory centre. Both types of asphyxia lead to acidosis, which is in part due to inadequate oxygen uptake by the placenta or lungs and thus inadequate oxygenation of body tissue cells. Under such circumstances the cells derive energy from anaerobic glycolysis, which results in the production of lactate and leads to metabolic acidosis. In animals with asphyxia, the concentration of carbon dioxide produced by the cells increases in the blood, because its elimination via the placenta or lungs is impaired. This results in respiratory acidosis (Bleul et al., 2007).

During normal delivery, a short period of foetal asphyxia may be observed during uterine contractions, and this leads to neonatal hypercapnoea and transitory acidaemia (Ruth and Raivo, 1988). As parturition progresses, a mixed acidosis develops and there is a significant increase in foetal CO_2 production (Wiberg et al., 2006). Under hypoxic conditions, tissue acidosis occurs earlier than blood acidosis (Abitbol et al., 1986).

Transition from intra- to extra-uterine life is often accompanied by varying degrees of hypoxia, which is remarkably well tolerated by newborns (Singer, 1999). Neonatal survival was found to strongly depend on weight and maturity at birth; furthermore, there is a rapid decrease in hypoxia tolerance with increasing postnatal age (Adolph, 1969). More recent studies have focused on the brain as the main target organ of perinatal hypoxic injury. Biochemical analysis has revealed a slower decline in tissue ATP in the hypoxic neonatal than in the adult brain (Duffy et al., 1975). Physiological studies have found a markedly delayed depolarisation and a later increase in extracellular potassium in neonatal as compared to adult rat neurons under hypoxic conditions (Trippenbach et al., 1990). Similar investigations have been directed on the heart and its ability to tolerate temporary ischaemia. It has been shown that during hypoxia, the neonatal myocardium of the doe maintains mechanical function better than the adult myocardium of the same species, which is again associated with a better preservation of electrical activity and a slower decline in tissue ATP (Jarmakani et al., 1978). Moreover, the post ischaemic recovery of neonatal hearts has proved to be superior to adults (Yano et al., 1987). The mammalian foetus has to cope with two problems – the limited intrauterine oxygen (and substrate) availability and the risk of perinatal asphyxia. To survive and to grow, the mammalian foetus must make use of similar mechanisms to those required for acclimatisation to high altitudes. These include optimised gas exchange through a large respiratory area (lung or placenta), improved oxygen transport by haematologic adaptations (polycythemia, increasing oxygen binding capacity and a leftward-shift of the haemoglobin dissociation curve), and metabolic adjustments at the tissue level (Monge and Leon-Velarde, 1991).

The most critical events in the delivery of puppies seem to occur during emergency C-sections. In this condition foetal distress can be a consequence of dystocia or hypoxic-ischaemic effects of uterine

contractions on placental vessels, anaesthesia, dam hypotension, and hypovolaemia. In this regard, there is physiological evidence for foetal acidosis at birth induced by uterine activity. Foetal acidosis at birth is mainly due to hyperlactemia, induced by hypoperfusion of peripheral tissues, and associated with increased uterine activity during the first and second stage of labour (Bakker et al., 2007).

2.3. Respiratory disorders

Several factors cause respiratory disorders in the newborn and direct diagnosis is not conclusive if based exclusively on general clinical examination, because clinical signs are not characteristic and might be caused by non – pulmonary secondary disorders. Thus, additional examinations are necessary. In veterinary medicine, radiographic evaluation of newborn lungs is uncommon, and this limits the therapeutic approach. Laboratory analyses contribute to the diagnosis of respiratory disorders in neonates. Blood gas analysis is routinely performed in humans to determine the degree of metabolic or respiratory acidosis and to estimate the need for intensive care and correction of acid – base imbalance (Siristatidis et al., 2003).

3. Neonatal assessment

The difficulty of performing a detailed physical examination associated with the absence of technical scientific knowledge contribute to inaccurate and empirical diagnosis of neonatal disorders and can explain the high incidence of morbidity and mortality (Silva et al., 2009). Newborn puppy mortality for normal deliveries is 5.55%, significantly lower than that for dystocia deliveries, which is 33% (Moon et al., 2001). In cases of elective or emergency caesarean section, Moon et al. (2000) reported neonatal death rates of between 6–11%.

Recognition of foetal acidosis by umbilical lactate measurement and Apgar score classification represent an advanced system in the evaluation of the canine newborn patient (Groppeti et al., 2010)

3.1. Apgar score

The Apgar score is used in human medicine to evaluate the main vital functions of neonates in the first minutes of life (Silva et al., 2009). In the veterinary adaptation the Apgar score includes measurement of the heart rate, respiratory activity, muscle tone, colour of mucous membranes and vocalisation (Moon et al., 2001).

In 1952, the physician and anaesthesiologist Virginia Apgar developed a simple, reliable scoring system for evaluating the health of babies immediately after birth (Apgar, 1953). She developed this method after observing that struggling babies were frequently placed out of sight and left to die. Apgar wished to quickly identify newborns that needed additional help in the moments after delivery. Her method, termed the Apgar score, was quickly adopted in many countries (Skolnick, 1996). The Apgar score encompasses five parameters that are easy to determine without interfering with the care of the infant. This score is particularly useful in assessing the clinical status of newborns. Although the score was originally named after its creator, in 1963 the acronym Apgar was coined as a mnemonic learning aid to easily remember these signs: Appearance, Pulse, Grimace, Activity, and Respiration. Each of these is evaluated on a scale from 0 to 2, with the sum of the five values resulting in an Apgar score that ranges from 0 to 10. This test is generally performed between 1 and 5 min after birth and may be repeated later for newborns with low scores. In humans, a score of less than three is usually considered critical, from four to six is low, and over seven is regarded as normal (Apgar and James, 1962). A low score means that the neonate requires medical attention; if the score improves in the following few minutes, then this usually means the absence of long-term problems. In contrast, an Apgar score of 0 at 10 min represents an important risk factor for subsequent death or disability (Harrington et al., 2007).

The Apgar score was not designed to make long-term predictions but rather to guide physicians in providing care to vulnerable individuals immediately after birth (Jepson et al., 1991). The Apgar score is a better predictor or survival than umbilical artery blood gas in very low birth weight infants (Gaudier et al., 1996). Finster and Wood (2005) demonstrate that the Apgar score cannot be used to measure perinatal asphyxia but should instead be considered an easy method for assessing the overall condition and, to some degree, the viability of the infant immediately after delivery and the effectiveness of resuscitation. Because of its usefulness for overall assessment and its unquestionable

reliability in short-term survival prediction, the Apgar score was introduced into use in veterinary medicine to assess the clinical status of newborns (Palmer, 2007).

3.2. Umbilical cord blood lactate

Asphyxia is usually defined as foetal hypoxia causing foetal acidosis and depression. The condition means a state of the foetus characterised by depressed vital functions and an increased risk of long-term morbidity. Intrapartum asphyxia is estimated to be accountable for 7–15% of neonatal mortality and severe morbidity (Blair and Stanley, 1988).

Different criteria have been used in an attempt to identify neonates who have been exposed to intrapartum asphyxia. The Apgar score gives no information of acidosis/hypoxia and has a very low predictive value in identifying long-term morbidity. pH by itself only indicates the degree of acidosis but not the aetiology. Respiratory acidosis is far less harmful to the foetus and neonate than metabolic acidosis (Westgate et al., 1994). Respiratory acidosis is a result of accumulating carbon dioxide usually caused by compression of the umbilical cord, decreased foetal cardiac output or insufficient placental perfusion. Metabolic acidosis develops in the last stage of foetal hypoxia when oxygen supply to the foetus becomes insufficient and the metabolism of carbohydrates is converted into anaerobic metabolism with the production of lactic acid. When the concentration of lactate rises, the standard base excess (SBE), and actual base excess (ABE) levels decrease. The levels of SBE and ABE are dependent on the lactate concentration. Therefore, lactate would seem to be the most direct parameter for measuring the severity of metabolic acidosis and lactate concentration in umbilical cord blood at delivery is a more precise tool in the assessment of foetal metabolic acidosis during labour (Gjerris et al., 2008). The main contributor to the foetal lactate increase during labour is the foetus itself and this increase is not significantly influenced by maternal or by uteroplacental lactate production (Nordstrom et al., 2001).

Gjerris et al. (2008) found a strong correlation between lactate levels and pH. This strong correlation suggests that the lactate value could be used as a supplement to or instead of pH. Westgren et al. (1995) showed that pH and lactate were equally accurate predictors of neonatal outcome.

Lactate plays a central role in human obstetric management as a marker of foetal and neonatal distress. The presence of excessive levels of lactate stems from the use of secondary oxygenation pathways due to hypoxic events occurring during parturition. When the oxygen supply to the foetus is significantly disrupted, tissue oxygen deprivation develops, acids begin to accumulate, and acidaemia ensues (Blickstein and Green, 2007). Lactate is a major component of metabolic acidosis. Sampling of blood from the foetus's scalp or umbilical cord, during labour and parturition, to analyse lactate, is regarded as the ideal method of identifying intrapartum foetal hypoxia in humans (Borruto et al., 2008).

Only a small portion of lactate crosses the placenta, so lactate acid in foetal blood during labour is thought to be primarily of foetal origin, rather than maternal, and is the end product of anaerobic glycolysis (Nordstrom et al., 2001). Umbilical cord venous lactate concentrations are similar to umbilical cord arterial lactate concentrations (Picquard et al., 1991). Lactate concentrations lower than 5 mmol/l should be considered a good prognostic factor in canine labour and neonatology.

Umbilical vein or arterial lactate could provide valuable clinical information and facilitate appropriate medical and surgical treatments or allow the proper and timely administration of oxygen and warmth to mother and newborn pup (Groppetti et al., 2010)

4. Conclusion

The economic value of pure-breed puppies, as well as the increasing emotional involvement of owners in their pets' birthing process, has resulted in increased interest in improving puppy survival (Veronesi et al., 2009).

Newborn puppies are very vulnerable individuals, because they are not capable of maintaining constant body temperature as shivering reflexes and vasoconstriction mechanisms are not fully developed at birth. In addition, puppies have little subcutaneous fat, a relatively large body surface and are hypothalamically immature (Johnston et al., 2001). Therefore viability assessment and clinical examination of puppies immediately after parturition is helpful for revealing individuals that need acute care. The Apgar score is the most suitable method for evaluating short- term survival prognosis for

individual puppies. The measuring of lactate levels, meanwhile, are best suited to long-term survival prognosis.

5. REFERENCES

Abitbol MM, Monheit AG, Stone ML (1986): Arterial PO_2, PCO_2, and pH versus transcutaneous PO_2 and PCO_2 and tissue pH in the fetal dog. American Journal of Obstetrics and Gynecology 155, 437–443.

Adolph EF (1969): Tolerance to cold and anoxia in infant rats. American Journal of Physiology 155, 366–377.

Apgar V (1953): A proposal for a new method of evaluation of the newborn infant. Current Research of Anesthesia and Analgesia 32, 260–267.

Apgar V, James LS (1962): Further observations of the newborn scoring system. American Journal of Diseases of *Children* 104, 419–428.

Bakker PCAM, Kurver PHJ, Kuik DJ, Van Geijn HP (2007): Elevated uterine activity increases the risk of fetal acidosis at birth. American Journal of Obstetrics and Gynecology 196, 313.e1–313.e6.

Blair E, Stanley FJ (1988): Intrapartum asphyxia: a rare cause of cerebral palsy. Journal of Pediatrics 112, 515–519.

Bleul U, Lejeune B, Schwantag S, Kahn W (2007): Blood gas and acid-base analysis of arterial blood in 57 newborn calves. Veterinary Record 17, 688–691.

Blickstein I, Green T (2007): Umbilical cord blood gases. Clinics in Perinatology 34, 451–459.

Borruto F, Comparetto C, Treisser A (2008): Prevention of cerebral palsy during labour: role of foetal lactate. Archives of Gynecology and Obstetrics 278, 17–22.

Buczinski SM, Fecteau G, Lefebvre RC, Smith LC (2007): Fetal wellbeing assessment in bovine near-term gestations: current knowledge and future perspectives arising from comparative medicine. Canadian Veterinary Journal 48, 178–183.

Chamchad D, Horrow JC, Nakhamchik L, Arkoosh VA (2007): Heart rate variability changes during pregnancy: an observational study. International Journal of Obstetric Anesthesia 16, 106–109.

Duffy TE, Kohle SJ, Vannuci RC (1975): Carbohydrate and energy metabolism in perinatal rat brain: relation to survival in anoxia. Journal of Neurochemistry 24, 271–276.

Finster M, Wood M (2005): The Apgar score has survived the test of time. Anesthesiology 102, 855–857.

Gaudier FL, Goldenberg RL, Nelson KG, Peralta-Carcelen M, Dubard MB, Hauth JC (1996): Influence of acid-base status at birth and Apgar scores on survival in 500–1000g infants. Obstetrics and Gynecology 87, 175–180.

Gjerris AC, Staer-Jensen J, Jorgensen J, Bergholt T, Nickelsen C (2008): Umbilical cord blood lactate: A valuable tool in assessment of fetal metabolic acidosis. European Journal of Obstetrics and Gynecology and Reproductive Biology 139, 16–20.

Groppetti D, Pecile A, Del Carro AP, Copley K, Minero M, Cremonesi F (2010): Evaluation of newborn canine viability by means of umbilical vein lactate measurement, apgar score and uterine tocodynamometry. Theriogenology 74, 1187–1196.

Harrington DJ, Redman CW, Moulden M, Greenwood CE (2007): The long-term outcome in surviving infants with Apgar zero at 10 min: a systematic review of the literature and hospital based cohort. American Journal of Obstetrics and Gynecology 196, 463–465.

Indrebo A, Trangerud C, Moe L (2007): Canine neonatal mortality in four large breeds. Acta Veterinaria Scandinavica 49 (Suppl. I), S2.

Jarmakani JM, Nakazawa M, Nagatomo T, Langer GA (1978): Effect of hypoxia on mechanical function in the neonatal mammalian heart. American Journal of Physiology 235, H469–474.

Jepson HA, Talashek ML, Tichy AM (1991): The Apgar score: evolution, limitations, and scoring guidelines. Birth 18, 83–92.

Johnston SD, Kustritz MVR, Olson PNS (2001): The neonate from birth to weaning. In: Johnston SD (ed.): Canine and Feline Theriogenology. WB Saunders, Philadelphia. 146–157.

Lucio CF, Silva LCG, Rodrigues JA, Veiga GAL, Vannucchi CI (2009): Peripartum haemodynamic status of bitches with normal birth or dystocia. Reproduction in Domestic Animals 44 (Suppl. 2), 133–136.

Miranda SA, Domingues SFS (2010): Conceptus ecobiometry and triplex Doppler ultrasonography of uterine and umbilical arteries for assessment of fetal viability in dogs. Theriogenology 74, 608–617.

Monge C, Leon-Velarde F (1991): Physiological adaptation to high altitude: oxygen transport in mammals and birds. Physiological Reviews 71, 1135-1172.

Moon PF, Erb HN, Ludders JW, Gleed RD, Pascoe PJ (2000): Perioperative risk factors for puppies delivered by cesarean section in the United States and Canada. Journal of the American Animal Hospital Association 36, 259–368.

Moon PF, Massat BJ, Pascoe PJ (2001): Neonatal critical care. Veterinary Clinics of North America: Small Animal Practice 31, 343–366.

Nordstrom L, Achanna S, Naka K, Arulkumaran S (2001): Fetal and maternal lactate increase during active sec-

ond stage of labour. British Journal of Obstetrics and Gynaecology 108, 692–697.

Palmer JE (2007): Neonatal foal resuscitation. Equine Veterinary Clinic 23, 159–182.

Picquard F, Schaefer A, Dellenbach P, Haberey P (1991): Is fetal acidosis in the human fetus maternogenic during labour? A reanalysis. American Journal of Physiology 261, R1294–1299.

Reynolds F (2010): The effects of maternal labour analgesia on the fetus. Best Practice and Research Clinical Obstetrics and Gynecology 24, 289–302.

Ruth VJ, Raivio KO (1988): Perinatal brain damage: predictive value of metabolic acidosis and the Apgar score. British Medical Journal 297, 24–27.

Silva LCG, Lucio CF, Veiga GAL, Rodrigues JA, Vannuchi CI (2009): Neonatal clinical evaluation, blood gas and radiographic assessment after normal birth, vaginal dystocia or caesarean section in dogs. Reproduction in Domestic animal 44 (Suppl. 2), 160–163.

Singer D (1999): Neonatal tolerance to hypoxia: a comparative-physiological approach. Comparative Biochemistry and Physiology Part A 123, 221–234

Siristatidis C, Salamalekis E, Kassanos D, Loghis C, Creatsas G (2003): Evaluation of fetal intrapartum hypoxia by middle cerebral and umbilical artery Doppler velocimetry with simultaneous cardiotocography and pulse oximetry. Archives of Gynecology and Obstetrics 270, 265–270.

Skolnick AA (1996): Apgar quartet plays perinatologist's instruments. Journal of the American Medical Association 276, 1939–1940.

Smith FO (2007): Challenges in small animal parturition – Timing elective and emergency cesarean sections. Theriogenology 68, 348–353.

Song J, Zhang S, Qiao Y, Luo Z, Zhang J, Zeng Y, Wang L (2004): Predicting pregnancy-induced hypertension with dynamic hemodynamics. European Journal of Obstetrics and Gynecology and Reproductive Biology 117, 162–168.

Trippenbach T, Richter DW, Acker H (1990): Hypoxia and ion activities within the brain stem of newborn rabbits. Journal of Applied Physiology 68, 2494–2503.

Veronesi MC, Panzani S, Faustini M, Rota A (2009): An Apgar scoring system for routine assessment of newborn puppy viability and short-term survival prognosis. Theriogenology 72, 401–407.

Westgate J, Garibaldi JM, Greene KR (1994): Umbilical cord blood gas analysis at delivery: a time for quality data. British Journal of Obstetrics and Gynaecology 101, 1054–1063.

Westgren M, Divon M, Horal M (1995): Routine measurements of umbilical artery lactate levels in the prediction of perinatal outcome. American Journal of Obstetrics and Gynecology 173, 1416–1422.

Wiberg N, Kallen K, Oloffson P (2006): Physiological development of a mixed metabolic and respiratory umbilical cord blood acidemia with advancing gestational age. Early Human Development 82, 583–589.

Yano Y, Braimbridge MV, Hearse DJ (1987): Protection of the pediatric myocardium: differential susceptibility to ischemic injury of the neonatal rat heart. Journal of Thoracic and Cardiovascular Surgery 94, 887–896.

Received: 2011–11–20
Accepted after corrections: 2011–12–07

Corresponding Author:

Gabriela Kredatusova, University of Veterinary Medicine and Pharmacy, Small Animal Clinic, Kosice, Komenskeho 73, 04181 Kosice, Slovak Republic

Tel. +421 917 324 633, E-mail: kredatusova@uvm.sk