Postnatal thyroxine status of piglets in response to prenatal thyroxine infusion of the sow

L. A. Bate, A. Finsten and J. G. Crossley

Department of Anatomy and Physiology, University of Prince Edward Island, Charlottetown, Prince Edward Island, Canada C1A 4P3. *Received 17 June 1992, accepted 6 April 1993.*

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Bate, L. A., Finsten, A. and Crossley, J. G. 1993. **Postnatal thyroxine status of piglets in response to prenatal thyroxine infusion of the sow.** Can. J. Anim. Sci. **73**: 533–538. Fifteen pregnant primiparous sows were infused intravenously with either 0 ($T_4$0), 25 ($T_4$25), or 50 ($T_4$50) mg thyroxine (T_4) d^{-1} between days 102 and 112 of gestation. Piglets were observed for the birth to suckling interval (BTS) during the first 6 h of life. At 6 h, pre-determined piglets were subjected to a cold challenge, consisting of exposure to an environment of 5°C for 2 h. Rectal and skin temperatures of piglets were recorded from birth to 8 h of life. Body weights of piglets and their plasma-T_4 concentrations were measured until 4 wk of age. Infusion with T_4 increased the sow's plasma-T_4 levels ($P < 0.05$) during the entire infusion period. No postnatal differences in piglet plasma-T_4 concentrations were observed as a consequence of the prenatal treatment of the sows. BTS was not influenced by treatment. Piglets of all groups had similar rectal temperatures within 2 min of birth ($P > 0.05$). During cold exposure, the rectal and skin temperatures of all the piglets decreased ($P > 0.05$). It can be concluded that prenatal priming of sows with T_4 does not influence BTS, thermoregulatory capability or subsequent performance of piglets, probably because of low rates of transport of thyroxine across the placenta.

Key words: Thyroxine, thermoregulation, temperature, cold, piglet

Bate, L. A., Finsten, A. et Crossley, J. G. 1993. **État thyroïdien postnatal des porcelets résultant d'infusion prénatales de thyroxine à la mère.** Can. J. Anim. Sci. **73**: 533–538. Quinze truies primipares gravides ont reçu des infusions intraveineuses journalières de 0, 25 ou 50 mg de thyroxine (T_4) entre le 102^e et le 112^e jour de gestation. On mesurait l'intervalle naissance-première tétée dans les six premières heures de vie des porcelets. À six heures, certains porcelets ont été soumis à un stress thermique, soit l'exposition pendant deux heures à une ambiance de 5°C. Les températures rectales et cutanées des porcelets étaient enregistrées jusque dans les huit premières heures, tandis que le poids corporel et les concentrations plasmatiques de T_4 étaient mesurés jusqu'à l'âge de quatre semaines. L'infusion de T_4 a accru ($P < 0{,}05$) les niveaux plasmatiques de la truie durant toute la durée de l'infusion. Toutefois, le traitement prénatal des truies n'a pas laissé de différences dans les concentrations plasmatiques de T_4 chez les porcelets. Il n'avait pas non plus d'effet sur la durée de l'intervalle naissance-première tétée. Dans tous les groupes, les porcelets avaient les mêmes températures rectales dans les 2 minutes suivant la naissance ($P < 0{,}05$). L'exposition au froid a causé une baisse non significative des températures rectales et cutanées chez tous les porcelets. Ces observations portent à conclure que l'administration de T_4 à la truie gestante n'influe pas sur l'intervalle naissance-première tétée, sur l'aptitude thermorégulaturice ou sur les performances ultérieures des porcelets, vraisemblablement à cause du faible taux de migration de la thyroxine à travers le placenta.

Mots clés: Thyroxine, thermorégulation, température, froid, porcelet

The ability of the newborn piglet to maintain homeothermic conditions immediately after birth has a significant effect on its subsequent survival. Unlike cows and ewes, sows do not lick the newborn and contribute to its drying. Therefore, the drying of placental fluids soon

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after expulsion imposes a significant challenge to the calorigenic mechanisms of newborn piglets (Curtis 1970) which results in a substantial drain on their energy reserves. Because the piglet is unable to cope with this demand, its rectal temperature decreases about 2°C within the first 2 h of life, though it eventually recovers to euthermic levels within the first day of life (Curtis 1983).

It has been shown that the thermogenic process used to maintain body temperature following exposure to cold relates to secretion of thyrotropin-releasing hormone (TRH) (Evans and Ingram 1974), thyroid-stimulating hormone (TSH) (Reichlin et al. 1972) and thyroxine (T_4) (Dauncey 1990). In the pig, the thermogenic activity that follows exposure to cold is associated with potentiation of catecholamine action by thyroid hormones (Ślebodziński 1979). In other species T_4 does not play such a role (Ślebodziński 1986). Some piglet runts, weighing less than 580 g, fail to increase their metabolic rate in response to cold exposure (Hayashi et al. 1987). This could be due to the lower number of thyronine receptors found in runt piglets compared with their normal littermates (Dauncey and Geers 1990). Thyroid hormones also appear to stimulate adipocyte development in fetal piglets (Ramsay et al. 1987), with the potential to enhance thermoregulation.

Therefore, a study was conducted to determine whether prepartal supplementation of T_4 in the sow resulted in modifications to the plasma concentration of T_4 and thus a better postnatal ability of the piglet to cope with cold challenges.

MATERIALS AND METHODS

Eighteen primiparous sows were randomly allocated to one of three treatments consisting of a continuous daily intravenous infusion with either 0 (T_40), 25 (T_425) or 50 (T_450) mg of sodium levothyroxine (Sigma Co., St. Louis, MO) in 500 mL of sterile saline d^{-1}. On the 100th d of gestation, the sows were catheterized through the ear vein following the established procedure of Bate and Hacker (1985) and allowed to rest for 2 d prior to initiation of the treatments. Three sows destroyed their catheters during the trial and hence had to be removed from the experiment, leaving 6, 5 and 4 sows in the T_40, T_425 and T_450 groups, respectively. On day 102 of gestation, the first day of infusion, a preinfusion blood sample was collected at 08:00 h. Infusion commenced at 08:15 h and was followed by sampling at 12:00 and 20:00 h. Thereafter, daily blood samples were taken from each sow between 08:00 and 09:00 h until parturition. All blood samples were collected in tubes containing 72 USP units of sodium heparin. These were then centrifuged, and the plasma was harvested, aliquotted and stored at −20°C for subsequent analyses. The infusions were dispensed from days 102 to 112 of gestation with a Gilson Miniplus 2 peristaltic pump.

At parturition, considered day 0, piglets were received, weighed, dried and identified. Within 2 min, and also at 3, 6, and 8 h after birth, their rectal and skin temperatures were recorded. Rectal and skin temperatures were recorded with a digital thermometer and an Omega OS71 (Omega Engineering, Inc. Samford, CT) infrared thermometer, respectively. Skin temperature was measured over the last four ribs. Blood samples (2.5 mL) were collected from the suborbital sinus of each piglet within 2 min and at 6 and 8 h after birth. After the first blood sample was collected, the piglets were released in the rear area of the farrowing crate and were continuously observed for 6 h to record the time of first suckling — the birth to suckling interval (BTS). Further blood samples were collected on days 1, 2, 4, 7, 11, 15, 20, 25 and 28. All blood samples from piglets were handled like those of the sows. Piglets 1, 3 and 5, of those born alive, were removed from the litter at 6 h and placed in a cold unit at 5°C for a 2-h cold challenge. During exposure to the cold challenge the pigs were individually housed in 40 cm × 30 cm pens with a floor made from nonmetallic window screen. This flooring material appeared comfortable to the feet and permitted free air circulation and elimination of urine from the pen. Subsequently, these pigs were returned to the sow and allowed to continue suckling.

Thyroxine was determined using a commercial radioimmunoassay kit (Diagnostic Product Corporation, Los Angeles, CA). This assay had intra- and inter-assay coefficients of variation of 6.0 and 9.8%, respectively, and a sensitivity of 0.3 $\mu g\ dL^{-1}$.

The data were analyzed as a split plot with prepartal hormone treatment as the main plot and postpartal temperature exposure as the subplots. The analysis was done using Statistical Analysis System Institute, Inc. software (Spector et al. 1985). The thermal treatment, which varies from normal recommended care of animals, was approved by the local Animal Care Committee prior to initiation of the research.

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RESULTS

Plasma concentrations of T_4 in sows increased dramatically ($P < 0.001$) in response to treatment (Fig. 1). The $T_4$50 group showed a large peak on the first day of infusion, which decreased to a more stable pattern by the fourth day. Plasma concentrations of T_4 in $T_4$25-treated sows increased at a slower rate than those in the $T_4$50 group. Sows in both T_4-treated groups had higher ($P < 0.01$) plasma-T_4 concentrations than those in the $T_4$0 group during infusion. By day 113 of gestation, one day after the infusion was suspended, plasma-T_4 concentrations had decreased rapidly in both groups of sows receiving T_4. By day 113 of gestation, these concentrations were similar to those in control sows ($P > 0.05$). Sow treatment did not influence postnatal plasma concentrations of T_4 in piglets ($P > 0.05$) (Fig. 2). There was, however, a clear elevation ($P < 0.05$) in the plasma-T_4 concentration of all piglets during the first 2 d of life, which decreased toward day 7 before it again increased during the second and third weeks of life (Fig. 2).

Weight at birth was reduced in $T_4$50 piglets ($P < 0.05$), but the difference disappeared by 8 h. However, $T_4$25 piglets were lighter than control piglets on days 7, 11, 20 and 25 ($P < 0.05$) (Table 1). Cold challenge did not influence subsequent growth performance ($P > 0.05$). All groups of piglets had similar (mean ± SE) BTS ($P < 0.05$): 38 ± 5.4, 33 ± 3.2 and 32 ± 3.7 min for piglets in the $T_4$0, $T_4$25 and $T_4$50 groups, respectively.

Neither treatment nor sex influenced rectal or skin temperature of the piglets within 2 min of life ($P > 0.05$); skin temperature, however, was consistently lower than rectal temperature ($P < 0.01$). At 2 h of life the rectal temperature within each group was similar to that recorded at birth, but skin temperature had increased in all groups. After the 2 h of cold challenge, rectal temperatures of all challenged animals decreased ($P < 0.05$) from 38.6 ± 0.1°C to 37.3 ± 0.3°C, from 38.2 ± 0.1°C to

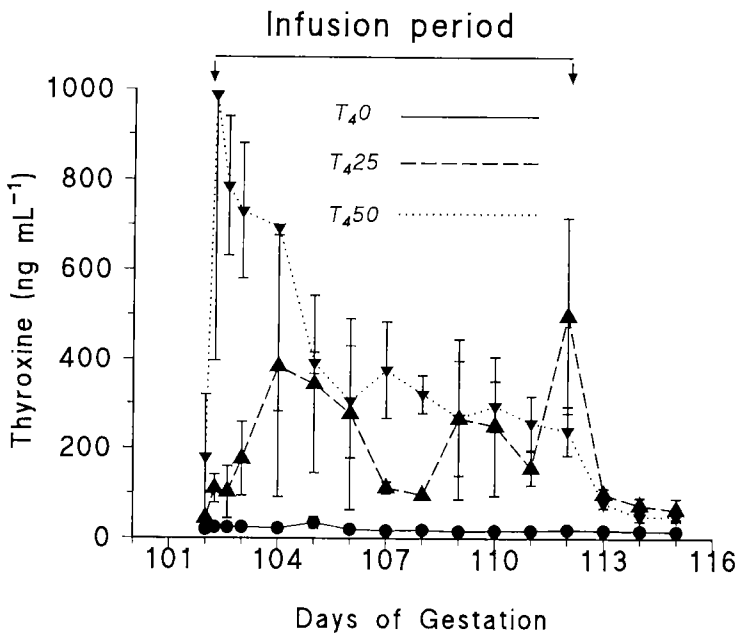

Fig. 1. Plasma concentrations of thyroxine (mean ± SE) in sows infused intravenously with 0 ($T_4$0, $n = 6$), 25 ($T_4$25, $n = 5$) or 50 ($T_4$50, $n = 4$) mg of thyroxine d^{-1} between days 102 and 112 of gestation.

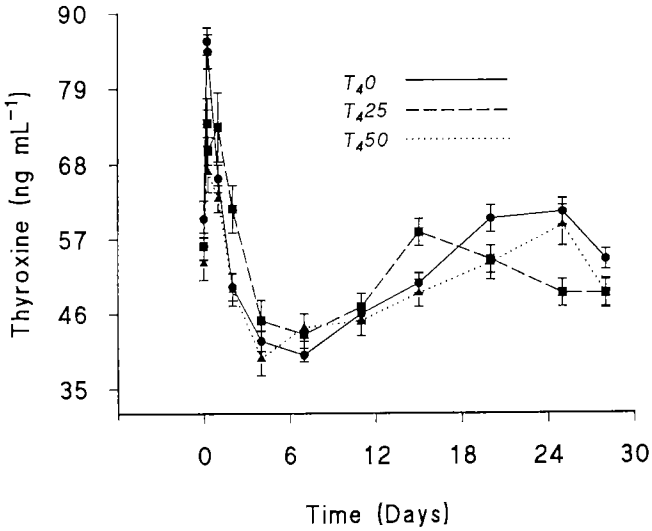

Fig. 2. Plasma concentrations of thyroxine (mean ± SE) in piglets born to sows infused intravenously with 0 (T_40, n = 47), 25 (T_425, n = 42) or 50 (T_450, n = 40) mg of thyroxine d^{-1} between days 102 and 112 of gestation.

Table 1. Body weight of piglets born to sows infused intravenously with 0 (T_40), 25 (T_425) or 50 (T_450) mg of thyroxine d^{-1} between days 102 and 112 of gestation

Age	Body weight (kg ± SE)		
	T_40 (n = 47)	T_425 (n = 42)	T_450 (n = 40)
0 h	1.41*a* ± 0.04	1.35*ab* ± 0.05	1.31*b* ± 0.04
8 h	1.46*a* ± 0.04	1.40*a* ± 0.05	1.39*a* ± 0.04
1 d	1.52*a* ± 0.04	1.44*a* ± 0.05	1.44*a* ± 0.05
2 d	1.65*a* ± 0.06	1.53*a* ± 0.06	1.59*a* ± 0.04
4 d	1.96*a* ± 0.06	1.80*a* ± 0.06	1.85*a* ± 0.05
7 d	2.56*a* ± 0.08	2.29*b* ± 0.09	2.43*ab* ± 0.09
11 d	3.50*a* ± 0.11	3.17*b* ± 0.12	3.35*ab* ± 0.13
15 d	4.43*a* ± 0.14	4.19*a* ± 0.15	4.40*a* ± 0.14
20 d	5.62*a* ± 0.17	5.17*b* ± 0.19	5.69*a* ± 0.16
25 d	6.94*a* ± 0.20	6.29*b* ± 0.23	6.60*ab* ± 0.19
28 d	7.69*a* ± 0.26	7.12*a* ± 0.31	7.23*a* ± 0.28

a,*b* Values within a row followed by different letters are different ($P < 0.05$).

37.5 ± 0.2°C, and from 38.3 ± 0.1°C to 37.6 ± 0.2°C, while skin temperatures dropped from 37.8 ± 0.4°C to 34.3 ± 0.5°C, from 36.0 ± 0.4°C to 35.5 ± 0.4°C, and from 36.8 ± 0.3°C to 35.1 ± 0.3°C for piglets in the T_40, T_425 and T_450 groups, respectively.

DISCUSSION

The initial plasma-T_4 peak observed in sows following initiation of infusion reflected the hormone being incorporated into the system. Shortly after, the sows appeared to be able to manage the large exogenous supply of T_4 more effectively, perhaps through

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enhanced catabolism. This possibility is further supported by the rapid decrease in sow plasma T_4 observed following suspension of the infusion. The large difference between piglet and sow plasma-T_4 concentrations is consistent with the findings of others (Nowak 1985; Dvorak et al. 1986).

Spencer et al. (1989) reported that thyroidectomized fetal pigs maintained constant serum-T_4 concentrations during the last 2 wk of gestation. Since the half-life of T_4 in circulation is in the range of minutes (Spencer et al. 1985), the only explanation for this sustained concentration is some form of T_4 crossing through the placenta from the maternal to the fetal compartment. If T_4 crosses the placental barrier and is capable of influencing further thermogenic activity in the newborn, elevating prepartal T_4 concentrations in the sow may benefit the newborn. After an animal is stimulated with T_4 for about 10 d, the resulting increased metabolic activity is normally maintained for at least 2 wk (Martin 1985).

The lack of differences in plasma-T_4 concentration observed at birth in the piglets of this study despite maternal treatment could have two explanations. The first explanation is that maternal T_4 crossed the placenta during maternal treatment, but by the time of parturition its concentration in the piglet plasma had returned to the basal levels because of its short half-life. Perhaps piglet plasma-T_4 concentrations followed the profiles of T_4 observed in the sows after suspension of the infusion. If this was the case, we would not have expected to see differences in plasma-T_4 concentrations in the piglets at birth, but we should have seen some differences in the thermoregulatory capability of piglets born to sows treated with T_4. The second explanation is that, as Mestman (1986) showed for humans, maternal T_4 is not able to cross the placenta into the fetal compartment. In humans, the placenta is impermeable to intact T_4 and triiodothyronine (T_3) because of the presence of an active inner-ring iodothyronine monodeiodinase capable of converting T_4 to reverse T_3 (rT_3) and T_3 to T_2 (Fisher 1986).

It is therefore reasonable to suggest that the absence of differences in the ability of piglets from the different T_4-treatment groups to cope with the cold stress is a consequence of an inadequate prepartal increase in fetal metabolic activity because maternal T_4 did not cross into the fetal compartments. In view of our findings and the evidence shown in humans, the results of Spencer et al. (1989) are difficult to explain.

Endogenous secretion of thyronines by piglets normally follows food ingestion (Houpt et al. 1986; Nowak and Ślebodziński 1986). Since piglets in this trial had all suckled before the cold challenge, their endogenous T_4 secretion may have been stimulated, resulting in the initial postnatal elevation in T_4 observed. The profiles of plasma-T_4 concentrations following birth were similar to those observed by Parker et al. (1980) and Scanes et al. (1987).

The elevated T_4 levels in the treated sows may have increased their metabolic rate, diverting nutrients from the fetal piglets and thus reducing piglet birth weight in comparison with piglets from control sows. The difference in birth weight may have been eliminated during lactation, probably as a result of increased milk production by sows treated with thyroxine (Cabell and Esbenshade 1990).

In the present experiment, drying the piglets may have reduced heat loss by evaporation, which leads to the rectal temperature drop reported by Curtis (1983). The change from intrauterine to extrauterine life is reflected in a decrease in skin temperature within 2 min of life. The postnatal cold challenge may not have been sufficiently long to affect the plasma-T_4 concentration of the piglets, or the ingestion of food prior to the challenge may have already elevated endogenous T_4 levels, as shown previously by Nowak and Ślebodziński (1986). Since T_4 apparently did not cross the placenta barrier in an intact form to elevate the circulatory-T_4 levels in the newborn, the similar thermoregulatory capabilities among different experimental groups is therefore to be expected.

In conclusion, this study suggests that prenatal elevation of T_4 in the sow by direct infusion of thyroxine does not bring about significant modifications in the thyroxine status of the newborn piglet.

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