DIAGNOSIS OF PERINATAL WELL-BEING OF DAIRY CALVES

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Abstract

At present, in veterinary practice the main emphasis should be placed on prevention of asphyxia of calves at birth since instruments suitable for a reliable clearing of respiratory passages and for the maintenance of this state and for artificial respiration of calves in the field are not yet widely available. The most important breeding objective is to reduce the number of calving assistance required. This is even more important, since calving assistance in itself may result in a shift of the calf's acid-base balance to acidosis. In case of difficult calving, the mode (traction or caesarean section) and time of calving assistance (within 2 h after rupturing the foetal sacs /Held 1983/) should be chosen with regard to profitability factors and in a manner which would allow the least possible shift of the calf's acid-base balance towards acidosis. Before applying traction, the measurements of the soft birth canal should always be considered when dilatation of the soft maternal passages is not sufficient they must be expanded non-surgically or surgically (episiotomy lateralise) and obstetric lubricants should be used to avoid tractions longer than 2 to 3 minutes [64] and rib and vertebral fractures due to excessive traction [50]. If a prolonged traction is expected, Caesarean section should be carried out to save the calf and to prevent injuries to the maternal birth canal. Recent studies have shown that before making a decision as to the mode of calving assistance in an animal hospital, the results of acid-base balance measurements from blood samples should be considered. The routine use of complex treatment of calves (initiation of respiration, intensive rubbing of the newborn calf especially the neck and shoulder region with a dry large towel cloth, oxygen supplementation, compensation of acidosis by bicarbonate treatment) born with severe asphyxia may reduce the postnatal calf losses [69, 44]. In addition to an adequate therapy, particular attention in the case of calves with asphyxia should be paid to the ingestion and absorption of sufficient amounts of colostrums [22, 4], since the lack of colostrum uptake is accompanied by an increased susceptibility to gastrointestinal disorders [4]. In case of diarrhoea or pneumonia early diagnosis and immediate adequate treatment is needed to decrease the rate of calf morbidity and mortality [54].

Key words: dairy calf, cow, diagnosis of prenatal well-being

INTRODUCTION

The profitability of cattle breeding is greatly influenced by the rate of calves are born alive and reared to adulthood. In spite of the speedy developments of animal breeding, prenatal mortality is still very high (4 to 7%) and constitutes approximately half of the total calf losses [2, 73, 59, 44, 72]. Prenatal mortality (stillbirth) is defined as the death of a mature calf foetus after at least 260 day gestation period during calving or in the first 24 to 48 h of postnatal life [69, 44]. Direct and indirect asphyxia was suggested as the cause of death because in 73 to 75% of the calves that died in the prenatal period no pathological changes were detected [24, 27]. In a recent study, occurrence of asphyxia in calves dying prenatally was 58.3% [50].

As a result of disturbances in the uteri-placental circulation occurring during parturition due to the rupture of foetal membranes and uterine contractions, all calf foetuses develop more or less severe hypoxia and consequently acidosis. The foetus responds to hypoxia by an oxygen-conserving adaptation of its circulation. This means that all organs, that are not essential for intra-uterine life (lungs, spleen, thymus, muscles

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The manuscript was received: 30.03.2012
Accepted for publication: 4.05.2012

and skin, gastrointestinal tract, possible also the liver and kidneys) are supplied with minimum blood. Oxygen is spared for essential organs like the brain, heart and adrenal glands. Increased heart rate (tachycardia), blood pressure and blood flow are also observed. In case of relatively high hypoxemia the frequency of heart activity decreases (bradycardia). Circulation changes and reduced oxygen consumption result in oxygen tension in the blood being maintained within physiological limits for some time. This oxygen-conserving adaptation, however, means anaerobic glycolises in all tissues with minimum blood supply. Under normoxic conditions glucose as the main energy source is reduced to pyruvate via the citric-acid cycle. The first step to pyruvate is anaerobic; the second step consists of oxidation of pyruvate via the citric-acid cycle to the final products, CO2 and H2O. During oxygen shortage glucose can only be metabolised an aerobically to pyruvate, which is mostly reduced to lactic acid. Energy output in this process is small, but it is sufficient to maintain metabolism for some time. Anaerobic glycolysis, however, has a great disadvantage because energy production is reduced, carbohydrate reserves are rapidly exhausted and metabolic acidosis develops by accumulation of acid metabolites (lactic acid). At birth all foetuses therefore suffer from a respiratory as well as metabolic acidosis. It is the degree of acidosis that finally determines whether the foetus lives or dies. Vital cell functions cannot take place in severe acidosis, at a blood pH value of 6.7 foetal life ends. Before that, the organism’s regulatory system of chemical buffering in the blood comes into operation to keep the offspring alive. Bicarbonate is the most important buffer. The others are haemoglobin, plasma proteins and phosphate buffers [74, 21 57, 25].

The duration of survivable asphyxia always depends on the reserves of glycogen in the heart muscle [11]. The surviving period for calves with induced anoxia is between 4 to 6 minutes: four of 6 foetuses subjected to 4 minutes of anoxia survived whereas all others died when the umbilical cord was clamped for 6 or 8 minutes [15].

The present paper focuses on the determination of foetal, neonatal and postnatal status diagnosis in the cow during per parturient period. In practice, it is generally not possible to measure the acid-base balance of foetuses or newborn calves therefore different methods are used to evaluate foetal, neonatal and postnatal well-being in the calf.

- Diagnosis of foetal well-being before calving

a) Clinical signs of life in anterior and posterior presentation

Clinically appreciable signs of life in anterior (interdigital reflex, bulbar reflex, swallowing reflex) and posterior presentation (interdigital reflex, anal reflex, pulse of umbilical cord) were evaluated and correlated to the acid-base status of foetuses intrapartum [30]. With increasing degree of acidosis (normal, acidotic, severely acidotic) foetuses in anterior presentation (n=180) failed to show first the interdigital reflex (88%, 65% and 20%) then the bulbar reflex (95%, 91% and 47%) and finally the swallowing reflex (100%, 98% and 80%). Due the limited number of foetuses in posterior presentation (n=37), a similar correlation between the appreciable signs of life (interdigital reflex: 52%, 25% and 12%, anal reflex: 76%, 62% and 50% and the pulse of the umbilical cord: 95%, 87% and 50%) in posterior presentation and the acid-base status of foetuses was not found. It is worth mentioning that there were 12 foetuses without reflexes (5.5%) although they were alive as confirmed by acid-base analysis and obstetrical assistance (Held 1983).

b) Changes of blood gases and acid-base parameters during calving

Foetal blood samples can be collected by puncturing the *v. metacarpals volaris superficialis* or v. *digitalis dorsalis communis* III before the onset of traction or a. and v. *umbilicalis* before the onset of extraction during Caesarean section. Capillary blood can also be used to diagnose foetal [7] or neonatal asphyxia [76].

Before and after birth, calves can be assigned according to their pH and/or BE values to one of three groups as suggested by Eigenmann et al (1981):

Group 1 blood pH > 7.2 (normal /physiological acidosis/=slight, combined respiratory and metabolic acidosis)

Group 2: blood pH 7.2 - 7.0 (acidotic = moderate, combined respiratory and metabolic acidosis)

Group 3: blood pH < 7.0 (severely acidotic = severe, combined respiratory and metabolic acidosis)

Shortly before the onset of traction, 15 out of 58 calves, or 25.8%, had moderate (14 calves) or severe (1 calf) acidosis [66]. Mülling et al (1979) reported that of the 20 calves they investigated from 70 minutes ante partum to rupture of the umbilical cord, only 3 (15%) had a pH lower than 7.2. Eichler-Steinhauff (1977) found 4 of 19 calves (21%) acidotic with pH <7.2 during the final 30 minutes before vaginal delivery. In the case of Caesarean section, 16 of 44 calves, or 36.4% had moderate or severe acidosis before the onset of the extraction from the uterus [66]. Somewhat higher rates 21 (48.8%) of 43 and 27 (47.4%) of 57 were reported by Amman et al (1974) and Eigenmann et al (1981), respectively.

On the other hand, Held et al (1985), using prenatal base-excess as a criterion in a study of 217 parturitions, found 57,6% of the calves to be normal (BE < -6,0 mmol/l), 24,9% acidotic (BE: - 6.0 and -12.9 mmol/l), and 17,5% severely acidotic (BE $\geq$ -13 mmol/l). Perinatal mortality occurred in 0%, 8% and 51% in these three groups, respectively.

The activity of individual foetuses in response to artificial anoxia varies considerably [15]. On average, first movement occurred 53 (range 10 to 109) seconds after clamping of the umbilical cord. Of the seven foetuses which died during their study, no movement was detected in only one foetus, after being subjected to four minutes of anoxia. The clinical evidence available indicates that intrauterine hypoxia or anoxia may cause vigorous foetal movements. This confirms our own findings because 4 out of 6 calves in Group 3 showed foetal movements during Caesarean section and were severely acidotic immediately after birth [66].

According to these results, besides disturbances of diaplacental circulation except for the abnormality of umbilical cord and foetal membranes, it is the duration of the expulsive period [30], the method of assistance [19, 60] and the duration of traction [61, 51] which may influence the acid-base balance of newborn calves.

c. Foetal circulation

Normocardia (heart rates: 80 to 155 beats per minute) and tachycardia (heart rates: > 155 beats per minute) were detected by cardiotocographic recording in 84 foetuses during the dilatation stage of parturition and close correlation was found between the heart rates and the degree of acidosis. All foetuses having tachycardia showed acidosis or severe acidosis (BE <-8.9 mmol/L) [32].

A great variation in ante partum foetal heart rate (FHR) pattern was found while uterine contractions had no significant effect on FHR in the last month of gestation based on transabdominal Doppler ultrasound examinations [34]. Basal FHR (90 to 120) gradually decreased towards the end of parturition, with a marked loss in variability. In a recent study [10] computer-assisted analysis after analog-digital conversion of the FHR data was used, which is more accurate than those calculated by visual inspection of paper recordings [35]. The reference values for FHR 2 days before expecting calving are 108.6$\pm$1.9 bpm comparing those with 2 (109.0$\pm$1.6 bpm) and 3 (114.2$\pm$1.4) weeks before calving [10].

When decelerations (periodic decrease in FHR) occurred beyond the end of a contraction the calf was born in a poor condition (Jonker et al 1989). In the acidotic group the mean baseline FHR increased from 113,5 to 138,6 bpm during the last 55 minutes before birth while in the normal group it changed from 116,9 to 121,3 bpm. Decelerations occurred during uterine contractions in acidotic foetuses and in the majority of normal foetuses (12 of 16) during the expulsive stage of parturition; accelerations (periodic increase in FHR) were hardly recorded. A mean fall in FHR during a uterine contraction increased significantly towards birth. It is concluded that intrapartum continuous FHR measurements may provide additional information on the acidotic state of the foetuses (Jonker et al 1996); however, short term measurements has no diagnostic values [33]. Therefore at least 30 min continuous recordings are suggested in the cow [10].

Continuous measurements of foetal oxygen saturation of arterial haemoglobin via pulse oximetry (FSpO2) in the last 30 minutes of stage 2 of parturition may contribute to early detection of foetal asphyxia. This method may be more accurate than assessments of vitality by heart beat or reflexes, and would potentially be more reliable than the point-in-time information supplied by blood gas and acid-base analysis [7].

The accuracy of predicting asphyxia is the highest when the oxygen saturation is below a given test criterion for more than half of the total measuring period, or for a period of at least 2 minutes. A cut–off value of <30% had the highest positive predictive value. In human medicine, values of <30% over at least 2 minutes are also used to predict acidosis directly after birth. Sporadic individual values <30% are not clinically significant as they may just represent physiological events at calving, e.g., the oxygen saturation can decrease temporarily during uterine contractions because of increased intrauterine pressure. According to Bleul and Kahn (2008) further studies are needed to determine whether an FSpO2 value of < 30% over a minimum of 2 minutes is a useful predictor of foetal asphyxia in the cow.

Transit-time ultrasonography during stage 2 of labour in cattle allows direct and continuous measurement of umbilical blood flow volume per unit time. It makes also possible to investigate the relationships between umbilical blood flow, uterine contractions and foetal heart rate [5]. A decrease in blood flow is most likely caused by compression of the umbilical vessels during uterine contractions. The venous blood flow is more severely affected than the arterial blood flow during strong contractions because the walls of the umbilical veins are thinner and have fewer muscle fibres than those of the umbilical arteries. Umbilical arterial and venous blood flow in acidotic calves was lower than that in non-acidotic calves during the last 30 min before birth [5].

- Diagnosis of neonatal well-being after calving

a) *Clinical signs of life after birth*

Several parameters have been recommended as alternative vitality classification systems after calving for field use including: respiration and reflexes [1]; time from birth till head-righting [15]; until sternal recumbency [15, 37, 47]; until the first obvious efforts to stand [15] until the calf standing up [25, 47]; until first suckling [16, 17, 23]; or a combination of attitude, vital signs, feeding behaviour and locomotion [9]. However, in most of these cases blood gases and acid-base parameters of newborn calves were not evaluated.

The modified human Apgar score (respiration rate, muscle tone, reflex activity, and skin colour) has been recommended for neonatal status diagnosis in calves [45] and was subsequently used by others [41, 38, 31, 53].

A simple, new score system, enabling the immediate precise judgement of neonatal state without the need for laboratory tests and thereby the immediate application of treatment whenever required, was developed by Szenci (1982). Neonatal status was judged by muscle tone and in problem cases cardiatic status was also considered. A total of 147 calves were examined immediately post partum for degree of vitality (V), which was characterised as follows:

V-III.: Normal tonicity, head erect, normal reflectoric movements

V-II.: Low tonicity, abdominal recumbency with head requiring support, reduced number and intensity of reflectoric movements

V-I.: Toneless, head dropping, limbs extended, cardiac activity present

V-0.: Toneless, head dropping, limbs extended, cardiac activity absent

There were statistically significant correlation between the vitality of newborn calf immediately after birth and the parameters characterising the acid-base balance. This scoring system enables us to access the newborn calf's general health status that is associated with the acid-base balance, without laboratory measurements, and allows us to take the necessary treatment in due course. As compared with the modified Apgar score and with the blood-test-based diagnosis of slight to severe asphyxia, an important advantage of the present method is that even individuals having only basic training can learn and use it. According to our experience, mainly in cases of Caesarean-derived calves immediately post-partum, an erroneous assessment may stem from the fact that as long as 2 to 3 minutes may elapse from the time when the calf lifts up its head until it changes its position from lateral to sternal recumbency. In such cases errors can be excluded by examining the calf's response to throwing cold water over its head [78].

Schuijt and Taverne (1994) examined 219 newborn calves and recommended the evaluation of the time from birth to attaining sternal recumbency (T-SR) for the diagnosis of the vitality of newborn calves. Calves were defined as vital if they received routine care without medical treatment and survived seven days from birth without any symptom of illness (n=192). Those which did not fulfil these conditions were categorised as non-vital (n=27). The mean ± SD T-SR values of the vital calves were 4.0±2.2 min (born spontaneously), 4.5±3.1 min (Caesarean section), 5.4±3.3 min (normal traction), 9.0±3.3 min (forced traction). Calves that were forcefully extracted had longer T-SR, more serious acidosis, recovered more slowly from acidosis, showed higher mortality and exhibited trauma more frequently. Moderate correlation was reported between T-SR values and 10-minute pH and base excess values, while there was a weak correlation between T-SR and pCO2 values.

Torres and Gonzales (1987) found that responsiveness to exogenic stimuli, rising of the head, suckling reflex, interest in the environment and the time needed to stand up successfully as criteria for evaluating the vitality showed good correlation with the acid-base status of newborn calves.

b) Meconium-stained newborn calves

In humans, meconium-stained amniotic fluid is one of the classic signs of early intrauterine hypoxia which necessitates immediate initiation of parturition, or depending on the foetal acid-base status, of intensive care [48]. In contrast, Duifhuizen et al (1979) reported that the pH, the blood gas tension and the viability of newborn lambs were identical in both meconium-stained and in unstained lambs. This is confirmed by our own findings as the percentage of meconium-stained calves delivered by Caesarean section was 8,7%, and only two calves were acidotic or severely acidotic [67]. In another of our study, the rate of meconium-stained calves was 12,1% and only 4 calves were acidotic or severely acidotic [68]. According to these clinical observations it seems that the presence of meconium staining in a live neonate is rarely accompanied by severe respiratory-metabolic acidosis. Further studies are needed to understand the complete mechanisms related to meconium staining of newborn calves [44].

c) Changes of blood gases and acid-base parameters after calving

At birth coinciding with the start of respiration, vasoconstriction is stopped and the accumulated acids enter the circulation. This may be the explanation for further decrease of *p*H and acid-base variables in the 10th minute after calving. These decreases in the metabolic values are higher in the case of traction [41, 49, 57, 64,] than in the case of Caesarean section [43, 60]. In posterior presentation this decrease was expressed more than in anterior presentation [57, 60]. The newborn calves requiring no assistance were born with physiological respiratory and metabolic acidosis. The metabolic disturbances were compensated for within an hour after birth, but the respiratory disorder was still not fully compensated at [24, 38, 41, 42, 74] and 48 hours after delivery [49, 56, 64]. The slight alkalosis demonstrated at 24-48 hours after calving may arise in compensation for the still relatively high pCO2.

In contrast, except one calf, the metabolic acidosis after Caesarean section became more expressed in the meconium-stained newborn calves (n=11) 10 minutes after birth and instead of its spontaneous normalization at 60 minutes after birth a further decline in 4 cases could be detected [68].

In the case of severe respiratory metabolic acidosis the postnatal compensation of metabolic acidosis was somewhat slower and was completed between 1 to 6 hours, the respiratory acidosis was present up to 24 and 48 hours after delivery [26, 39, 43, 49].

The mean lactate concentrations (3,8 mmol/L) in the venous blood of 24 normal calves immediately after calving tended to decrease to 2,8 mmol/L at 24 hours after calving, while mean pyruvate concentration changed between 144,2 and 228,2 μmol/L during the first 24 hours of life [76]. A significant decrease in blood lactate (4.64 mmol/L to 2,85 mmol/L) during the first 3 hours of life occurred in calves of pluriparous dams while blood glucose concentrations changed between 2,44 and 3,48 mmol/L [13] or increased significantly during the first hour of birth and showed a significant negative linear correlation with pH at birth [40]. At the same time a wide variability of lactate concentrations is characteristic of newborn calves even in cases of normal, unassisted deliveries 5 to 10 minutes after birth [55].

d) Pulmonary adaptation in newborn calves

In newborn calves there are some rapid and important changes in lung mechanics during the first 24 h of life. The foetal lungs are expanded with fluid, which is actively secreted by the lung epithelium during the gestation period. The foetal lung fluid volume decreases by about 35 % before birth. Some of the fluid is pressured out by the vaginal squeeze and replaced by air and the remainder (35-40 % of the total volume) is absorbed or cleared from the lungs by breathing. Most of the fluid moves rapidly into the interstitial spaces and subsequently into the pulmonary vasculature with less than 20% of the fluid being cleared by the pulmonary lymphatic system during spontaneous breathing [28]. During normal calving, uterine contraction and rupture of the foetal membranes cause disturbances in foeto-placental circulation, which lead to slight respiratory and metabolic acidosis ($pH \geq 7.2$) in each case [19, 64, 66]. The slight respiratory and metabolic acidosis together with cooling and environmental tactile stimuli after birth helps to stimulate the initiation of the first breath and spontaneous respiration in the newborn calves [41, 42]. During the first breath, the lung is inflated with air and this leads to an increased pulmonary blood flow, better blood oxygenation and decreased pulmonary resistance. These circulatory changes will result in the closure of *ductus arteriosus*, foramen ovals and the beginning of the neonate’s own circulation [12].

The compensation of acidosis is associated with the improvement in lung mechanics using the oesophageal balloon catheter technique and these changes mainly occur during the first 6 h of life. Moderate to pronounced acidosis does not affect the pulmonary adaptation negatively although some respiratory mechanics parameters (maxΔPpl), blood pH and $Ca2+$ ion concentrations remain significantly different between the normal and acidotic groups at 24 h after birth. This might be the result of overcompensation of acidosis and the interdependence between blood pH and $Ca2+$ concentrations [71]. Body positioning immediately after calving [79] or cleaning of the foetal fluid from the upper airways by using a hand-powered vacuum pump, or hypothermal stimulation of breathing by pouring five litres of cold water over the newborn heads immediately after birth or prevention of heat losses by using an infrared radiant heater for 24 h after birth [78] may positively influence respiratory and metabolic adaptation to extra-uterine life. However, further studies are needed to determine any possible cumulative effects of these resuscitation protocols when applied together, including in asphyctic calves. Examination of any long-term effect on overall well-being of newborn calves before instituting a systematic application is also warranted [78].

Pulse oximetry by continuous measurements of oxygen saturation of arterial haemoglobin (SpO2) can be used to monitor non-invasively the pulmonary adaptation in the field. According to Uystepruyst et al (2000) there is a high correlation between SpO2 and arterial oxyhaemoglobin saturation (SaO2) measured by blood gas analyser. The transmission-type sensors of the pulse oximeter are suggested to fix at the base of the calf tail, where the skin had been shaved and was not pigmented. Based on five-hundred paired analyses the authors suggest that pulse oximetry provides a relatively accurate, non-invasive, immediate, portable, easy-to-use and inexpensive method to monitor SaO2 and to evaluate objectively the pulmonary function in newborn calves during their adaptation to extra-uterine life. The equipment does not require any calibration and can also be used by relatively unskilled persons. The accuracy of a pulse oximeter may be limited by several technical issues such as the device itself, the type of transducer, the site of measurement, the tissue perfusion, the pigmentation of the site, the ambient light (i.e. infrared heat lamps) and/or animal movements therefore correct interpretations of the results are required (Uystepruyst et al 2000, Bleul and Kahn 2008).

ACKNOWLEDGEMENTS

This study was partly supported by GAK fund; grant number OMFB-00173/2006.

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