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Body temperatures of lambs and their mothers measured by radio-telemetry during parturition

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Abstract. Using temperature-sensitive radio-telemeters chronically implanted in the abdomens of 8 fetal lambs and their mothers, we measured body temperature changes induced by parturition. Maternal body temperature rose at 0.70 ± 0.06 °C/hour (mean $\pm$ SEM) in the final stages of labour. Fetal body temperature also rose, but at a significantly lower rate, 0.45 ± 0.06 °C/hour ($p < 0.05$). The fetus appears to be protected from excessive hyperthermia during the birth process.
Key words. Parturition; body temperature; labour; birth; fetus; sheep.

In all species studied to date[1-4] including humans[5], the temperature of the late-gestation fetus is about 0.6 °C higher than that of the mother's body core. The feto-maternal temperature gradient is established before the final quarter of gestation[3] and reflects a balance between the rate of metabolic heat production by the fetus and fetal heat loss, which occurs mainly via the utero-placental circulation[6]. Decreased uterine blood flow would be expected to compromise fetal heat loss, and so result in a rise in the feto-maternal temperature gradient. Such a situation occurs during maternal fever, when peripheral vasoconstriction apparently leads to reduced uterine blood flow, and potentially dangerous fetal hyperthermia ensues[3]. Another such situation is labour, during which uterine blood flow declines at least during periods of myometrial contractions[7-9]. One therefore expects an increased feto-maternal temperature gradient during labour. Moreover, increased muscular activity during labour[10] produces maternal hyperthermia[11]. A widened feto-maternal gradient when maternal body temperature is elevated would exacerbate hyperthermia in the fetus with potential pathological consequences, especially during prolonged parturition.

Previously[3] we reported the first use of radio-telemetry to monitor fetal body temperature. The technique, which we have used in sheep, is of particular advantage in allowing temperature measurement while physiological processes, such as labour, occur spontaneously and without restriction. We believe the measurements reported here are the first continuous records in any species of fetal body temperature during the process of parturition. Our findings show that, despite possible compromise to the utero-placental circulation, excessive fetal hyperthermia is not a normal accompaniment of labour.

Materials and methods

Animals and surgery. Using techniques we have described previously[3], we implanted sterile radio-telemeters into 8 pregnant Dorper-cross or Merino ewes and their fetuses, approximately 110 days after the ewes had been mated. The ewes were anaesthetised with fluothane (Halothane, Hoechst, 1.5–8% to effect). Under sterile theatre conditions, the uterus was exposed and the fetus was partially delivered by Caesarian section. A sterile radio-telemeter (see below) was inserted into the abdomen of the fetus through a small abdominal incision, and an identical radio-telemeter was placed into the abdomen of the mother, following which the incisions were closed by layered suturing. The ewes received antibiotic cover (ampicillin, 500 mg) intravenously during surgery and a long-acting benzylpenicillin (Peni LA, Phenix South Africa, 1 ml/15 kg) after surgery, and went on to deliver live lambs between 145 and 150 days after mating. All animals were killed about 10 weeks post-partum using an intravenous overdose of barbiturate (Eutha-naze, Centaur Laboratories, 100 mg/kg).

After surgery the animals were housed in individual indoor pens in an environment the ambient temperature of which ranged between 22 and 24 °C, and in which the natural light/dark cycle was maintained. Water and hay were provided ad libitum and pellets of concentrate (about 1 kg) were given once daily at about 15.00 h, although food intake was reduced for up to 24 h prior to labour onset. None of the animals was shorn. Newborn lambs had access to their mothers at all times.

Radio-telemeters. The radio-telemeters (Mini-Mitter, Sunriver, Oregon, USA) had the approximate shape, once encapsulated, of a cylinder of length 38 mm and diameter 23 mm. The major bulk of the unit was constituted by two 850 mAh batteries connected in parallel, which allowed us to measure temperatures continuously for 3 to 4 months. The telemeter, including batteries, weighed about 30 g (about 3% of fetal mass at insertion) and was coated with inert wax (Elvax, from Mini-Mitter) and calibrated according to procedures described previously[3]. The temperature of the tissue surrounding each telemeter could be measured to an accuracy of 0.06 °C.

Temperature measurements. Body temperatures of the fetuses and ewes were monitored for several hours pre- and post-delivery, while the ewes were unrestrained. In the immediate pre- and post-partum period, temperatures were measured at ten min intervals.

Statistical analysis. We used Student's t-test, with the Bonferroni correction for repeated measures when appropriate[12], when assessing changes of or differences in temperatures. Correlations were performed using the Spearman Rank Correlation Coefficient. Values of $p < 0.05$ were considered significant.

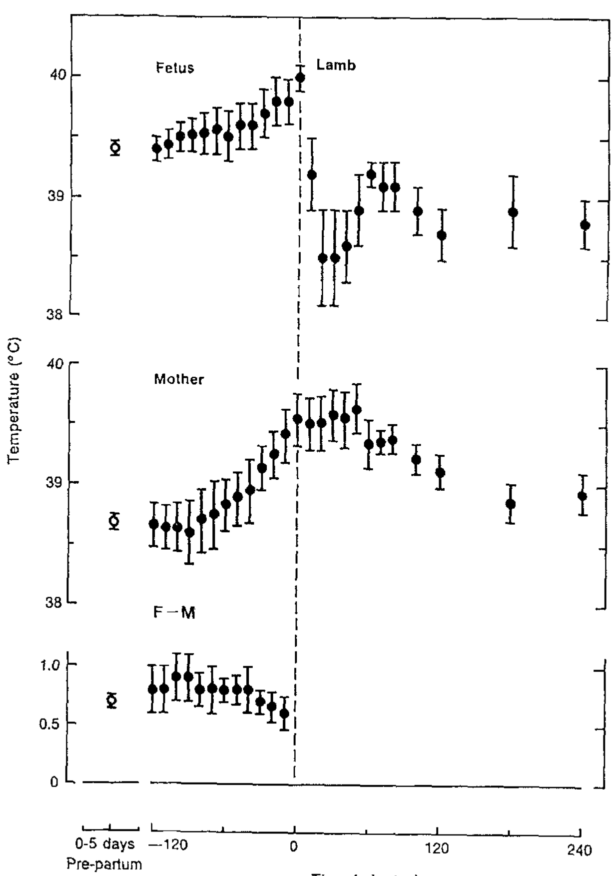
Ethics. All procedures were cleared by the Animal Ethics Committee of the University of the Witwatersrand under protocol numbers 86/30 and 89/117/5.

Results

The figure shows body temperature changes in the ewes and fetuses in the final 2 h of labour. Initially, ewe and fetal body temperatures were stable, but ewe temperature rose at a rate of 0.70 ± 0.06 °C/hour (mean $\pm$ SEM, $n = 7$) in the 60 min leading up to delivery. During this period rupture of the membranes occurred (47 ± 2 min, prior to parturition, $n = 7$) and the ewes were observed to bear down strenuously. There was no significant correlation between time from rupture of the membranes to delivery, and magnitude of the increase in maternal body temperature ($R = 0.57$, $p > 0.05$). Body temperature of the fetuses also rose during the last hour of labour, but at a significantly lower rate of rise, viz. 0.45 ± 0.06 °C/hour ($n = 8$, $p < 0.05$, t-test). Fetal body temperature immediately prior to delivery had reached 40.0 ± 0.1 °C ($n = 8$). The feto-maternal temperature gradient (F-M, fig.) was maintained at about 0.6 °C, a level similar to that which prevails during the last months of gestation[3], despite clear evidence of repeated, intense uterine contractions. Within minutes of birth, body temperature of all the lambs had fallen precipitously and mean falls of 1.6 ± 0.3 °C ($n = 8$) were recorded. Twenty minutes after birth lamb body temperature was 38.5 ± 0.4 °C ($n = 8$), significantly lower than fetal body temperature some 2 h earlier ($p < 0.05$, t-test; fig.).

Immediately after birth, the lambs usually lay on straw-covered concrete and were licked and nuzzled by the mothers. The lambs were on their feet within 60 min of birth and all had suckled by that time or soon thereafter. After the initial fall, lamb body temperature rose, but did not attain fetal temperature levels. Four hours post-partum, lamb body temperature had stabilized, but at a level significantly lower ($p < 0.05$) than the weighted mean for fetal body temperature as measured over the last 5 days pre-partum (fig.).

Body temperature of the ewes remained significantly higher than that prevailing 2 h prior to parturition, for up to 100 min post-partum. Mother animals were quietly attending to their lambs during this time.



Abdominal temperatures of fetus or lamb, and mother animal, and the difference between fetal and maternal temperature (F-M), measured for 2 h before and for 4 h after lambing (at time zero). Each point is the mean $\pm$ SEM of 7 ewes and 8 fetuses/lambs. Also shown (○) is the weighted mean $\pm$ SEM calculated for the last 5 days prior to parturition for fetal and maternal temperature, and F-M[3].

Discussion

Our results, the first measurements of fetal body temperature measurements during labour and birth, show that, despite periods of intense uterine contractions in the ewes, the expected accelerated rise in fetal body temperature did not occur; the feto-maternal temperature gradient was maintained no higher than pre-labour levels, and indeed tended to fall (fig.). We had predicted that the feto-maternal gradient would rise during labour, because research has shown that uterine blood flow declines in association with myometrial contractions[7-9]. This decline would compromise the vascular transfer of heat from fetus to mother. The situation, we thought, was analogous to the generation of a fever, during which physiological heat conservation mechanisms in the mother animal apparently compromise fetal heat dissipation[3]; fetal body temperature rises more rapidly than does maternal temperature, and the feto-maternal temperature gradient is significantly increased.

Our predictions were wrong. What actually occurred was a significantly lower, not higher, rate of rise of fetal body temperature compared to that of the mother during labour. The events were similar to the response we had observed previously during environmental heat stress[3]. When a pregnant animal is exposed to mild heat stress, more heat is lost from the fetus, presumably as the mother's peripheral blood vessels vasodilate. The feto-maternal temperature gradient falls, and the fetus is partially protected from the consequences of the environmental stress. Labour does indeed present pregnant animals, and women, with another form of heat stress; the heat derives from the increased oxygen consumption associated with uterine contractions[10], and maternal body temperature rises, not only, as we have shown, in sheep, but also in parturient sows[13], bitches[14] and women[11], especially women given analgesics[15]. The degree of increase of body temperature during the last part of labour may be related to the duration of labour, but we found no significant correlation between time from rupture of the membranes to delivery, and increase in maternal body temperature. In women, as in our sheep, a body temperature rise during labour precedes rupture of the membranes and the second stage of labour[16]. The rate of rise in body temperature in ewes during labour was significantly higher than that which we observed in pregnant sheep in the rising phase of a fever (0.70 ± 0.06 °C/hour versus 0.47 ± 0.06 °C/hour)[3]. A decrease in the feto-maternal temperature difference during the maternal hyperthermia of parturition hypothetically could result from fetal thermal inertia; maternal temperature rises rapidly without an immediate similar rise in temperature of the fetus, and maternal body temperature approaches that of the fetus. One would then expect, after a delay, rates of rise of maternal and fetal temperature to be similar. However, we observed a significantly lower rate of rise of body temperature in the fetuses. We suggest that there may have been active changes in fetal and/or maternal physiology, so as to dissociate the rates of rise of body temperature of the fetus and its mother during parturition. One such possibility is that fetal metabolic rate was reduced during labour. Fetal lamb metabolic rate apparently decreases if umbilical blood flow is reduced[17], or if arterial oxygen saturation decreases below 50%[18]. Brar et al.[7], however, found no fall in umbilical blood flow during labour in women. Another possibility is that heat loss from fetus to mother animal may have been enhanced despite the intermittent disturbance to uterine blood flow that labour causes[7-9]. There is evidence for enhanced heat loss to the environment in parturient animals[19] and women[20,21] during labour. It may be that concomitant internal adjustments during labour, for example changes in circulation, allow for increased heat transfer across the placenta or uterine wall too. Whatever the mechanism, a lower rate of rise in fetal body temperature during parturition means that in labour, as in mild heat stress, the fetus is protected from the risk of excessive hyperthermia when maternal temperature is rising.

If maternal mechanisms increase heat loss during labour, it is paradoxical that maternal body temperature was higher than pre-labour temperatures for some hour and a half after lambing (fig.). The body temperatures of women and other parturient animal species also rise after delivery[13,14,20,22,23]. Whether the elevated temperature is actively regulated, as in fever, is not known. The body temperature of the neonatal lamb, like that of its human counterpart, falls precipitously immediately after birth[24,25]. Our lambs experienced a fall in body temperature of more than 1.5 °C, on average, within 20 min of birth, even though the ambient temperature at birth was more benign than that which the lambs could experience in natural birth in the field. Newborn human babies, not actively warmed, but not actively neglected either, may undergo falls of 2 to 3 °C in the first hour of extra-uterine life[1]. The fall can be reversed by thermoregulation by the infant even in these early stages[26]. That the normal newborn lamb is able to thermoregulate effectively is in no doubt[27]. Nevertheless our newborn lambs had body temperatures which were stable at more than 1 °C lower than pre-birth temperatures, for at least 4 h after birth (fig.).

In conclusion, we have taken advantage of the technique of radio-telemetry to show the thermal consequences for both mother and fetus of normal labour. Despite disturbances to uterine blood flow and a rise in maternal body temperature during labour, the fetus appears adequately protected against excessive hyperthermia. Fetal thermal protection may well be incidental to thermoregulation in the mother during labour, or may be specific to the near-term fetus, or newborn animal. Similar thermal protection occurs in fever, which is suppressed in neonatal animals[28,29] in the immediate peri-partum period. Fetal hyperthermia in early gestation may be teratogenic[30] and in late gestation may cause intra-uterine growth retardation[31]. During parturition, fetal and/or neonatal hyperthermia may exacerbate neuronal damage in the event of peri-partum cerebral ischaemia[32].

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