ENERGY METABOLISM AND THERMOREGULATION IN THE NEWBORN CALF; EFFECT OF CALVING CONDITIONS

M. VERMOREL[1], J. VERNET[1], C. DARDILLAT[2], SAIDO[1], C. DEMIGNE[3], and MARIE-JEANNE DAVICCO[3]

[1]*Laboratoire d'Etude du Métabolisme Energétique;* [2]*Laboratoire de la Digestion; and* [3]*Laboratoire des Maladies Métaboliques, I.N.R.A., C.R.Z.V. Theix, 63122 Ceyrat, France.* *Received 10 June 1987, accepted 1 Sept. 1988.*

VERMOREL, M., VERNET, J., DARDILLAT, C., SAIDO, DEMIGNE, C. AND DAVICCO, M.-J. 1989. Energy metabolism and thermoregulation in the newborn calf. Effect of calving conditions. Can. J. Anim. Sci. **69**: 113–122.

Rectal temperature (RT) and heat production (HP) were measured continuously during the first day of life, using indirect calorimetry, in 16 eutocial and 13 dystocial Holstein-Friesian (HF) calves held at 10°C. Blood parameters were determined 0, 2, 4, 6, 12 and 24 h after birth. Twin eutocial calves, as well as calves born after early surgical removal showed variations in RT, HP, and blood parameters similar to those of single eutocial calves. However, dystocial calves, especially those born after a very difficult and delayed parturition, had severe and prolonged acidosis, with high lactataemia and alaninemia, and lower plasma NEFA, T3, and T4 levels during the first hours of life than did eutocial calves. They were also less physically active and frequently did not shiver. Their HP was, on average, 22% lower than that of eutocial calves 2 h after birth and 14% lower from 13 h of life onwards. The difference was 26–36% in a dystocial calf born after a delayed surgical removal. RT of dystocial calves decreased by 2.9 ± 0.7°C, on average, and increased slowly. Their appetite was low or nil and immunoglobulin absorption was delayed and reduced, which can explain the high mortality and morbidity rates of dystocial calves during the first week of life. The results are discussed in relation to the effects of hypoxia and acidosis on metabolism.

Key words: Calf, newborn, energy metabolism, thermoregulation, calving conditions, dystocia

[Metabolisme énergétique et thermorégulation du veau nouveau-né. Influence des conditions de vêlage.]
Titre abrégé: Métabolisme énergétique des veaux dystociques.
Nous avons mesuré en continu au cours du premier jour de vie la température rectale (RT) et la production de chaleur (HP) de 29 veaux Holstein × Frisons: 16 veaux eutociques et 13 veaux dystociques maintenus à la température de 10°C. Les paramètres sanguins ont été mesurés 0, 2, 4, 6, 12 et 24 h après la naissance. Les veaux jumeaux eutociques présentent des variations de RT, HP et des paramètres sanguins semblables à ceux des veaux simples eutociques. En revanche, les veaux dystociques présentent une acidose grave et durable, une lactatémie et une alaninémie élevées et des concentrations plasmatiques d'AGNE, de T3 et de T4 inférieures à celles des veaux eutociques. Les veaux dystociques ont une activité physique réduite et souvent ne frisonnent pas. Leur production de chaleur est inférieure à celle des veaux eutociques, en moyenne de 22% deux heures après la naissance et de 14% à partir de l'âge de 13 heures. La RT des veaux dystociques diminue en moyenne de 2,9 ± 0,7°C après la naissance puis augmente lentement. Leur appétit est faible ou nul et l'absorption des immunoglobulines colostrales est retardée et réduite. Ces résultats sont discutés en tenant compte des effets connus de l'hypoxie et de l'acidose sur le métabolisme.

Mots clés: Veau, nouveau-né, métabolisme énergétique, thermorégulation, conditions de mise-bas, dystocie

The rate of difficult parturition differs widely among breeds: Angus or Hereford, 16%; Friesian, 7%; Charolais, 8% and Salers, 1%. Furthermore, it is much higher in heifers calving at 2 yr of age than in multiparous cows: 43 vs. 10% in Angus and Hereford, 15.6 vs. 4.7% in Friesian and 46.5 vs. 6.6% in Charolais breeds (Laster and Gregory 1973; Philipsson 1976; Menissier 1979). In 2-yr-old Charolais heifers, surgical removal is performed in 43% of difficult parturition cases (Menissier 1979).

Still births and early postnatal mortality rate (0–24 h) is much higher in dystocial than in eutocial calves, being 21.2 vs. 0.9% and 24.7 vs. 3.5% in adult Friesian cows and heifers, respectively (Philipsson 1976), and 19.8 vs. 4.4% in Charolais heifers (Menissier 1979). Similarly, total mortality rate is greater in twin than in single calves (29 vs. 10.9%), especially at birth and during the first 5 h of life (18.9 vs. 7.9% in Charolais calves; Vallet 1983). After surgical removal dystocial calves had a higher mortality rate than did eutocial calves during the first two days of life, i.e., 5.6 vs. 2.3% in Charolais calves (Vallet 1983). Finally, mortality and morbidity rates of low-vitality dystocial calves are increased by adverse climatic conditions (Martin et al. 1975).

The aim of the present experiment was, therefore, to study the effects of difficult calving conditions (severe calf pulling, delayed parturition, surgical removal) on the thermoregulation and energy metabolism of single or twin calves during the first day of life.

MATERIALS AND METHODS

Animals and Management

The experiment was carried out on 29 Holstein-Friesian calves, consisting of 10 single and 6 twin eutocial (E) calves born without or with minor assistance; 5 calves born after difficult parturition (D, when 2 or 3 people pulled); 5 calves born after very difficult (VD, 3 people pulled with mechanical assistance) or delayed parturition; and 3 calves born by surgical removal (SR). Birth weight of the calves and parity of their dams are presented in Table 1. The calves were born between October and December. Their dams were fed a mixed diet based on maize silage for 1 or 2 mo according to allowances before calving.

The vitality of calves at birth was estimated according to clinical criteria. Good vitality calves breathed spontaneously within the first 10 s after birth and had normal locomotory reflexes and head stand. Very low vitality was characterized by an absence of spontaneous breathing, limited movements and often elimination of meconium in utero. Very low vitality calves were revived by several treatments: hanging by hind legs, cleaning the respiratory tracts, rhythmic compression of breast, or administration of respiratory and cardiac analeptics and of oxygen. Other treatments of calves were described in a previous paper (Vermorel et al. 1988). The calves were taken immediately after birth and wiped off with straw. Two hours after birth, they were fed warm colostrum (5% of liveweight) from a frozen pool (9.6 g gamma

Table 1. Distribution of the newborn calves according to calving conditions (means and standard errors of treatment means)

Calves and calving conditions		Number of calves	Birth weight (kg)	Parity of the dams†
Easy parturition	Single	10	40.5 ± 1.2	3 Prim., 7 Mult.
	Twins	6	33.3 ± 1.9	3 Prim., 3 Mult.
Difficult parturition‡		5	42.4 ± 3.8	4 Prim., 1 Mult.
Very difficult parturition‡		5	46.5 ± 3.5	3 Prim., 2 Mult.
Surgical removal	Early	2	46.0	1 Prim.
			63.5	1 Mult.
	Delayed	1	56.0	1 Mult.

†Prim., primiparous; Mult., multiparous.
‡See text.

globulins per liter of colostral serum) either from a nipple or, when necessary, by stomach tube. A second meal was offered in the respiration chamber, using a tube with a nipple on the end, at 12 h of age, and voluntary intake was recorded.

Measurements of Rectal Temperature, Metabolic Rate and Blood Parameters
Rectal temperature (RT) was measured about 5 min after birth in all calves, then recorded every 5 min. Heat production was determined continuously by indirect calorimetry at an ambient temperature of 10°C, using two open-circuit respiration chambers (Vermorel et al. 1988). It was computed for 1-h periods and expressed in W m^{-2}. The time spent standing was recorded when the calves were in the respiration chambers. Physical activity and shivering were observed during the first 4 h of life and, thereafter, before each blood sampling. Resting HP was computed when the calves were lying down and quiet.

Venous blood samples were taken within 10 min after birth by jugular venipuncture, then at 2, 4, 6, 12 and 24 h after birth by means of a jugular catheter. Blood pH was measured immediately; glucose, lactate, alanine, glutamate, nonesterified fatty acids (NEFA) and immunoglobulin levels were determined in the defrost plasma (Vermorel et al. 1988). A seventh blood sample was taken by jugular venipuncture 48 h after birth. Triiodothyronine (T3) and thyroxine (T4) contents were determined in the seven plasma samples by radioimmunoassay (RIA kit T3 and RIA kit T4, Amersham).

Statistical Analyses
The experiment was based on a factorial design using calving conditions as the main factor with repeated measures to take account of the time trend. The results were analyzed using the GLM procedure, option repeated time, of the SAS package (Statistical Analysis System Institute, Inc. 1985). Discrete variables were treated by two-way analysis of variance. The results are expressed as means and standard errors of treatment means.

RESULTS

Effect of Twin Birth

Twin calves were born, on average, 5 d before single calves and were 7.2 kg lighter ($P<0.01$, Table 1). Their RT varied differently from that of single calves ($P<0.05$). It was 0.4°C lower at birth, similar 2 h later and 0.5°C higher up to 12 h of age. Their HP was not significantly different from that of the single calves when expressed per square metre of body surface, but 5% higher per kg body weight. Their respiratory quotient (CO_2 production/O_2 consumption) was significantly lower (0.77 vs. 0.81 on average; $P<0.001$). Therefore, twin calves seemed to use relatively more lipids than single calves for heat production. Blood pH at birth (7.32 ± 0.02) and plasma metabolite levels during the first day of life were not significantly different in twin and single calves born under good conditions.

Effects of Difficult Parturition

Dystocia was mainly due to large calves in multiparous cows and to the smaller size of the pelvic opening in heifers calving at 2 yr (Table 1). All the dystocial calves had a low or very low vitality and most of them had to be revived. Their appetite was very low or nil 2 h after birth and the colostrum was fed by stomach tube. Furthermore, they drank less colostrum than eutocial calves at the 12-h meal (0.24 ± 0.08 vs. 0.91 ± 0.023 L, $P<0.01$).

VARIATIONS OF RECTAL TEMPERATURE. Rectal temperature varied significantly with time ($P<0.05$) and with calving conditions ($P<0.01$, Fig. 1). It was higher at birth in dystocial than in eutocial calves: 39.72 ± 0.24, 39.52 ±0.20 and 38.98 ±0.18°C in VD, D and E calves, respectively. Rectal temperature decreased by 0.5 ± 0.4, 1.1 ± 1.0 and 2.9 ±0.7°C 1.5 h after birth in the E, D and VD calves, respectively. It then increased rapidly in the E and D calves but remained 0.4°C lower in the D calves up to 10 h of age. In the VD calves RT increased very slowly between 3 and 10 h of age and stabilized 0.5°C below that of E calves (Fig. 1).

TOTAL AND RESTING HEAT PRODUCTIONS (HP). Total HP decreased curvilinearly with time due to haircoat drying, but the variation was significant ($P<0.002$) only up to 6 h of age. Total HP also varied with calving

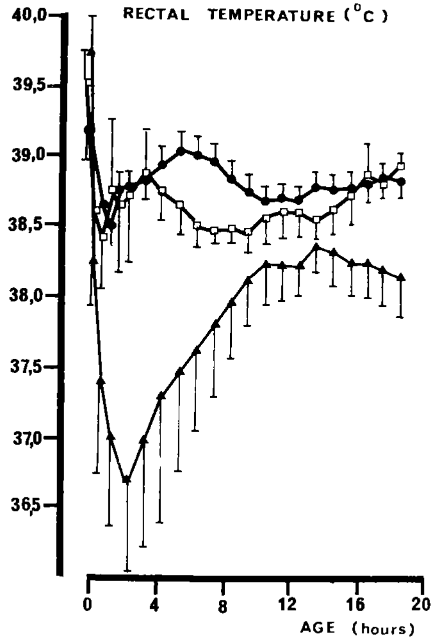

Fig. 1. Variations of rectal temperature of Holstein × Friesian calves during the first day of life depending on calving conditions. ●, eutocial calves; □, difficult parturition; ▲, very difficult parturition. (Means and standard errors of treatment means.)

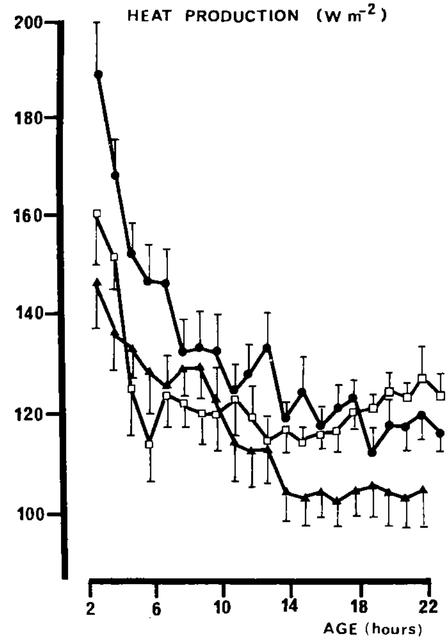

Fig. 2. Variations of total heat production of Holstein × Friesian calves during the first day of life depending on calving conditions. ●, eutocial calves; □, difficult parturition; ▲, very difficult parturition. (Means and standard errors of treatment means.)

conditions. It was 16% and between 22 and 13% lower in D and VD calves, respectively, than in E calves from 1.5 to 6 h of age ($P<0.002$, Fig. 2). Heat production of VD stabilized 14% below that of E calves from 13 h of age onwards ($P<0.02$).

The lower HP of dystocial calves could be partly due to their reduced physical activity and to the frequent absence of or reduced shivering after a very difficult parturition. They laid still and did not try to stand up in the respiration chambers. Furthermore, their resting HP decreased significantly with time ($P<0.01$) and was 10% lower in the VD than in the E calves ($P<0.05$) during the first day of life (Fig. 2). The respiratory quotient did not vary significantly with time and calving conditions and averaged 0.80 from 3 h of age onwards.

BLOOD PARAMETERS Blood pH varied significantly with time ($P<0.001$) and calving conditions ($P<0.001$). It was lower in the VD (7.01 ± 0.04) and D calves (7.17 ± 0.04) than in the E calves (7.31 ± 0.03) at birth. It increased rapidly in the E calves to 7.37 ± 0.02 2 h after birth, but increased slowly in the VD calves and took 12 to 24 h to reach the normal range (7.38 – 7.40; Fig. 3).

Lactataemia also varied significantly with time ($P<0.001$) and calving conditions ($P<0.001$). It was three or two times higher in the dystocial than in the eutocial calves at birth: 15.8 ± 1.1, 10.9 ± 1.5, and 5.2 ±0.6 mmol L^{-1} plasma in the VD, D and E calves, respectively. It decreased slowly in the D calves over 6 h and reached a plateau 60% higher than that of E calves (Fig. 4). In the VD calves, lactataemia was 5, 4, 3, 2.2 and 2 times higher than in eutocial calves 2, 4, 6, 12 and 24 h after birth, respectively.

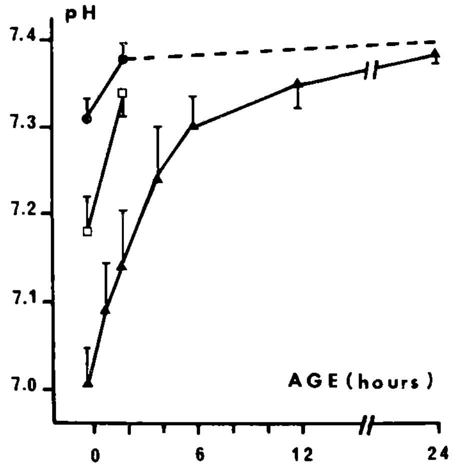

Fig. 3. Variations of blood pH in eutocial calves (●) and dystocial calves born after difficult (□) or very difficult (▲) parturition, during the first day of life. (Means and standard errors of treatment means.)

The variations of alaninaemia were similar to those of lactataemia and significant with time ($P<0.001$) and calving conditions ($P<0.001$). Plasma levels of alanine were, on average, 40% higher in D than in E calves during the first day of life (Fig. 4). Furthermore, in the VD calves, alaninaemia was very high at birth and even increased for 4 h, being 3, 5 and 4 times higher than that of the E calves, 0, 2 and 4 h after birth. Plasma alanine concentrations then declined regularly and were close to those of D and E calves 1 d after birth.

Glutamataemia varied significantly with time ($P<0.001$), decreased during the 2 h after birth and increased after the colostrum meal, but this increase was delayed in the VD calves (Fig. 5). Glutamataemia did not vary significantly during the first day of life but in VD calves plasma glutamate levels were

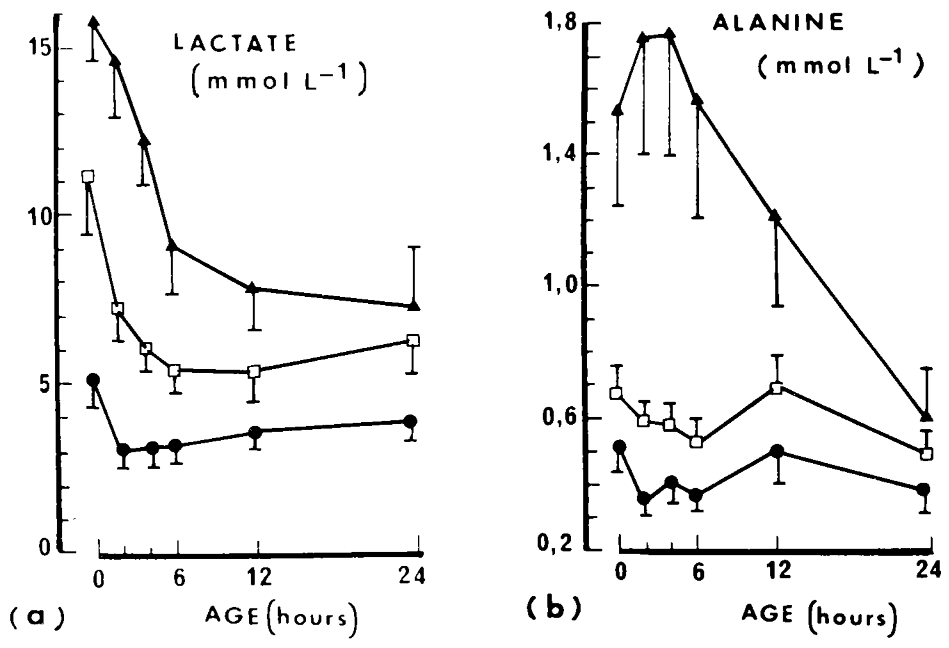

Fig. 4. Variations of plasma lactate (a) and alanine (b) levels of Holstein × Friesian calves during the first day of life depending on calving conditions. ●, eutocial calves; □, difficult parturition; ▲, very difficult parturition. (Means and standard errors of treatment means.)

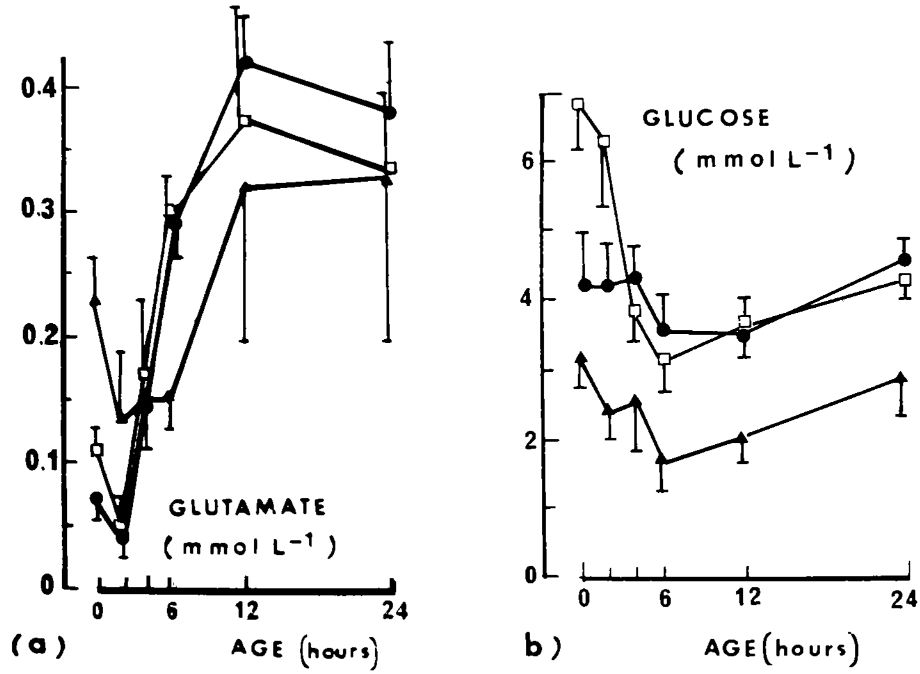

Fig. 5. Variations of plasma glutamate (a) and glucose (b) levels in Holstein × Friesian calves during the first day of life depending on calving conditions. ●, eutocial calves; □, difficult parturition; ▲, very difficult parturition. (Means and standard errors of treatment means.)

3.3 times higher than in E calves at birth and 2 h later.

Similarly, plasma glucose concentrations varied significantly with time ($P<0.001$) and calving conditions ($P<0.05$). They were 60% higher in D than in E calves at birth and 2 h later; thereafter, they decreased rapidly and were similar from 6 h of age onwards (Fig. 5). The variations of glycaemia were similar in the VD and E calves, but the plasma glucose level was 40% lower in VD than in E calves during the first day of life.

Plasma NEFA level varied significantly with time ($P<0.001$) but not with calving conditions during the first day of life (Fig. 6). It increased to 1.0 mmol L^{-1} during the first 2 or 4 h of life then stabilized at 0.85 mmol L^{-1}. However, it was 30% lower in the D calves at 0 and 2 h of age and 30, 41 and 37% lower ($P<0.05$) in the VD calves at 0, 2 and 4 h of age, respectively, than in the E calves.

Plasma immunoglobulin (Ig) level varied significantly with time ($P<0.001$). It increased rapidly from the colostrum mean (2 h) to 6 h, then slowly to 24 h of age (Fig. 6). The variations were similar in the E and D calves. However, the increase in plasma Ig level was much slower in the VD calves and the differences amounted to 74, 36 and 41% at 6, 12 and 24 h of age, respectively ($P<0.02$).

The plasma thyroid hormone levels varied significantly ($P<0.005$) with time. They increased during the first 6 h of life then decreased up to 1 d (T3) or 2 days (T4) of life (Fig. 7). They did not vary significantly with calving conditions during the first 2 d of life; however, they were 42% lower at birth ($P<0.05$) in dystocial than in eutocial calves, and the plasma T4 level was still 30% lower 2 h after birth, but the differences were not significant thereafter.

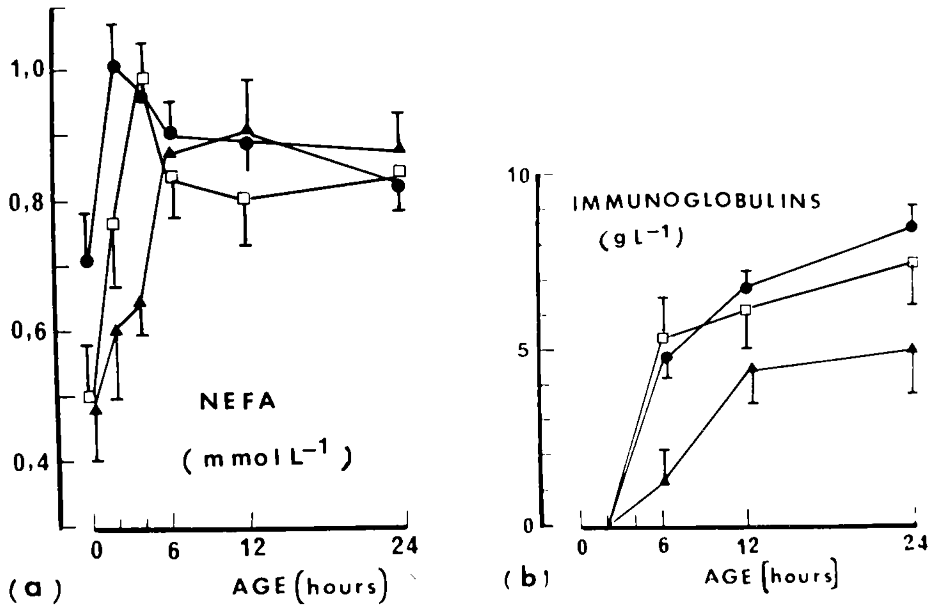

Fig. 6. Variations of plasma nonesterified fatty acid (NEFA) (a) and immunoglobulin levels (b) in Holstein × Friesian calves during the first day of life, depending on calving conditions. ●, eutocial calves; □, difficult parturition; ▲, very difficult parturition. (Means and standard errors of treatment means.)

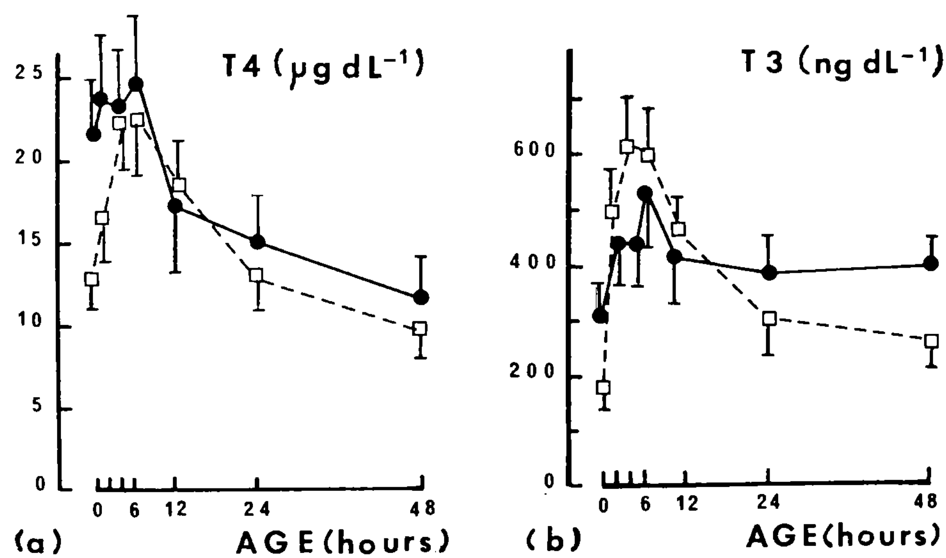

Fig. 7. Variations of plasma thyroxine (T4) (a) and triiodothyronine (T3) (b) levels in Holstein × Friesian calves during the first 2 d of life depending on calving conditions, ●, eutocial calves; □, dystocial calves. (Means and standard errors of treatment means.)

Effect of Surgical Removal (SR)

Energy metabolism was studied in three calves born after an early or after a delayed surgical intervention (Table 1). The two calves born after an early surgical removal due to excess weight had a good vitality, stood up 1 h after birth and spent much time standing in the respiration chambers. The variations of RT and HP of both calves during the first day of life were similar to those of eutocial calves. Blood pH, lactataemia, and alaninaemia at birth were very close to those of eutocial calves. Plasma NEFA levels were lower than in eutocial calves during the first 2 h of life, but immunoglobulin absorption was not affected by early surgical removal.

The delayed surgical removal was due to excess weight and bad presentation of the calf. This calf had to be revived, and its RT dropped from 40.0 to 35.5°C in 2 h. Stomach infusion of 2.8 L warm colostrum was followed by a 0.8°C increase in RT. In spite of shivering, RT dropped to 34.9°C at 3 h of age then stabilized at 37°C by 7 h after birth. HP decreased continuously and was 26–35% lower than that of E calves. The low HP was related to the severe acidosis of the calf. Blood pH decreased from 7.18 to 7.10, and lactataemia increased from 12.5 to 15.6 mmol L^{-1} during the first 2 h of life, after which they stabilized at 7.28 and 11 mmol L^{-1}, respectively. Plasma T3 and NEFA levels were very low at birth and increased slowly; immunoglobulin absorption was delayed and reduced. Blood parameters, HP, and RT variations of this calf were similar to those of the VD calves during the first hours of life, but it was unable to maintain its HP after 9 h and died from pneumonia during the second day of life.

DISCUSSION AND CONCLUSION

The higher RT of dystocial calves at birth could result from both uterus contractions over a long period and reduction in utero-placental exchanges during parturition (Schwartz et al. 1978). Gradual loosening of placental cotyledons and crushing of the umbilical cord also cause an oxygen deficit. Hypoxia produces an intensive stimulation of both the central nervous system, which induces secretion of ACTH and corticosteroids, and of the sympathetic nervous system, followed by a massive secretion of catecholamines (Comline and Silver 1966; Jones 1977; Lewis et al. 1982).

The drop in blood pH and the high levels of plasma lactate and alanine observed at birth in the dystocial calves may result from liver glycogen mobilization induced by adrenaline and cortisol secretions (Jones and Ritchie 1978; Massip 1980) and from anaerobic glycolysis caused by oxygen deficit. In less than 10 min after the calf began to breathe, respiratory acidosis disappeared; conversely, metabolic acidosis increased during the first minutes of life, probably due to diffusion of lactate from the muscles to the blood (Vermorel et al. unpubl. data). The slow decrease in lactataemia and alaninaemia in the VD calves (Fig. 4) could result from a reduction of gluconeogenesis, which was observed by Warnes et al. (1977) in hypoxic lambs. The high glutamataemia of the dystocial calves at birth may arise from protein catabolism and from the fight against acidosis through elimination of H^+ ions in the form of NH_4^+ (Chartier 1981). The increase in glutamataemia 6 and 12 h after birth in the eutocial calves could result from amino acid absorption, the colostrum being rich in glutamate (Patureau-Mirand 1984). This increase would be postponed in the VD calves, due to delayed colostrum digestion.

Severe hypoxia during parturition inhibits cortisol secretion after birth (Stott and Reinhard 1978) and could depress the sympathetic nervous system, thereby reducing catecholamine secretion (Eales and Small 1980). This phenomenon was experimentally demonstrated in asphyxiated newborn calves (Comline and Silver 1966), but was not observed in newborn calves prevented from breathing at birth (Davicco et al. 1986).

The drop in RT of the VD calves during the first 2 h of life was in agreement with the results obtained in newborn lambs by Alexander and McCance (1958) and Vermorel and

Vernet (1985). It could result from both a higher heat loss and lower heat production than in eutocial calves. As a matter of fact, Tahti et al. (1972) showed that, in a newborn hypoxic baby, peripheral vasoconstriction was inhibited. Furthermore, severe hypoxia reduces muscular tonicity and inhibits shivering after birth (Stott and Reinhard 1978), which are important factors of thermogenesis in newborn calves.

Reduction of plasma thyroid hormone levels at birth and during the first hours of life in the dystocial calves (Fig. 7) was also observed in hypoxic lambs (Klein et al. 1979). It probably limits the cellular metabolic activity during this period, as blockage of T3 and catecholamine production in lambs caused a stronger drop in RT than inhibition of catecholamine secretion alone (Andrews et al. 1979).

The low plasma NEFA level of dystocial calves at birth and its delayed increase (Fig. 6) may arise from a limitation of lipid mobilization due to deficiency of thyroid hormones (Wrutniak and Cabello 1984), inhibition of catecholamine secretion, and hyperlactataemia (Bjorntrop 1965). The reduction of available energy sources associated with an oxygen deficiency (Alexander and Williams 1970) and acidosis (Malan 1978) may reduce the metabolic activity of brown adipose tissue, which normally plays an important role in thermogenesis of the newborn calf (Thomson and Bell 1976).

All of these phenomena may account for the reduced thermogenesis of the dystocial calves, which was 22% lower on average than that of eutocial calves at 2 h of age. This difference decreased during the first day of life as acidosis was progressively overcome.

Finally, dystocial calves, mainly the VD calves, had reduced and sometimes no physical activity and no appetite. These observations agree with those of Edwards (1982) showing that hypoxia and hypothermia reduce teat-seeking activity and colostrum intake by calves. Furthermore, our results demonstrate that, in the VD calves, absorption of nutrients and immunoglobulins is delayed and reduced (Fig 6), probably associated with the lower plasma thyroid hormone levels (Cabello and Levieux 1978). Hypothermia may also be responsible for the delay of immunoglobulin absorption (Olson et al. 1980). All these factors contribute to reducing the resistance of dystocial calves to cold and infectious diseases, which can explain their high mortality and morbidity rates during the first day and week of life. By contrast, twin calves born under good conditions and calves born after an early surgical removal exhibited blood parameters and heat production similar to those of eutocial calves. Therefore, the main causes of early postnatal mortality of twin calves may be prematurity, bad presentation, or simultaneous presentation of two fetuses, and prolonged parturition.

ACKNOWLEDGMENTS

This study was supported by a grant from INRA (Recherches Programmées sur la Physiologie Périnatale).

The authors wish to gratefully acknowledge the skillful technical assistance of Y. Anglaret, J. P. Donnat, J. Lefaivre, P. Lamby, C. Leoty, R. Souchet and the staff of the experimental farms and the statistical advise of E. Jolivet, Odile Pons, Claire Chabanet and P. Neveu (Laboratoire de Biométrie, INRA, 78350 Jouy-en-Josas).

Alexander, G. and McCance, I. 1958. Temperature regulation in the newborn lamb. I. Changes in rectal temperature within the first six hours of life. Austr. J. Agric. Res. **9**: 339–347.

Alexander, G. and Williams, D. 1970. Summit metabolism and cardiovascular function in young lambs during hyperoxia and hypoxia. J. Physiol. **208**: 85–97.

Andrews, J. F., Lynch, M. and Moore, R. E. 1979. The early metabolic response of lambs to small doses of 3, 3ʳ, 5 triiodothyronine. J. Physiol. Lond. **293**: 49.

Bjorntrop, P. 1965. The effect of lactic acid on adipose tissue metabolism in vitro. Acta Méd. Scand. **178**: 253–255.

Cabello, G. and Levieux, D. 1978. The effect of thyroxine and climatic factors on colostral gammaglobulin absorption in newborn calves. Ann. Rech. Vét. **9**: 309–318.

Chartier, F. 1981, Etude de la reydratation des veaux diarrhéiques par voies orale et parentérale.

Thèse Doct-Ing. Sciences Agronomiques, Option Zootechnie, ENSA Montpellier, France.

Comline, R. S. and Silver, M. 1966. Development of activity in the adrenal medulla of the foetus and newborn animal. Br. Med. Bul **22**: 16–20.

Davicco, M. J., Dardillat, C., Vermorel, M. et Delost, P. 1986. Réponse surrénalienne du Veau nouveau-né à l'anoxie. Réunion de l'Association des Physiologistes, Limoges, 6–7 novembre 1986.

Eales, F. A. and Small, J. 1980. Summit metabolism in newborn lambs. Res. Vet. Sci. **29**: 211–218.

Edwards, S. A. 1982. Factors affecting the time to first suckling in dairy calves. Animal Prod. **34**: 339–346.

Jones, C. T. 1977. The development of some metabolic responses to hypoxia in the foetal sheep. J. Physiol. **265**: 743–762.

Jones, C. T. and Ritchie, J. W. K. 1978. The metabolic and endocrine effects of circulating catecholamines in fetal sheep. J. Physiol. **285**: 395–408.

Klein, A. H., Eliot, R. J., Glatz, T. H., Nathanielsz, P. W. and Fisher, P. A. 1979. The effect of hypoxia on the pituitary thyroïd axis in lambs. Pediatr. Res. **13**: 360.

Laster, D. L. and Gregory, K. E. 1973. Factors influencing peri and early postnatal calf mortality. J. Anim. Sci. **37**: 1092–1097.

Lewis, A. B., Evans, W. N. and Sischo, W. 1982. Plasma catecholamine response to hypoxemia in foetal lambs. Biol. Neonate **41**: 115–122.

Malan, A. 1978. Intracellular acide-base state at a variable temperature in air-breathing vertebrates and its representation. Resp. Physiol. **33**: 115–119.

Martin, S. W., Schwabe, C. W., Franti, C. E. 1975. Dairy calf mortality rate: influence of meteorologic factors on calf mortality rates in Tulare Country California. Am. J. Vet. Res. **3**: 1105–1109.

Massip, A. 1980. Relationships between pH plasma cortisol and glucose concentrations in the calf at birth. Br. Vet. J. **136**: 593–601.

Menissier, F. 1979. Un exemple d'action conjointe des effets directs et maternels: les difficultés de mise-bas chez les bovins. Bull. Tech. Dépt. de Génétique Animale **29–30**: 132–190.

Olson, D. P., Papasian, C. J. and Ritter, R. C. 1980. The effects of cold stress on neonatal calves: II. Absorption of colostral immunoglobulins. Can. J. Comp. Med. **44**: 19–23.

Patureau-Mirand, P. 1984. Métabolisme azoté chez le foetus et le nouveau-né. Pages 231–246 in R. Jarrige ed. Physiologie et Pathologie chez les animaux de ferme. INRA, Paris, France.

Philipsson, J. 1976. Studies on calving difficulty, stillbirth and associated factors in Swedish cattle breeds. Acta Agric. Scand. **26**: 151–164.

Schwartz, R. H., Hey, E. W. and Baum, J. D. 1978. Management of the newborn's thermal environment. Pages 205–225 *in* J. P. Sinclair, ed. Temperature regulation and energy metabolism in the newborn. Crune and Stratton, New York, N.Y.

Statistical Analysis System Institute, Inc. 1985. SAS Stat guide for personal computers, Version 6 Edition. SAS Institute Inc., Cary, N.C.

Stott, G. H. and Reinhard, E. J. 1978. Adrenal function and passive immunity in the dystocial calf. J. Dairy Sci. **61**: 1457–1461.

Tahti, E., Lind, J., Osterland, K., Rylander, E. 1972. Changes in the temperature of the neonate at birth. Acta Pediatr. Scand. **61**: 159–164. (Quoted by Schwartz, Hey and Baum (1978).)

Thompson, G. E. and Bell, A. W. 1976. Heat production in the newborn ox during noradrenaline infusion. Biol. Neonate **28**: 375–381.

Vallet, A. 1983. Le rôle des facteurs du milieu dans la pathologie du Veau nouveau-né. Epidémilogie et santé animale. Bull. Ass. Etude Epidéomiologie des Maladies Animales **3**: 5–24.

Vermorel, M. and Vernet, J. 1985. Major factors affecting thermogenesis and cold resistance of newborn lambs. Pages 35–47 *in* G. Alexander, J. D. Barker and J. Slee ed. Factors affecting the survival of newborn lambs. CEC, Luxembourg.

Vermorel, M., Vernet, J., Dardillat, C., Saido and Demigne, C. 1988. Energy metabolism and thermoregulation in the newborn calf. Variations during the first day of life and differences between breeds. Can. J. Anim. Sci. **69**: 103–111.

Warnes, D., Seamark, R. F. and Ballard, F. J. 1977. The appearance of gluconeogenesis at birth in the sheep. Activation of the pathway associated with blood oxygenation. Biochem. J. **162**: 627–634.

Wrutniak, C. and Cabello, G. 1984. Thyroïd hormones action on the lipolytic effect of norepinephrine in the newborn lamb. Ann. Endocrinologie **45**: 1–38.