

Paper

Association between birth conditions and glucose and cortisol profiles of periparturient dairy cows and neonatal calves

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Parturition in cattle is a stressful event for both the dam and the offspring. Stress and pain can alter the energy profile of calves and calving cows, producing a metabolic imbalance at birth. This study aimed to assess the effects of dystocia and oxytocin and calcium infusion on metabolic homeostasis in dairy cows and calves. Thirty Holstein cows and their calves were divided into three groups: an eutocia group (n=10), in which no calving assistance was needed; a dystocia group, which required mild-to-severe obstetric assistance (n=10); and a uterine inertia group, which was treated with oxytocin and calcium (n=10). To assess serum cortisol and blood glucose levels, blood samples were collected during the peripartum period from cows and during the first hour since birth from calves. All groups were hyperglycaemic following parturition. Infusion of oxytocin and calcium resulted in lower maternal glucose concentrations and lower levels of stress than in cows in the dystocia group. Birth condition was significantly associated with blood glucose and cortisol concentrations in calves. Glucose concentration was lower in calves born with oxytocin and calcium infusion than those born with fetal extraction. In conclusion, assisted calving with fetal extraction causes important metabolic changes for the dam and calf. Conversely, the practice of oxytocin and calcium infusion for hypotonic cows has no harmful effects on metabolic balance and can be safely employed as a medical treatment.

Parturition in cattle is a stressful event for both the dam and the offspring. Even in normal labour, pelvic canal dilation, uterine and abdominal contractions and pain associated with fetal expulsion are involved in a complex pattern of neuroendocrine regulation that culminates in extreme maternal and fetal physiological changes.

During gestation, the metabolic system undergoes few changes unless a stressful event occurs (Landim-Alvarenga 2006). At spontaneous parturition, however, stress and algia provoke endocrine changes, for example, in cortisol, adrenaline, noradrenaline, oxytocin, vasopressin and endorphin concentrations (Hydbring and others 1999). During gestation, carbohydrates of maternal origin can be stored in the fetal liver to an extent that depends on adrenal activity. For example, fetal adrenocorticotropic hormone or corticosteroids enhance hepatic glycogen stock (Prestes and Landim-Alvarenga 2006); therefore, at birth, blood

glucose concentrations in neonatal calves are related to hepatic metabolism and muscular glycogen, which are in turn controlled by catecholamines such as noradrenaline and adrenaline (Chan and others 1998). These mechanisms mean that stress and pain can alter the energetic profile of neonatal calves, producing a metabolic imbalance at birth.

Dystocia has been found to be related to several negative outcomes, such as increased rates of periparturient infections, longer calving intervals, lower milk production and reduced health of cows and survival of newborn calves (Civelek and others 2008). During dystocia, the efforts of labour are prolonged or require fetal extraction, resulting in low neonatal vitality or adverse maternal consequences (Rice 1994). Calves exposed to dystocia become hypoglycaemic more rapidly primarily due to the depletion of glycogen storage (Arnott and others 2012). Low birth weight neonates or those subjected to hypoxaemia during birth are prone to hypoglycaemia. Moreover, most low-vitality newborns are hypoglycaemic due to hepatic immaturity (Macintire 1999). However, 30 minutes after birth, dystocia calves show blood glucose concentration higher than that of eutocia calves (Bellows and Lammoglia 2000). According to Massip (1980), this transient increase in blood glucose derives from direct hepatic glycogenolysis. In ill patients, hyperglycaemia is a stress response (Fahy and others 2009). Such situations, also known as stress hyperglycaemia, are a consequence of increased levels of cortisol, cytokines, growth hormones and catecholamines. A primary function of cortisol is to maintain glucose equilibrium. Increases in cortisol serve primarily to prevent hypoglycaemia during acute and prolonged stress

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through influence on metabolic activities that provide energy (Benfield and others 2014). Hence, glucose increase occurs as a consequence of stress experienced during calving or first contact with the extra-uterine environment. For example, cold stress places severe demands on the energy stores of calves under adverse climatic conditions, due to the need to produce heat at birth. This process leads to extreme hypoglycaemia (Vaala and others 2006).

During parturition, the concentration of maternal glucocorticoids increases, indicating the presence of ongoing stress (Vermorel and others 1983). At high concentrations or under extremely stressful circumstances, cortisol crosses the placental barrier, increasing the fetal cortisol concentration during birth and immediately postpartum (Hunter and others 1977). The neonatal period is also considered a challenge to the newborn, as survival depends on adaptation to the extra-uterine environment. Hoyer and others (1990) have found that plasma glucocorticoid concentrations increase during the initial days of life, especially in calves with asphyxia during the perinatal period. In a previous experiment, we showed that obstetric conditions can influence neonatal outcome in distinct ways. Assisted calving resulted in severe acidosis, low vitality and hydro-electrolytic imbalance (Rodrigues 2008). In dairy herds, dystocia resulting from uterine atonia or hypotonia represents 10 per cent of whelping problems in pluriparous cows (Mee 2008). In such cases, oxytocin infusion is considered to be one of the most frequent medical treatments to induce uterine contractions (Noakes and others 2001). Moreover, studies on oxytocin administration during farrowing have shown increases in intrapartum mortality due to acute fetal distress, severe anoxia and an extreme weakness of piglets (Alonso-Spilsbury and others 2005). Nevertheless, under poor obstetric conditions, the factors that negatively influence neonatal outcome are not well understood. Metabolic imbalance was chosen as one of the variables to be assessed. It was hypothesised that metabolic imbalance occurring during dystocial calving could affect a calf's ability to survive the perinatal period.

This study aimed to verify the effects of dystocia and oxytocin and calcium infusion on maternal and neonatal metabolic homeostasis of dairy cows and calves, respectively. Moreover, it aimed to evaluate the magnitude of stress during the calves' initial hour of life under different obstetric conditions.

Materials and methods

Animals and experimental groups

The current study was approved by the Bioethics Committee of the School of Veterinary Medicine and Animal Science—University of São Paulo (number 1033/2006).

Data were collected between July 2007 and February 2008 on a single dairy farm. The herd consisted of 4000 cows, with 1460 lactating cows and 1600 calvings per year. Cows yielded approximately 30 kg of milk per cow per day and the cows had body condition score between 2.5 and 3.5. A prospective study was conducted involving 30 neonatal calves born to primiparous (13–21 months of age) and pluriparous (average age of four years) Holstein dams. All animals were healthy at the time of the study and the herd was kept under sanitary conditions throughout the study. The dams were free from anatomic or reproductive disorders and were fed a total mixed ration (corn silage and Tifton hay as forage and a corn, soybean and cottonseed meal-based concentrate) twice daily during the study period. Preparturient heifers and cows were housed individually in roofed calving sheds bedded on sand approximately one week before they were due to calve. Animals were provided with ad libitum access to water and sheds were cleaned regularly.

Experimental groups were formed based on the obstetric condition of the dam, as follows:

Eutocic group (five primiparous cows and five pluriparous cows): no calving assistance; stage II of birth taking less than two hours (six male calves and four female calves).

Dystocia group (10 primiparous cows): calving assistance due to fetal malpresentation or oversize; stage II of birth taking more than two hours (seven male calves and three female calves).

Inertia group (nine primiparous cows and one pluriparous cow): calving assistance due to uterine inertia; stage II of birth taking more than two hours and no signs of calving progress. Cows were subjected to oxytocin and calcium infusion (six male calves and four female calves).

All cows were supervised from the prodromic phase of calving (cows straining, tail raised and restlessness) until the complete elimination of the placenta. Dystocia diagnosis was initially based on the duration of the second stage of calving (initiated by the rupture of the allantoic sac), judged by the absence of labour progress, distress of the cow, vocalisation and straining without progress. For diagnostic purposes, vaginal and rectal palpations were performed in order to detect calf malpresentation (deviation of fetal presentation, position and posture in the birth canal) and overall dimensions, as well as uterine inertia. Obstetric examinations were always performed by the same veterinarian, who decided which therapeutic procedure should be adopted. In the Dystocia group, cows had calving assistance from two or more people or a mechanical extraction (severe dystocia). For dams in the Inertia group, uterine relaxation was diagnosed, and oxytocin (Orastina, Merck Animal Health) was infused slowly (30 minutes) via a catheter placed into the jugular vein; 100 ml of 0.9 per cent physiological saline, containing 50 IU oxytocin. Calcium gluconate (11.62 g; Glucafós, Merck Animal Health) was also administered intravenously.

After birth, calves were maintained in the calving sheds with their dams for an additional one hour before they were transferred to individual cages. After blood collection at one hour of birth, calves were fed colostrum.

Experimental design and analysis

To evaluate maternal serum cortisol concentration and glycaemia, 5 ml of total blood was collected from the coccygeal vein of dams at the following moments:

- ▶ Prepartum: 48 hours before the rupture of the amniotic sac. This period is also considered to be the preparatory phase of calving and is characterised by obvious abdominal discomfort, an elevated tail, constant cycles of urination, defecation and the elimination of vaginal mucus.
- ▶ Intrapartum: the period from the rupture of the allantois to complete fetal expulsion. Maternal evaluations were performed at a random time during this period.
- ▶ Postpartum: up to approximately 20 minutes after fetal expulsion.
- ▶ One hour postpartum: one hour after the previous evaluation (postpartum).

Within five minutes and one hour after birth, neonatal blood samples (3 ml) were collected following asepsis by puncturing the right or left jugular vein.

Immediately after collection, maternal and neonatal blood samples were subjected to glucometry (Accu-Chek). For cortisol assay, blood samples were allowed to clot at room temperature into the evacuated tubes without anticoagulant and centrifuged for 10 minutes at 1500×g. The serum was drawn off, separated in aliquots and stored at –20°C until it was analysed.

Serum cortisol concentrations were measured by radioimmunoassay with ¹²⁵I labelled using the commercial kit Cortisol Coat-A-Count (DPC), developed for human serum and previously validated for bovine samples. The sensitivity of the cortisol assay at 94 per cent binding was 0.05 ng/ml and the low and high intra-assay coefficients of variation were 1.77 per cent and 0.83 per cent, respectively.

Statistical analysis

All data were evaluated using the SAS System for Windows (SAS Institute, Cary, North Carolina, USA). The effects of group, time of evaluation and interactions between those factors were

estimated by the repeated measures analysis of variance (Mixed Procedure of SAS). Differences between treatments were analysed using parametric and non-parametric tests, according to the residual normality (Gaussian distribution) and variance homogeneity. Whenever necessary, data were transformed in order to obey these statistical assumptions. In case no significant interactions were observed, the effect of groups was analysed merging all times of evaluation and, conversely, times of evaluation were compared combining all groups; otherwise, comparisons were performed taking into account both effects. Differences between treatments were analysed using the Least Significant Difference (LSD) test for multiple comparisons. The response variables also underwent Spearman correlation analysis.

Results are reported as untransformed means±SE. The significance level was set at 5 per cent. In other words, P values of <0.05 were considered to be statistically significant.

Results

An interaction between groups and time of evaluation was observed only for maternal cortisol concentration (Table 1).

Maternal analysis

Dams in the dystocia group had the highest blood glucose concentrations (Fig 1). However, no difference was verified between non-normal calvings (dystocia and inertia groups) and normal calving (Fig 1). It is important to note that dams on dystocia were hyperglycaemic, whereas inertia cows presented normoglycaemia (45–75 mg/dl; Fig 1). Additionally, an increased concentration of maternal glucose over time (prepartum—58.7±2.2; intrapartum—67.3±2.4 and postpartum—76.5±2.9 mg/dl) was found, reaching the highest levels one hour after calving (88.6±3.5 mg/dl). Moreover, from postpartum onwards all groups were considered hyperglycaemic.

Oxytocin and calcium infusion intrapartum led to a lower maternal cortisol concentration compared with the normal calving group (Fig 2). On the other hand, immediately postpartum, dystocia cows had higher cortisol concentrations. Comparing time of evaluation, in the eutocia group, there was a significant increase of intrapartum serum cortisol compared with prepartum serum cortisol (Fig 2). Conversely, an increase in cortisol immediately postpartum was observed in dystocia until one hour after calving. For the Inertia group, blood cortisol concentrations were higher during postpartum (immediately and after one hour) than during prepartum (Fig 2).

Neonatal analysis

Neonatal calves in the Inertia group had the lowest blood glucose concentrations compared with dystocia calves (Fig 1). No significant difference was observed between calf glycaemia between times of evaluation (at birth—76.3±6 and one hour after birth—65.7±4.8 mg/dl). Similarly, no differences in cortisol concentrations were observed during the study period (at birth—167.3±11.9 and one hour after birth—158.8±8.7 ng/ml). Dystocia calves had the highest cortisol levels compared with calves in the other groups (Fig 1).

TABLE 1: Results of the repeated measures analysis of variance analysing the probability (P) values for main effects of groups (Eutocia vs. Dystocia vs. Inertia), time of evaluation (Cow: prepartum, intrapartum, postpartum and one hour postpartum; Calves: 0 and 60 minutes) and the interaction groups×time of evaluation on cows' and calves' blood glucose and cortisol concentration.

	Group	Time	Group×time
Neonatal glucose	0.14	0.07	0.96
Neonatal cortisol	0.08	0.43	0.06
Maternal glucose	0.03	<0.001	0.15
Maternal cortisol	0.01	<0.0001	0.008

Correlation analysis

In the normal calving cows, there was a *negative* correlation between intrapartum glucose and one hour postpartum cortisol levels ($r=-0.80$; $P=0.009$). Glucose concentration in calves at birth *positively* correlated with cortisol level at birth ($r=0.70$; $P=0.02$) and cortisol level after 60 minutes of birth ($r=0.64$; $P=0.02$).

In the Dystocia group, there was a *negative* correlation between maternal postpartum glucose concentration and calves' cortisol levels at birth ($r=-0.83$; $P=0.003$; Fig 3) and after 60 minutes of birth ($r=-0.82$; $P=0.004$; Fig 3).

In the Inertia group, there was a *negative* correlation between maternal postpartum glucose concentrations and cortisol levels postpartum ($r=-0.65$; $P=0.05$) and one hour postpartum ($r=-0.68$; $P=0.05$).

Irrespective of the experimental group, maternal postpartum cortisol levels *positively* correlated with maternal postpartum glycaemia ($r=0.40$; $P=0.04$) and one hour postpartum glycaemia ($r=0.37$; $P=0.04$). In the calves, there was a *positive* correlation between cortisol concentration at birth and glycaemia at birth ($r=0.47$; $P=0.009$) and after 60 minutes of birth ($r=0.35$; $P=0.05$).

Discussion

Birth is known to be a stressful event in which significant changes occur in the plasma concentrations of catecholamines in both the fetus and the mother (Chen and others 1998). Moreover, hepatic carbohydrate metabolism is under the direct influence of glucocorticoids and catecholamines (stress-related substances) (Chan and others 1998). One of the major physiological effects of cortisol is to increase fetal and infant hepatic gluconeogenesis and minimise glucose uptake and metabolism by muscle, resulting in elevated blood glucose (Chen and others 1998; Nikischin and others 1990). Irrespective of their obstetric condition, all cows were hyperglycaemic following parturition in this study. In addition, a positive correlation between maternal blood cortisol and glycaemia during the postpartum period was found. These results suggest a causal relationship between maternal cortisol and glucose concentrations, that is, elevated blood glucose may act as a marker of stress during calving. In agreement with this relationship, the data on normally calving cows show that serum cortisol increases once parturition begins, suggesting the onset of a stressful event. Similarly, a significant increase in maternal blood glucose was soon observed intrapartum. Therefore, we can assume that calving is a stressful process for cows and that hyperglycaemia is one of its consequences.

In contrast, a negative correlation was observed between intrapartum glucose and cortisol levels one hour postpartum in the normally calving cows. Given this result, it can be speculated that the consumption of energy via glucose metabolism during parturition enhances the degree of postpartum stress. Specifically, a low energy profile intrapartum influences postcalving stress, and this can ultimately affect lactation and reproductive performance. In fact, Jacob and others (2001) showed reduced *in vivo* and *in vitro* immune responses when cortisol levels were high during the periparturient period in cows, predisposing them to infections. This assumption highlights the fundamental importance of the metabolic balance of periparturient dairy cows.

For the non-normally calving cows (dystocia and inertia groups), the infusion of oxytocin and calcium resulted in lower blood glucose concentrations. Surprisingly, this finding is similar to that obtained for normally calving dams, counteracting the original hypothesis. Moreover, the cows in the inertia group were not hyperglycaemic, regardless of the time of evaluation. These results suggest that straining during labour as a result of exogenous oxytocin and calcium was not excessive and required less energy uptake but was therapeutically efficient. Furthermore, a negative correlation between postpartum glucose and cortisol levels was observed, implying that a lower

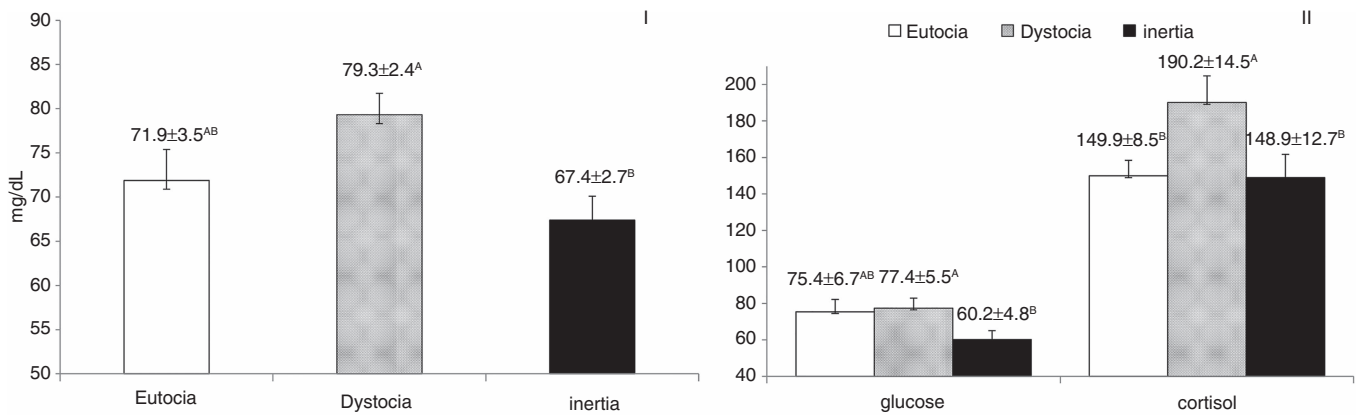


FIG 1: Maternal glucose concentration (I) and neonatal glucose (mg/dl) and cortisol (ng/ml) concentrations (II) in Eutocia, Dystocia and Inertia groups. ^{A,B} Different upper-case letters indicate a significant difference (P < 0.05)

consumption of glucose during calving lowers the degree of stress following labour. Accordingly, in terms of medical management, intrapartum infusion of oxytocin and calcium has no detrimental effect on the dams and can be safely administered to cows experiencing difficulty in calving. In agreement with this proposition, the Inertia group showed lower cortisol levels during parturition than the Eutocia group. Additionally, the level of stress in dystocical cows during the immediate postpartum period was higher than that in the dams that received oxytocin and calcium during calving. Thus, for cows, an increase in stress and increase in glucose concentration previously described as resulting from oxytocin infusion in humans and sheep was not observed in this study (Wallin and others 1989, Ochedalski and others 2001).

Horwitz and Horwitz (1982) showed that peaks in hypertension can explain enhanced cortisol levels. The current authors have previously shown that intrapartum blood pressure in dystocical cows is higher than that observed under other birth conditions (Rodrigues and others 2010). Thus, the increased maternal cortisol concentration in the Dystocia group during the immediate postpartum period can also be explained by the distinct haemodynamic characteristics of dystocical cows. However, the influence of fetal extraction on acute stress observed during dystocical calving cannot be disregarded. A marked increase in cortisol levels during postpartum may be linked to the physical stress associated with delivery complications. Cortisol is essential to maintaining glucose concentration when glycogen stores are depleted with a long labour and difficult second stage. High levels of cortisol maximise glucose availability for the fetus and myometrium (Benfield and others 2014). The results of the current study are in agreement with the findings of Burton and others (2006), in which prolonged parturition due to maternal

dystocia produced stressful conditions. In addition, Osawa and others (1998) showed that β -endorphin and cortisol concentrations increase at the time of dystocical calving, rather than after rupture of the amnion in cows with eutocic calving.

No neonatal differences over time in cortisol or blood glucose concentrations were observed in the present study. However, irrespective of the type of birth, there was a positive correlation between neonatal glucose and cortisol concentrations. This finding supports the hypothesis that the degree of stress influences calves' energetic mobilisation during the first hour of birth. Neonatal glucose homeostasis immediately after birth depends on hepatic glycogen storage because hepatic glycogen must provide a sufficient amount of energy before suckling. If maternal nutrition is adequate, the neonatal energetic requirement is satisfied (Prestes and Landim-Alvarenga 2006).

Conversely, birth condition significantly influenced calves' blood glucose and cortisol concentration. Dystocical calves showed greater stress (cortisol concentration). In fact, the negative correlation found between maternal postpartum glucose and neonatal cortisol concentration in the Dystocia group shows that the extreme consumption of maternal energy during assisted parturition had a direct impact on the stress levels of calves. These results confirm that fetal extraction is a stressful procedure and can be a cause of low vitality in calves at birth. Several authors have stated that increased corticosteroid levels occur in response to acidosis and hypoxia during birth (Massip 1980, Vermorel and others 1983, Civelek and others 2008). The present authors have previously shown that dystocical calves have a lower arterial blood pH than eutocic calves or calves receiving oxytocin and calcium infusion (Rodrigues 2008). However, the trauma associated with dystocia causes neonatal release of stress-inducing substances (catecholamines and cortisol) that are responsible for counteracting the deleterious effect of acidosis (Chan and others 1998). In fact, Chen and others (1998) suggested, in human beings, that the surge in catecholamines increases blood flow to the heart and brain, mobilises fuel and increases infant alertness.

In contrast, this study demonstrated that glucose concentration is lower in calves born with oxytocin and calcium infusion than in those born by fetal extraction, and no signs of additional stress were found in the inertia group. Lucio and others (2009) found that oxytocin infusion given to whelping bitches had no stressful effects on neonatal puppies. It is probable that the rhythm of uterine contractions determined by oxytocin and calcium acted in a eutocic manner, facilitating the progression of the calf through the birth canal in a way resembling that occurring during normal calving. Conversely, dystocical calves experienced a more stressful situation due to difficult and prolonged calving. Thus, the therapeutic employment of oxytocin and calcium to stimulate uterine contractions in calving cows is also safe for neonatal calves.

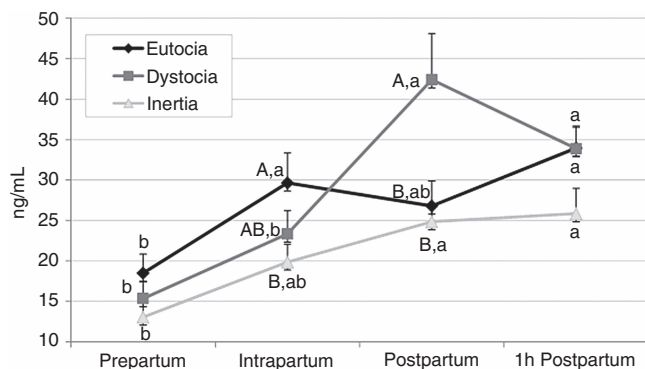


FIG 2: Maternal peripartum cortisol concentration (ng/ml) in Eutocia, Dystocia and Inertia groups. ^{A, B} Different upper-case letters at the same time stage indicate a significant difference (P < 0.05); ^{a, b} Different lower-case letters in the same group indicate a significant difference (P < 0.05)

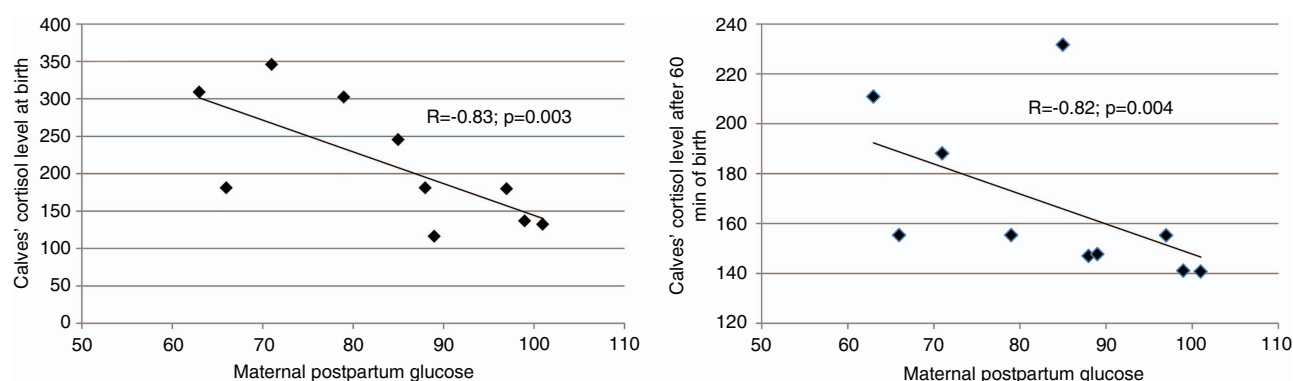


FIG 3: Correlations between maternal postpartum glucose and neonatal cortisol at birth (I) and after 60 minutes of birth (II) in the Dystocia group

Irrespective of the obstetric condition, the level of neonatal cortisol did not change during the first hour of life. Although Hoyer and others (1990) have stated that reversal of stress occurs rapidly during the first hours of neonatal life, the results presented here do not support this statement. The results verify that a period of 60 minutes was not sufficient to significantly decrease cortisol level in calves. This suggests that the first hour of life is a period of continuing neonatal fragility and deserves special medical attention regardless of the type of birth.

In conclusion, assisted calving with fetal extraction causes important metabolic changes for the dam and calf. Conversely, the practice of oxytocin and calcium infusion for hypotonic cows has no harmful effects on the metabolic balance of the mother or the neonate and can be safely employed as a medical treatment. Finally, calving is confirmed as a stressful event for neonatal calves that deserves a close follow-up during the period beyond the first hour of birth.

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References

- ALONSO-SPILSBURY, M., MOTA-ROJAS, D., VILLANUEVA-GARCÍA, D., MARTÍNEZ-BURNES, J., OROZCO, H., RAMÍREZ-NECOECHEA, R., MAYAGOITIA, A. L. & TRUJILLO, M. E. (2005) Perinatal asphyxia pathophysiology in pig and human: a review. *Animal Reproduction Science* **90**, 1–30
- ARNOTT, G., ROBERTS, D., ROOKE, J. A., TURNER, S. P., LAWRENCE, A. B. & RUTHERFORD, K. M. (2012) Board invited review: the importance of the gestation period for welfare of calves: maternal stressors and difficult births. *Journal of Animal Science* **90**, 5021–5034
- BELLOWS, R. A. & LAMMOGLIA, M. A. (2000) Effects of severity of dystocia on cold tolerance and serum concentrations of glucose and cortisol in neonatal beef calves. *Theriogenology* **53**, 803–813
- BENFIELD, R. D., NEWTON, E. R., TANNER, C. J. & HEITKEMPER, M. M. (2014) Cortisol as a biomarker of stress in term human labor: physiological and methodological issues. *Biological Research for Nursing* **16**, 64–71
- BURTON, J. L., WEBBER, P. S. D., BUSH, A. A. & NEUDER, L. (2006) Parturient steroids and labor duration associated with dystocia and stillbirth. *Journal of Dairy Science* **89** Supplement, 8
- CHAN, P., XU, D. Y., LIU, J. C., CHEN, Y. J., TOMLINSON, B., HUANG, W. P. & CHENG, J. T. (1998) The effect of stevioside on blood pressure and plasma catecholamines in spontaneously hypertensive rats. *Life Sciences* **63**, 1679–1684
- CHEN, D. C., NOMMSEN-RIVERS, L., DEWEY, K. G. & LONNERDAL, B. (1998) Stress during labor and delivery and early lactation performance. *The American Journal of Clinical Nutrition* **68**, 335–344
- CIVELEK, T., CELIK, H. A., AVCI, G. & CINGI, C. C. (2008) Effects of dystocia on plasma cortisol and cholesterol levels in Holstein heifers and their newborn calves. *Bulletin of the Veterinary Institute in Pulawy* **52**, 649–654
- FAHY, B. G., SHEEHY, A. M. & COURSIGN, D. B. (2009) Glucose control in the intensive care unit. *Critical Care Medicine* **37**, 1769–1776
- HORWITZ, K. B. & HORWITZ, L. D. (1982) Canine vascular tissues are targets for androgens, estrogens, progestins, and glucocorticoids. *The Journal of Clinical Investigation* **69**, 750–758
- HOYER, C., GRUNERT, E. & JOCHLE, W. (1990) Plasma glucocorticoid concentrations in calves as an indicator of stress during parturition. *American Journal of Veterinary Research* **51**, 1882–1884
- HUNTER, J. T., FAIRCLOUGH, R. J., PETERSON, A. J. & WELCH, R. A. (1977) Foetal and maternal hormonal changes preceding normal bovine parturition. *Acta Endocrinol (Copenh)* **84**, 653–662
- HYDBRING, E., MADEJ, A., MACDONALD, E., DRUGGE-BOHOLM, G., BERGLUND, B. & OLSSON, K. (1999) Hormonal changes during parturition in heifers and goats are related to the phases and severity of labour. *The Journal of Endocrinology* **160**, 75–85
- JACOB, S. K., RAMNATH, V., PHILOMINA, P. T., RAGHUNANDHANAN, K. V. & KANNAN, A. (2001) Assessment of physiological stress in periparturient cows and neonatal calves. *Indian Journal of Physiology and Pharmacology* **45**, 233–238
- LANDIM-ALVARENGA, F. C. (2006) Gestação. In: *Obstetrícia veterinária*, Eds N. C. PRESTES, F. C. LANDIM-ALVARENGA. Guanabara Koogan. pp 70–81
- LUCIO, C. E., SILVA, L. C., RODRIGUES, J. A., VEIGA, G. A. & VANNUCCHI, C. I. (2009) Peripartum haemodynamic status of bitches with normal birth or dystocia. *Reproduction in Domestic Animals* **44**(Suppl 2), 133–136
- MACINTIRE, D. K. (1999) Pediatric intensive care. *The Veterinary Clinics of North America. Small Animal Practice* **29**, 971–988, vii–viii
- MASSIP, A. (1980) Relationship between pH, plasma cortisol and glucose concentrations in the calf at birth. *The British Veterinary Journal* **136**, 597–601
- MEE, J. F. (2008) Prevalence and risk factors for dystocia in dairy cattle: a review. *Veterinary Journal* **176**, 93–101
- NIKISCHIN, W., WEISNER, D. & OLDIGS, H. D. (1990) Perinatal glucose metabolism as an indicator for stress and hypoxia during different forms of delivery. *Journal of Perinatal Medicine* **18**, 209–213
- NOAKES, D. E., PARKINSON, T. J. & ENGLAND, G. C. W. (2001) Maternal dystocia: causes and treatment. In: *NOAKES, D. E., PARKINSON, T. J., ENGLAND, G. C. W., Eds. Arthur's Veterinary Reproduction and Obstetrics*. 8th edn. WB. Saunders. pp 229–244
- OCHEDALSKI, T., ZYLINSKA, K., LAUDANSKI, T. & LACHOWICZ, A. (2001) Corticotrophin-releasing hormone and ACTH levels in maternal and fetal blood during spontaneous and oxytocin-induced labour. *European Journal of Endocrinology* **144**, 117–121
- OSAWA, T., NAKAO, T., MORIYOSHI, M. & NAKADA, K. (1998) Plasma beta-endorphin around parturition and its relationship to cortisol level and resumption of pituitary and ovarian functions in dairy cows. *Animal Reproduction Science* **52**, 27–38
- PRESTES, N. C. & LANDIM-ALVARENGA, F. C. (2006) *Obstetrícia veterinária*. Rio de Janeiro: Guanabara Koogan
- RICE, L. E. (1994) Perinatal mortality in beef herds. In: *KASARI, T. R., WIKSE, S. E., Eds. Veterinary Clinics of North America: Food Animal Practice*. Elsevier, pp 53–68
- RODRIGUES, J. A. (2008) *Assistência clínica materna e neonatal às diferentes condições obstétricas em bovinos da raça Holandesa*. Dissertação (Mestrado). São Paulo: Faculdade de Medicina Veterinária e Zootecnia, Universidade de São Paulo, 94p
- RODRIGUES, J. A., LUCIO, C. E., SILVA, L. C. G., VEIGA, G. A. L., NIEMEYER, C. & VANNUCCHI, C. I. (2010) Avaliação clínica e hemodinâmica periparto de fêmeas bovinas da raça holandesa em diferentes condições obstétricas. *Brazilian Journal of Veterinary Research and Animal Science* **47**, 468–476
- VAALA, W. E., HOUSE, J. K. & MADIGAN, J. E. (2006) Parte três. Distúrbios e tratamento do neonato. Barueri, Manole
- VERMOREL, M., DARDILLAT, C., VERNET, J., SAIDO & DEMIGNE, C. (1983) Energy metabolism and thermoregulation in the newborn calf. *Annals of Veterinary Research* **14**, 382–389
- WALLIN, L. A., FAWCETT, C. P. & ROSENFELD, C. R. (1989) Oxytocin stimulates glucagon and insulin secretion in fetal and neonatal sheep. *Endocrinology* **125**, 2289–2296

