Body Temperature and Circulating Progesterone Levels before and after Parturition in Killer Whales (Orcinus orca)

Etsuko KATSUMATA1), Sukanya JAROENPORN2,3), Hiroshi KATSUMATA1), Seiki KONNO4), Yoshiaki MAEDA4), Gen WATANABE2,3) and Kazuyoshi TAYA2,3)

1)International Marine Biological Research Institute, Kamogawa Sea World, Chiba 296–0041, 2)Department of Basic Veterinary Science, The United Graduate School of Veterinary Sciences, Gifu University, Gifu 501–1193, 3)Laboratory of Veterinary Physiology, Department of Veterinary Medicine, Faculty of Agriculture, Tokyo University of Agriculture and Technology, Tokyo 183–8509 and 4)Marine Mammal Section, Kamogawa Sea World, Chiba 296–0041, Japan

Abstract. Killer whales were used to evaluate peripartum changes and interactions between body temperature and circulating progesterone concentration. Daily body temperature was measured between 0800 h and 0830 h before activity. Body temperature clearly increased during the first phase of pregnancy, and this was followed by a gradual decline until full term. The initial increase was paralleled by circulating levels of progesterone. A decrease in body temperature was first detected on day 5 (p<0.01) before parturition, and body temperature decreased significantly every 2 days until delivery. Five days before delivery, body temperature was 0.3 C lower than the mean value during the pregnancy period, and the decrease was more marked on day 1 before delivery (0.8 C). Serum progesterone levels during pregnancy showed a general pattern of initial rapid elevation (increasing phase), followed by a gradual decline (decreasing phase) throughout the remainder of pregnancy. However, statistically significant correlations between body temperature and progesterone pattern were only found only during the increasing phase. These results suggest that monitoring body temperature variation can be considered valuable for predicting impending parturition in killer whales.

Key words: Body temperature, Killer whales, Parturition, Pregnancy, Progesterone


Killer whales, Orcinus orca, are large aquatic mammals. They live in water, which removes heat from a submerged mammal’s body about 25 times faster than for the same body in air [1]. Reproductive endocrinology during ovarian cycles and pregnancy has been studied in captive killer whales [8–10]. However, other physiological changes during pregnancy and parturition have not been clarified. Numerous physiological changes occur during maternal adaptation to pregnancy, parturition, and lactation. Body temperature is one indicator that changes during the periods of pregnancy, parturition, and lactation. A drop in body temperature below normal levels before parturition has been observed in several mammals, such as cattle [2, 3], sheep [4], dogs [5], and rats [6, 7]. Therefore, it may be possible to use body temperature changes before parturition to predict the onset of parturition in other mammal species, and this might be useful in determining when to give obstetrical assistance to increase the...
offspring survival rate.

To date, no data exists regarding body temperature change during pregnancy in the killer whale. The objectives of this study were to evaluate peripartum body temperature changes in killer whales, and to determine possible interactions between body temperature and circulating progesterone concentrations in captive killer whales.

Materials and Methods

Animals and Facilities

Two wild killer whales, captured and brought in 1988 from Iceland, were reared at Kamogawa Sea World (Chiba, Japan) and used in this study. Individual profiles for the two killer whales are shown in Table 1. These animals were trained to rest on their abdomens on the water surface for blood collection and body temperature measurement. Daily health examinations were routinely conducted for all whales by the resident veterinarian. Animals were kept in a pool; the rearing facility contained 4,800 tons of water with a depth of 6 m, and consisted of two compartments connected by gated channels. The mean water temperature was 17.8 °C (range: 12.5 to 19.5 °C; the water is cooled in summer), and the mean atmospheric temperature was 16.4 °C (range: 4 to 34 °C). Diagnosis of pregnancy was made by measurement of serum progesterone and daily observation of social interactions and copulatory behavior.

Body Temperature Monitoring

The body temperature of pregnant killer whales was measured daily during pregnancy and on day 10 after parturition. Rectal temperature was measured with a Terumo Finer CTM-303 (Terumo) by inserting a probe PK-K041 heat sensitive (heat sensitive probe temperature range: 0 to 50 °C; Terumo) via the anus to a depth of 40 to 50 cm between 0800 h and 0830 h before activity.

Radioimmunoassay of Progesterone

Serum concentrations of progesterone were measured in two female killer whales (A and B) between March 1993 and August 1997, and January 1996 and December 2003, respectively. The blood was collected every 2 to 4 weeks from the fluke blood vessels (Fig. 2) into vacuum tubes (Venoject II Autosep, Terumo, Tokyo, Japan) and centrifuged at 1700 g for 15 min. The serum was separated and stored at −20 °C until assayed for progesterone. The intra- and inter assay coefficients of variation were 4.2% and 6.8%, respectively. The lower limits of the assay sensitivity were 0.1 ng per ml.

Statistical Analysis

The results were expressed as means ± standard error of the means (SEM). Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) program. Differences among

Table 1. Profiles of the two female killer whales

<table>
<thead>
<tr>
<th>Whale</th>
<th>Date into KSW</th>
<th>Birth year</th>
<th>Length at capture (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whale A*</td>
<td>03/29/1988</td>
<td>1983</td>
<td>401</td>
</tr>
<tr>
<td>Whale B**</td>
<td>03/29/1988</td>
<td>1986</td>
<td>274</td>
</tr>
</tbody>
</table>

Birth year was estimated from length-growth curves according to the method of Duffield and Miller [22]. KSW: Kamogawa Sea World.

*Whale A's first offspring died 30 min after birth. Her second offspring was delivered stillborn (225 cm in length) at 16 months of pregnancy, and she died 3 days later.

**Whale B gave birth successfully each time.
times of sampling were evaluated by one-way analyses of variance (ANOVA) for factorial or repeated measures designs with post-hoc testing by least significant difference (LSD) test. P values of less than 0.05 were considered to be statistically significant. Serum progesterone levels versus body temperature were compared using a Mann-Whitney U-Wilcoxon Rank Sum W test to look for shifts in distribution.

Results

Killer whales are polyestrous animals showing spontaneous ovulation with anestrus. The gestation period of the killer whales was 545 ± 3.7 days (n= 4) based on 4 normal pregnancies from the 2 animals.

Body temperature markedly increased during the first phase of pregnancy, followed by a gradual decline until full term. This initial increase in body temperature was paralleled by circulating levels of progesterone (Figs. 3 and 4). The body temperature of the pregnant killer whales significantly decreased between day 5 and day 1 (p<0.01) before the onset of parturition (Fig. 6), and increased to

Fig. 2. Picture of blood collection from a killer whale. The blood was taken from the fluke blood vessel.
baseline after parturition. The decrease of body temperature was first detected on day 5 before parturition, and significantly decreased every 2 days until delivery. Five days before the beginning of delivery, body temperature was 0.3°C lower than the mean value (35.6 ± 0.06°C) during the pregnancy period, and the decrease was more marked on day 1 before delivery (0.8°C). There were significant differences between days as follows: Day-1 versus Days-2 to -10; Day-2 versus Days-4 to -10; Day-3 versus Days-5 to -10; Day-4 versus Days-6 to -10; and Day-5 versus Days-7 to -10 before parturition.

The serum progesterone levels were between 0.020 and 0.121 ng/ml during anestrus, and between 2.28 and 3.392 ng/ml during the luteal phase of the estrous cycle (Figs. 3 and 4). During the first gestational period, the serum progesterone levels of the killer whales (A and B) ranged between 3.7 and 22.1 ng/ml and 2.1 and 23.9 ng/ml, respectively. In addition, serum progesterone levels tended to increase during the next gestation (between 6 and 23.5 ng/ml and 5.3 and 32 ng/ml, respectively).
BODY TEMPERATURE IN PREGNANT KILLER WHALES

respectively). The serum progesterone levels during pregnancy showed a general pattern of initial rapid elevation (increasing phase), followed by a gradual decline (decreasing phase) throughout the remainder of pregnancy. However, statistically significant correlations between body temperature and progesterone pattern were only found during the increasing phase ($R^2=0.5388$, $n=51$) (Fig. 5).

**Discussion**

In the present study, a statistically significant decrease in body temperature was recorded between day 5 and day 1 before the onset of parturition (day 0), suggesting that monitoring of body temperature variation can be considered valuable for predicting the onset of parturition in captive killer whales. Correlation between serum concentrations of progesterone and body temperature was only observed during the increasing phase ($R^2=0.5388$, $n=51$) (Fig. 5).

Fig. 6. Changes in body temperature before and after parturition. Day 0 is the day of parturition. Values are means ± SEM of four normal pregnancies. *p<0.01 vs Day –10.

serum concentrations of progesterone and body temperature. However, these results suggest that body temperature measurement is useful for predicting impending parturition in this species. *In vivo* studies [13] and model predictions [14] have indicated that fetal lambs lose 80 to 85% of their heat via transfer to the placenta and the other 15 to 20% via transfer through the uterine wall. Blood flow to the placenta, was directly affected by maternal temperature, and this effect would influence heat dissipation by the fetus [14]. In addition, fetal lamb temperature increased before lambing and decreased by approximately 1.5°C within 20 min after lambing, even in a temperature-controlled environment [15], indicating that this mechanism may protect newborn lambs from hyperthermia. We suggest that similar mechanisms may also occur in the killer whale. We also speculate that the decrease in maternal body temperature before parturition may be biologically important for decreasing uterine blood flow and heat dissipation by the fetus. Brar et al. [16] found that fetal temperature continues to increase through parturition because myometrial contractions also decreased uterine blood flow and heat dissipation by the fetus. They hypothesize that the increase in fetal temperature before parturition may be an important compensatory mechanism for the loss in body temperature that occurs in newborns after delivery. In the previous study, the body temperature of a pregnant killer whale did not decrease when their offspring died before parturition [Etsuko Katsumata, unpublished]. We also suggest that the decrease in body temperature before parturition may be an important mechanism to protect the offspring's life and may be useful in determining when to give obstetrical assistance to increase the offspring survival rate in this species.

Cetaceans, including killer whales, are highly specialized marine mammals that spend their entire life in water. One of the greatest physiological challenges for these marine endotherms is thermoregulation [17]. They possess a vascular countercurrent heat exchanger (CCHE) that functions to regulate the temperature of their intra-abdominal reproductive organs [18, 19]. The cetacean reproductive system is surrounded by thermogenic locomotory muscle and insulating blubber. This arrangement suggests that an
elevated temperature in the uterus could induce detrimental effects on fetal development [20]. Pabst et al. [21] reported that the temperature in the region of the colon flanked by the CCHE decreases with exercise in dolphins. In addition, colonic temperatures adjacent to the CCHE were maximally 1.3°C cooler than temperatures measured outside this region [19]. Therefore, CCHE may thermally regulate temperature during the parturition of killer whales. However, further studies are required to determine the mechanism of thermoregulation for the intra-abdominal reproductive organs of the killer whale during pregnancy.

In conclusion, the present study is the first report to detail changes in the body temperature of pregnant killer whales during parturition. The results from this study suggest that body temperature measurement and monitoring of progesterone levels is suitable for detection of impending parturition and available to the clinician as a tool to indicate problems during parturition in this species.

Acknowledgments

We would like to express our appreciation to the members of the International Marine Biological Research Institute, Kamogawa Sea World, Kamogawa, Chiba, Japan. This study was supported in part by a Grants-in-Aid for Scientific Research (The 21st Century Center of Excellence Program, E-1) from the Ministry of Education, Culture, Sport, Science and Technology of Japan.

References

17. Whittow GC. Thermoregulatory adaptations in


