

Change in Tail Skin Temperature during Exposure to Various Ambient Temperatures in Chronic Spinal Rats

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Abstracts: Change in tail skin temperature during exposure to various ambient temperatures was studied in chronic spinal rats. Lower end of the cervical cord (C-8) was transected by aspiration under pentobarbital anesthesia, and then the rats were reared in 30°C as chronic spinal rats. Rectal temperature (Tre), tail skin temperature (Ttail), heart rate (HR) and ambient temperature (Ta) were recorded simultaneously in three groups of conscious rats, Group α (about 3 days after spinalization, N=9), β (15 days, N=7) and γ (30 days, N=6) during exposure to constant temperature or to various Ta. After exposure to 20°C for 60 min, Tre became $31.1 \pm 0.4^\circ\text{C}$ and $34.6 \pm 0.3^\circ\text{C}$ in Group α and γ , respectively.

Chronic spinal rats were exposed to sequential and reciprocal change of Ta ranging from 25°C to 35°C. Statistically significant ($p < 0.001$) correlation was recognized between Ta and dT, or excess temperature of the tail skin ($dT = T_{\text{tail}} - T_a$). Mean regression coefficient of dT on Ta was -0.58 ± 0.05 , -0.38 ± 0.05 and -0.30 ± 0.03 in Group α , β and γ , respectively. And when Ta was 25°C, corresponding value of dT was $5.9 \pm 0.4^\circ\text{C}$, $4.8 \pm 0.4^\circ\text{C}$ and $4.5 \pm 0.3^\circ\text{C}$ in Group α , β and γ , respectively. In both parameters, values in Group β and γ are significantly smaller ($p < 0.05$) than those in α . Because heat loss by conduction, convection and radiation depends on dT, heat loss from the tail may be progressively reduced with an increase of days after spinalization.

Key Words: Rats, Chronic Spinalization, Rectal, Tail Skin and Ambient Temperatures, Conscious Condition.

INTRODUCTION

It is well known that ability of temperature regulation recovers gradually after spinalization (Thauer, 1935). Since Thauer's pioneering experiment, many studies have been performed concerning with roles of spinal mechanisms for thermoregulation in spinal-intact

animals and also with recovery of thermoregulatory ability in chronic spinal animals (Simon, 1974). Thermoregulatory adjustment of peripheral circulation (Walther *et al.*, 1971 b, Lin and Chai, 1974; Chambers *et al.*, 1974; Liu *et al.*, 1979) and the differential activity of the sympathetic nerve in the spinal level (Walther *et al.*, 1971 a; Jänig and Kümmel, 1981) were studied in chronic spinal animals. Moreover, recovery of shivering response during cold stimulation of the spinal cord or of the periphery in chronic spinal animals was reported (Simon *et al.*, 1966; Kosaka and Simon, 1968; Herdman, 1978). However, changes in the spinal function during gradual recovery of thermoregulation in chronic spinal animals have not been fully clarified.

The rat tail is a localized and well-developed organ for control of heat dissipation (Johansen, 1962; Rand *et al.*, 1965; Carlisle and Laudenslager, 1979; Young and Dawson, 1982; Raman *et al.*, 1983). It is known that blood flow through the rat tail is effectively regulated by arteriovenous anastomoses in the caudal glomerulus which are innervated by sympathetic nerves (Grant, 1963; Kondo, 1972; Gemell and Hales, 1977; Molyneux, 1977; Hales *et al.*, 1978). Because of a well-developed vasomotor mechanism in the tail and comparative resistance to infection after the surgical operation, the rat may be an advantageous animal to study the change in autonomic function in spinal level concerned with thermoregulation. Purpose of this study is to elucidate the recovery process of thermoregulatory adjustment of the tail vasomotion in chronic spinal rats.

MATERIALS AND METHODS

Adult male rats (Wistar strain) ranging in weight from 420g to 530g were used in this study. Animals were individually reared in a room of 24°C. The spinal cord was transected at the lowest cervical level (C-8) by aspiration under pentobarbital anesthesia. After recovery from anesthesia, a small quantity of Procain Penicillin G in oil was injected subcutaneously. Rats were transferred to a room of 30°C to avoid the drop of body temperature and then were reared as chronic spinal rats. Food and water were available *ad libitum* before and after spinalization and even during the experiment. Each of animals was placed in a wire-meshed cage of dimensions 5cm×5cm×15cm in conscious condition. This cage was too small to allow major movements, and the animal could not turn around in the cage. The small cage containing rat was suspended in the air of the wooden chamber of 255 l. The rats extended their tails outside of the cage avoiding contact with the structure of the cage. Air temperature in the chamber was controlled by circulating water through coils of copper tubes as a heat exchanger. The vertical temperature gradient was reduced by stirring air using a small fan in the chamber. Inner walls of the chamber were covered by blocks of polystyrene (5 cm thickness) for thermo-insulation. Observation was made through a thermo-insulative double glass window. Temperature difference be-

tween the inner wall of polystyrene and air in the chamber was within 1°C. All results from the three groups, Group α (about 3 days after spinalization, N=9), β (15 days, N=7) and γ (30 days, N=6) were compared with each other.

In one experiment, rats were exposed to a constant temperature of 20°C for more than 60 min. In another, rats were exposed to the temperature which changed sequentially and reciprocally at a constant rate of 0.1 to 0.3°C/min between 25°C and 35°C. Rectal temperature (Tre), tail skin temperature (Ttail), heart rate (HR, not in all cases) and air temperature (Ta) in the chamber were recorded simultaneously. Tre was detected by a thermistor probe inserted into the rectum beyond 5 cm from the anus. Ttail was detected by a thermistor probe attached on the ventral surface in the middle of the tail. The probe on the skin was wrapped by a surgical tape. HR was calculated with a heart rate counter (Nihon Koden, AT-600G) by R-R interval measurement by electrocardiogram, recorded with conventional Lead I. All parameters were recorded in a UV oscillograph (Type 5L, Sanei). Every 4 or 5 min, numerical evaluations of the curve of recorded parameters were made.

Equations of regression line for correlation between excess temperature (dT) of the tail skin and Ta were computed with the least square method ($dT = T_{tail} - T_a$). Data given as $a \pm b$ refer to arithmetical mean value and standard error (mean \pm S.E.). Statistical significance of change in parameters were determined by Mann-Whitney U test.

After experiment, animals were sacrificed under intraperitoneal administration of sodium pentobarbital, the spinal cord was removed carefully and fixed in 10% formalin solution and then complete disconnection of the spinal cord was confirmed under a binocular microscope.

RESULTS

General condition of chronic spinal rats

The rats which were chronically spinalized at cervical level were reared in the room of 30°C. Tre, Ttail and body weight were measured at 1:00 P.M. every day. Changes in parameters are demonstrated in Fig. 1. Mean Tre of spinal rats was $37.3 \pm 0.1^\circ\text{C}$ (N=6), $37.0 \pm 0.1^\circ\text{C}$ (N=6), $36.9 \pm 0.1^\circ\text{C}$ (N=3) and $36.8 \pm 0.1^\circ\text{C}$ (N=3) during the 1st, 2nd, 4th and 6th week after spinalization, respectively. In the intact control rats, mean Tre was $37.4 \pm 0.1^\circ\text{C}$ (N=6) during the 1st week after beginning of exposure to 30°C. Mean dT was $5.0 \pm 0.2^\circ\text{C}$ (N=4), $4.4 \pm 0.2^\circ\text{C}$ (N=4), and $4.1 \pm 0.1^\circ\text{C}$ (N=3) during the 1st, 2nd and 6th week after spinalization, respectively. Mean body weight was 487 ± 15 g (N=6) just before spinalization, but it decreased markedly day by day after spinalization. It became $74.5 \pm 1.9\%$ (N=6) and $69.8 \pm 4.4\%$ (N=3) at the 10th and 25th day after spinalization, in comparison to that just before spinalization.

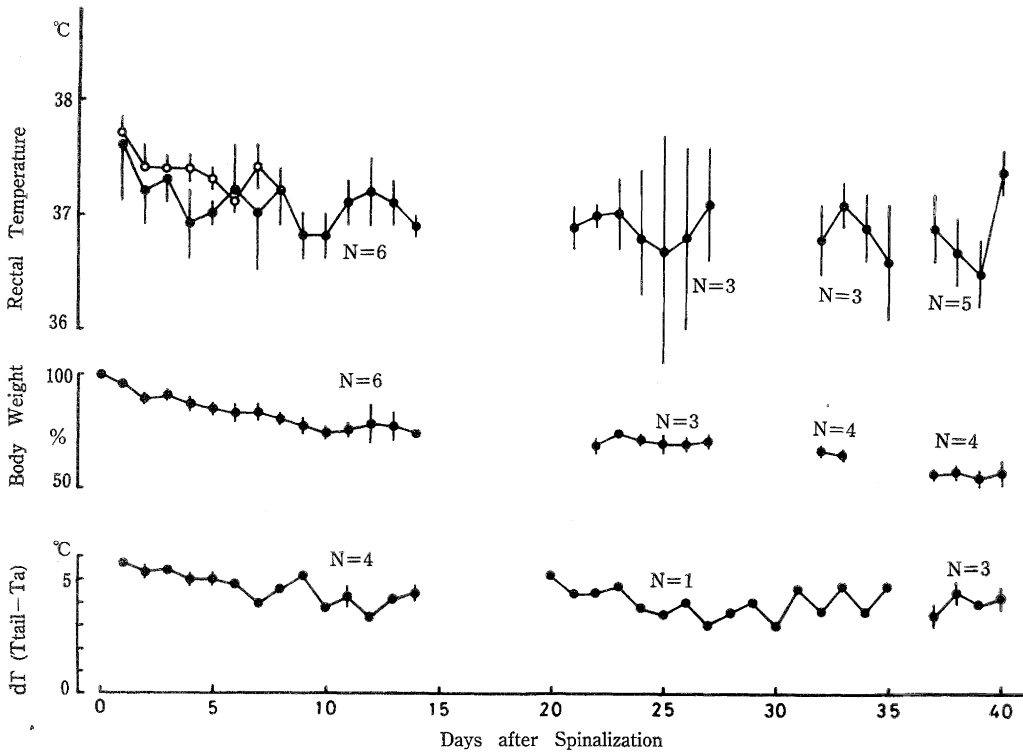


Fig. 1. Rectal temperature, body weight and dT , excess temperature of the tail skin from the ambient temperature after cervical spinalization (solid circles, mean \pm S. E.). Vertical bars are standard errors. Room temperature was $30.1 \pm 0.2^\circ\text{C}$. Open circles represent results obtained from spinal-intact animals ($N=6$) as the control.

Exposure to a constant temperature, 20°C

In order to assess the cold tolerance of chronic spinal rats, change of T_{re} during exposure to 20°C in conscious condition was compared between two groups of rats, Group α (2.8 ± 0.9 days after spinalization, $N=4$) and Group γ (29.8 ± 1.5 days, $N=5$). Rats were conveyed to the experimental chamber as fast as possible, and thermistor probes were attached. During the procedure of preparation T_{re} dropped in some extent especially in Group α . Drop of T_{re} during exposure to 20°C for 60 min was smaller in Group γ than in Group α . In Group α , mean T_{re} became $32.5 \pm 0.4^\circ\text{C}$ at 30 min and $31.1 \pm 0.4^\circ\text{C}$ at 60 min after the exposure to 20°C . In Group γ , mean T_{re} was $35.6 \pm 0.3^\circ\text{C}$ at 30 min and $34.6 \pm 0.3^\circ\text{C}$ at 60 min after the exposure. Mean T_{re} of Group α was always lower than that of Group γ , and these differences are statistically significant ($p < 0.05$). As shown by open circles in the top of Fig. 2, in the control experiment with a spinal-intact rat, T_{re} was 38.1°C at the beginning of exposure to 20°C . This temperature was kept fairly constant with maximal change of 0.3°C during exposure to 20°C for 60 min. During

exposure to 20°C, dT , the excess temperature of the tail skin from T_a also decreased with lapse of time both in Group α and γ but differences between these values are not statistically significant. In the control experiment with a intact animal as shown in the bottom of Fig. 2 with open circles, mean dT measured at every 10 min for the first hour of the exposure was 0.7 ± 0.1 °C ($n=7$).

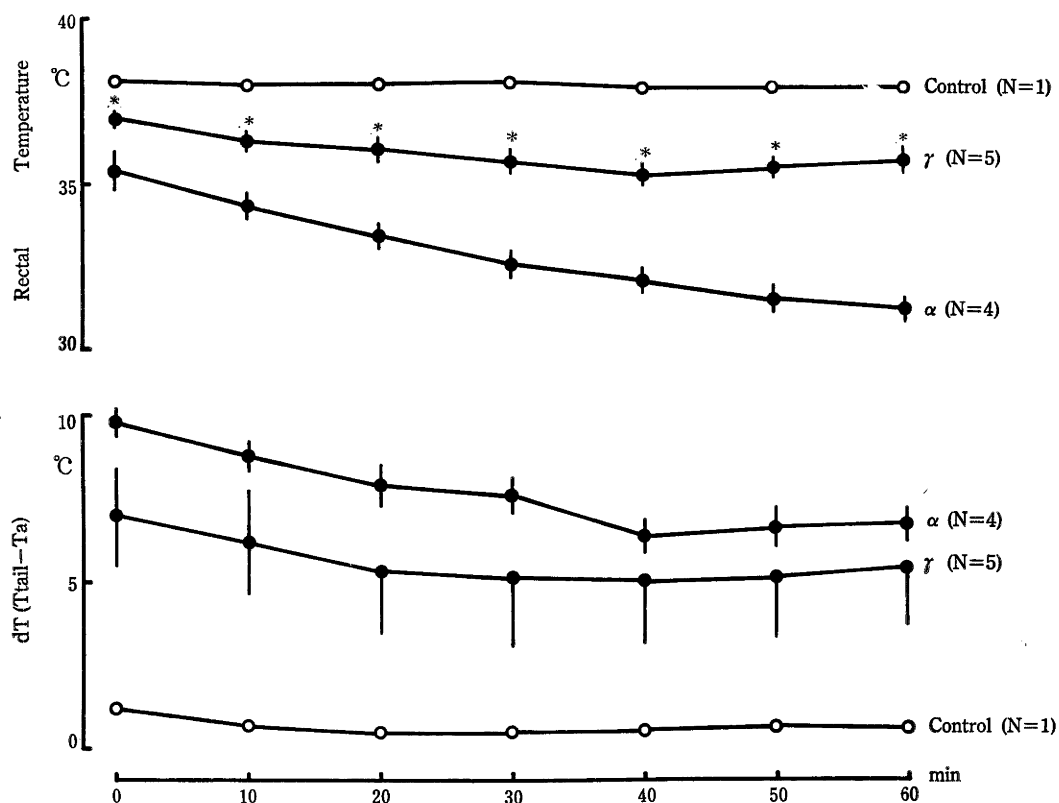


Fig. 2. Rectal temperature and excess temperature (dT) of the tail skin from the ambient temperature of a spinal-intact rat (open circles) and chronic spinal rats (solid circles) during exposure to 20°C (Mean \pm S. E.). Vertical bars are standard errors. Rats were adapted to 30°C previously. α : Records obtained from Group α , 2.8 ± 0.9 days after spinalization ($N=4$), γ : Records obtained from Group γ , 29.8 ± 1.5 days after spinalization ($N=5$). Asterisks (*) on plots indicate statistical significances ($p < 0.05$) between values in Group α and γ .

Exposure to various ambient temperatures between 25°C and 35°C

Tail vasomotor activity during sequential and reciprocal change of the ambient temperature was studied. Air temperature (ambient temperature, T_a) in the chamber was gradually increased and decreased at a constant rate between 25°C and 35°C. Fig. 3-A demonstrates changes in T_{re} , in T_{tail} , and in HR during change of T_a in case of a rat 3 days after spinalization. T_{re} fluctuated slightly along with the change of T_a . Change in T_{tail} during the change of T_a was relatively small. Therefore, dT , the excess temperature of tail skin from T_a was nearly zero at 35°C of T_a , and it was about 7.5°C at 25°C of

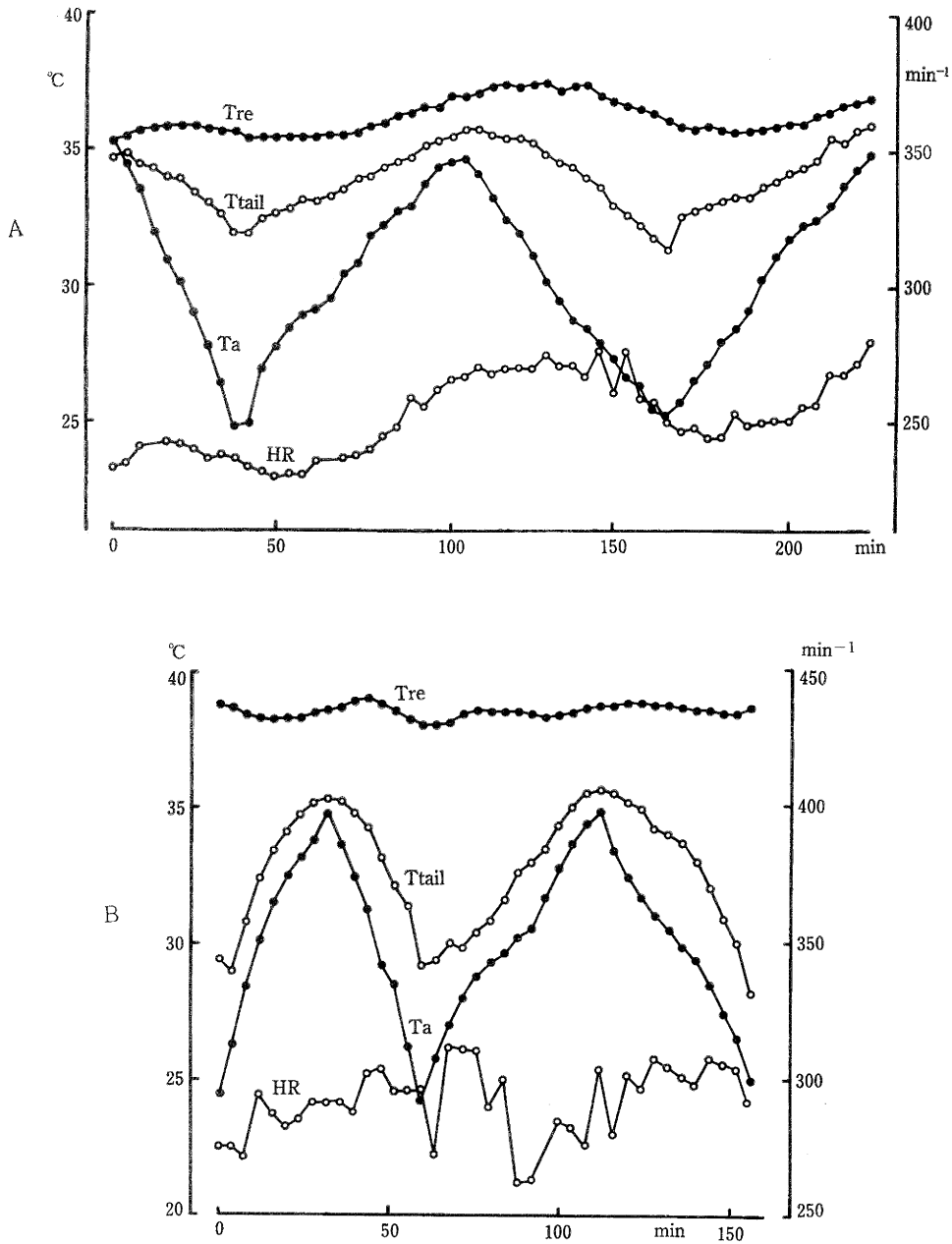


Fig. 3. Changes in rectal temperature (T_{re}), tail skin temperature (T_{tail}) and heart rate (HR) during sequential and reciprocal change of ambient temperature (T_a) ranging from 25°C to 35°C in chronic spinal rats. A: An example in a rat 3 days after spinalization, B: An example in a rat 30 days after spinalization.

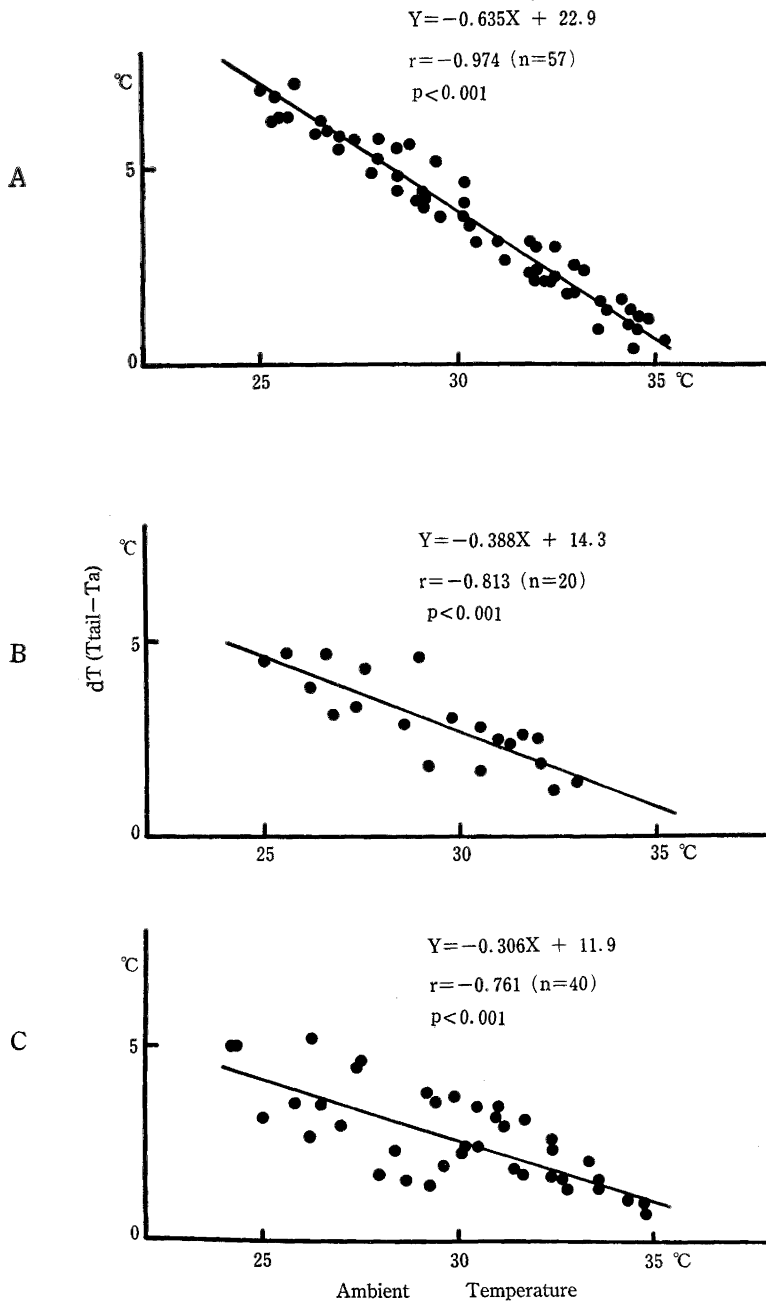


Fig. 4. Relationship between ambient temperature (T_a) and the excess temperature (dT) of the tail skin from T_a . A, B, and C are typical examples in different rats 3 days, 15 days and 30 days after spinalization, respectively.

Ta. On the other hand, in an example shown in Fig. 3-B obtained from a rat 30 days after spinalization, T_{tail} was 2°C to 5°C higher than and parallel to Ta. T_{re} was considerably stable during the change of Ta and in this case (Fig. 3-B) dT during the change of Ta was smaller than that in the rat 3 days after spinalization (Fig. 3-A).

dT is an important factor to evaluate the heat flow from the tail surface to the ambient air. dT evaluated numerically at every 4 or 5 min were plotted against Ta. In the range of Ta, 25–35°C, statistically significant ($p < 0.001$) negative correlation between dT and Ta was recognized always with few exceptions in Group α , β and γ . Typical examples are demonstrated in Fig. 4-A, B and C. As shown in the figures, slope of the regression line (regression coefficient of dT on Ta) in Fig. 4-A is steeper than those in Fig. 4-B and C. In three groups of rats, Group α (3.0±0.7 days after spinalization, N=9), β (15.6±0.9 days, N=7) and γ (31.2±2.8 days, N=6), values of dT during the change of Ta between 25°C and 35°C were compared systematically. Regression coefficient of dT on Ta

Table 1. Days after spinalization, number of experiment, regression coefficient of dT on Ta, corresponding values of dT to Ta of 25°C and 30°C, T_{re} during change of Ta, difference between maximal and minimal T_{re} and heart rate (HR) when ambient temperature was changed sequentially and reciprocally between 25°C and 35°C at a constant rate ranging of 0.1 to 0.3°C/min in three groups of rats, Group α (3.0±0.7 days after spinalization), β (15.6±0.9 days) and γ (31.2±2.8 days). Asterisks (*) indicate statistical significances ($p < 0.05$) tested by Mann-Whitney U test in comparison with values in Group α

Group	α	β	γ
Days after spinalization	3.0 ±0.7	15.6 ±0.9	31.2 ±2.8
Number of experiment	9	7	6
Regression line			
Regression coefficient of dT on Ta	-0.58 ±0.05	-0.38* ±0.05	-0.30* ±0.03
Corresponding value of dT to Ta (°C)			
when Ta=25°C	5.9 ±0.4	4.8* ±0.4	4.5* ±0.3
when Ta=30°C	3.0 ±0.3	2.9 ±0.2	3.0 ±0.2
Rectal temperature (°C)			
Mean	35.5 ±0.4	36.9* ±0.2	37.2* ±0.3
Difference between Max. and Min.	2.3 ±0.4	1.5 ±0.2	1.1* ±0.3
Heart rate (beats/min)	274 ±10 (N=5)	329 ±33 (N=3)	321 ±15 (N=3)

became smaller with an increase of days after spinalization. Mean regression coefficient was -0.58 ± 0.05 , -0.38 ± 0.05 , and -0.30 ± 0.03 in Group α , β and γ , respectively. Values in Group β and γ are smaller than those in α , these differences are statistically significant ($p < 0.05$). When T_a was 25°C , mean corresponding values of dT on each regression line were $5.9 \pm 0.4^\circ\text{C}$, $4.8 \pm 0.4^\circ\text{C}$ and $4.5 \pm 0.3^\circ\text{C}$ in Group α , β and γ , respectively. Values in the latter are significantly different ($p < 0.05$) from the former. And when T_a was 30°C , the values were $3.0 \pm 0.3^\circ\text{C}$, $2.9 \pm 0.2^\circ\text{C}$ and $3.0 \pm 0.2^\circ\text{C}$ in Group α , β and γ , respectively. The differences among them are not statistically significant. These data are summarized in the upper part of Table 1. Though the plots of dT against T_a were seen along the regression lines in Fig. 4-A, the plots are distributed around the line in Fig. 4-B and C. In case of rats in Group α , curves of T_{tail} were smooth and those of HR were stable at low level, but in Group β and γ , spontaneous fluctuations in curves of T_{tail} and HR were observed. These spontaneous change in T_{tail} and HR resulted in the inclination of the increase along the days after spinalization. Fig. 5 shows a typical example for the spontaneous fluctuation in curves of T_{tail} and HR in case of a rat 45 days after spinalization.

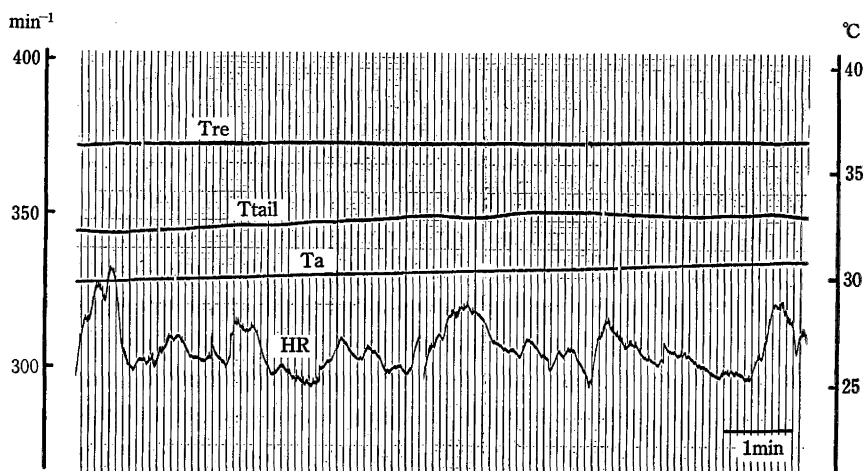


Fig. 5. Changes in rectal temperature (T_{re}), tail skin temperature (T_{tail}) and heart rate (HR) during change of ambient temperature (T_a) in an chronic spinal rat 45 days after spinalization.

In order to compare the stability of T_{re} during change of T_a between 25 – 30°C , difference between the maximal and minimal T_{re} was calculated in each case. Mean of the difference was $2.3 \pm 0.4^\circ\text{C}$, $1.5 \pm 0.2^\circ\text{C}$ and $1.1 \pm 0.3^\circ\text{C}$ in Group α , β and γ , respectively, the last value is significantly different from that in Group α ($p < 0.05$).

Mean heart rate during change of T_a was 274 ± 10 beats/min ($N=5$), 329 ± 33

beats/min (N=3) and 321 ± 15 beats/min (N=3) in Group α , β and γ , respectively. All data are summarized in Table 1. Asterisks indicate statistical significances ($p < 0.05$) in comparison with values obtained in Group α . Differences between values in Group β and γ are not statistically significant in any of the cases.

DISCUSSION

In this study on chronic spinal rats, with increase of days after spinalization, drop of T_{re} during exposure to 20°C became smaller, and T_{re} became stable at higher level during change of T_a . These results show that chronic spinal rats recovered their thermoregulatory ability as already reported. And skin temperature of the tail was measured during change of T_a . Excess temperature (dT) of the tail skin measured at thermoneutral ambient temperature, which is an important factor for heat loss from the tail, reduced gradually with an increase of days after spinalization, presumably due to decrease of blood flow in the tail.

It is well known that nearly naked tail of the rat is an important organ for temperature regulation. Rectal temperature was kept at higher level in rats whose tails were amputated than in intact ones during exposure to heat environment (Hainsworth, 1971; Spiers *et al.*, 1981). During heat stress, abrupt and simultaneous increases in the skin temperature, in blood flow and in heat flow of the rat tail were observed (Johansen, 1962, Grant, 1963; Rand *et al.*, 1965; Little and Stoner, 1968). According to Rand *et al.* (1965), even though the rat tail had only about 5% of the total surface area, it could dissipate 17% of the total heat loss, and blood flow through the tail rose from less than 5 ml to about 40ml/min \cdot 100ml tissue during the reflex vasodilation. The threshold temperature of ambient (Johansen, 1962, Rand *et al.*, 1965) and the threshold temperature of hypothalamus (Thompson and Stevenson, 1965; Little and Stoner, 1968; Young and Dawson, 1982) for occurrence of these reflex vasodilation were reported. On the other hand, Carlisle and Laudenslager (1979) observed that the threshold temperature of the preoptic hypothalamus for the tail vasodilation decreased with an increase of the ambient temperature. Because of the localized heat loss from the tail during the reflex vasodilation and of the distinct threshold for it, the rat tail would be a good model to study recovery of the thermoregulatory adjustment of the peripheral circulation and of the differential activity of spinal sympathetic nerves in chronic spinal animals.

Heat dissipation from the tail surface is expressed by the following equation: $H = R + C + E$, where H represents the heat loss from the tail, R, C, and E refer heat loss from the tail by radiation, conduction + convection and evaporation (Hart, 1971). The rat has no sweat glands except for foot pads (Ring and Randall, 1947). Although insensible evaporative heat loss from the rat tail was reported, it may not be significant in physiological range (Thorington, 1966). Because the tail was extended from the small cage

without contact with any structure in this experiment, the heat loss by conduction may be neglected. Therefore, C means only the heat loss by convection to the ambient air. Heat transfer by radiation depends on the difference between skin temperature of the tail and temperature of the surrounding wall which was almost the same as the air temperature in the chamber. Both R and C are functions of dT , respectively. Therefore, dT is the important factor to assess the heat loss from the tail. In this study, when T_a was 30°C , mean corresponding values of dT in Group α , β and γ had no significant difference. This explains that chronic spinal rats could maintain the core temperature at near 37°C in the room of 30°C as shown in Fig. 1. However, when T_a was 25°C , and the value of dT in Group α was larger than in Group β and γ which had been reared in chronic spinal condition for longer days after spinalization than Group α . Severer hypothermy during exposure to 20°C in Group α than in Group γ could be explained by this fact.

Raman *et al.* (1983) who studied heat flow of the rat tail of which skin temperature was kept at desired levels by immersing the tail into water in conscious condition. They stated from their experimental results, that when rectal temperature was 39°C , both heat flow from the tail to surrounding water and the tail blood flow increased with increase of tail temperature in the range from 15°C to 30°C (skin temperature in this case meant temperature of the water). This fact means that skin with high temperature dissipates much heat in this range.

Skin temperature positively correlates with blood flow, and it is a good indication for blood flow in a certain range of ambient temperature (Fetcher *et al.*, 1949; Aschoff, and Wever, 1957). During change of the ambient temperature between 25°C and 35°C in this experiment, the order of mean core temperature maintained was Group $\gamma > \beta > \alpha$, but that of dT at 25°C was Group $\alpha > \beta > \gamma$ (Table 1). From the above facts it is reasonable to suppose that tail blood flow and heat loss from the tail in the thermoneutral zone decreased with an increase of days after spinalization.

In the intact rats, as mentioned above, an intensive vasodilation of the tail was reported (Johansen, 1962; Grant, 1963; Rand *et al.*, 1965). In this experiment, spontaneous small fluctuations of T_{tail} were observed in chronic spinal rats, especially in Group γ (Fig. 5). Lin and Chai (1974) observed statistically significant increase of 1.2°C and decrease of 1.0°C in the tail subcutaneous temperature during the spinal cord heating and cooling, respectively, in chronic spinal rats. It remains to be solved whether the difference between these tail vasomotion of small magnitude in chronic spinal rats and intensive ones in the intact rats is quantitative or qualitative. Gradual decrease of tail blood flow during recovery process in the chronic spinal rats may be explained by the following two reasons: (1) re-arrangement of blood flow distribution due to change of sympathetic activity in the spinal level, (2) decrease of cardiac output (Page *et al.*, 1954).

The rat tail has a complex vascular bed, the caudal glomerulus, in which are abundant arteriovenous anastomoses, AVA (Gemell and Hales, 1977; Thorington, 1966) by

which blood flow through the tail is controlled effectively. Many studies support the sympathetic innervation of adrenergic vasoconstrictors on AVA (Folkow, 1955; Molyneux, 1977; Kondo, 1972; Hales *et al.*, 1978). Although active vasodilation was suggested in the tail of the rat (Johansen, 1962; Ebeigbe *et al.*, 1983), the reflex vasodilation responding to thermal stress are explained as the result of inhibition of the vasoconstrictor tone.

Thermoregulatory adjustment of peripheral blood flow evoked by spinal thermal stimulation was reported in chronic spinal dogs (Walther *et al.*, 1971b; Liu *et al.*, 1979), cats (Chambers *et al.*, 1974), rabbits (Walther *et al.* 1971a), and rats (Lin and Chai, 1974). Recovery of the tonic activity of sympathetic nerve was demonstrated in chronic spinal animals (Walther *et al.*, 1971a; Ardell *et al.*, 1982). Ardell *et al.* (1982) observed low discharge of the renal sympathetic nerve, low systemic blood pressure and no effect of ganglion blocker in 2 days after spinalization of cats. And in 19-14 days after spinalization they observed recoveries of the renal sympathetic nerve activity, of the blood pressure and of a depressive effect of the ganglion blocker. These results suggest gradual increase of participation of the sympathetic nerve activity for cardiovascular control in chronic spinal animals. The differential activity of the sympathetic nerves in the spinal level was demonstrated concerned with the relationship between sympathetic vasoconstrictor nerves innervating on the vessels in the ear skin and on the visceral vascular beds in chronic spinal rabbits (Walther *et al.*, 1971a) and with the relationship between the sudomotor and vasoconstrictor nerves in spinal cats (Jänig and Kümmel, 1981). Sustained vasodilation in the peripheries shortly after spinalization may be due to marked decrease of sympathetic nerve activity. Spontaneous fluctuation of the curve of Ttail which were observed in the recovering process of temperature regulation as shown in Fig. 5 is presumably due to change in the sympathetic nerve activity.

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慢性脊髄ラットの尾部皮膚温と環境温の関係

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慢性脊髄動物の尾部の放熱調節能の脊髄切断後の経時的变化を検討した。

ラットの頸髄下端をペントバルビタール麻酔下で切断し、その後室温 30°C で慢性脊髄ラットとして飼育した。体重は日々減少したが、直腸温 (Tre) は一ヶ月以上に亘り 37°C 附近に維持された。慢性脊髄ラットを無麻酔で 20°C に暴露して一時間後、直腸温は脊髄切断後約 3 日及び約 30 日の α 群, γ 群において各々 $31.1 \pm 0.4^\circ\text{C}$, $34.6 \pm 0.3^\circ\text{C}$ となり、体温調節能は γ 群に於いてより回復している事が示された。この二群に加え脊髄切断後約 15 日の β 群を加えた三群について、環境温を 25°C から 35°C の間を 0.1 から 0.3°C/min の定速度で往復変化させ、無麻酔脊髄ラットの直腸温 (Tre), 尾部皮膚温 (Ttail), 心拍数 (HR) 及び環境温 (Ta) を連続記録した。dT (=Ttail-Ta) は、この温度範囲で Ta に対し有意な相関関係を示し、dT の Ta に関する回帰係数は α , β , γ の各群について各々 -0.58 ± 0.05 , -0.38 ± 0.05 及び -0.30 ± 0.03 であり、Ta が 25°C の時の dT の値は $5.9 \pm 0.4^\circ\text{C}$, $4.8 \pm 0.4^\circ\text{C}$ 及び $4.5 \pm 0.3^\circ\text{C}$ であった。 β と γ 群の値は α 群の値に比し有意の差を示した。この事から室温 25°C に於ける尾部からの放熱は脊髄切断後日数を経るに従い減少している事が明らかになった。この原因として尾部血管床の末梢抵抗増加による血流分配の変化等が考えられる。