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Effects of General Heat Exposure on the Gastrointestinal Motility of Anesthetized Animals

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Abstract: There are many reports related to the disordered alimentary functions during severe heat stress, but its underlying mechanism is not fully clarified. In the present experiment, therefore, the effects of severe general heat exposure of 45°C on the gastric motility were investigated in anesthetized dog and rabbit. Gastric movement was recorded with the balloon method. A decrease in gastric motility with the rise of core temperature was observed during general heating, while an increase in the motility with the fall of core temperature was observed after the end of general heating. In the experiment with Magnus method, motility of isolated rabbit's jejunum was also affected by the change in temperature of Tyrode's solution in the bath. From these results, it is suggested that the gastrointestinal motility should be directly and/or indirectly affected by raised core temperature during general heat exposure.

Key words: gastrointestinal motility, hyperthermia, anesthetized animal, rectal temperature, general heat exposure.

INTRODUCTION

The disorder of the alimentary functions observed under a severe heat stress is the important problem for tropical inhabitants (Edholm *et al.*, 1962). By Cannon (1906) and Meyer and Carlson (1917), decreases both in appetite and in gastrointestinal motility were already pointed out in the febrile dog. There are many reports concerned with inhibitions of gastric motility and of gastric secretion in febrile state with pyrogen and in afebrile state with small doses of pyrogen (reviewed by Miert, 1980). On the other hand, Misiewicz *et al.* (1968) reported the inhibition of human gastric motility evoked by elavated body temperature during heat exposure. From the results, they suggested that raised body temperature might have specific effect on the gastrointestinal motility. In

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explanation of the alimentary disorder in the heat stress, it is reasonable to take account of the direct effect of raised body temperature on the gastrointestinal system including its controlling mechanism. Therefore, to clarify this point, the present study on the gastrointestinal motility in hyperthermia was designed both *in vivo* and *in vitro*.

MATERIALS AND METHOD

Adult male rabbits weighing between 2.5kg and 3.5kg and an adult male dog of 10kg were used. All three rabbits were anesthetized with 1g/kg urethane injected intraperitoneally, while a dog was anesthetized with 25mg/kg sodium pentobarbital injected intraveneously. When necessary, small supplementary doses were injected during the experiment. The trachea was cannulated and animal breathed spontaneously through out the experiment. Anesthetized animals were placed in a chamber of 250 liters of which temperature was regulated at range of 42°C–45°C for general heating and at a range of 20°C–25°C for recovering. For measuring the gastric movement, a balloon, made of a thin rubber membrane of 5 cm in length, was embedded in the pyloric part. The balloon was filled with water under the pressure of 20 to 25 cmH_2O and was connected to a pressure bottle partially filled with air. The pressure change in the air space of the bottle was detected with a pressure transducer (Nihon Koden, MPU-0.1). Mean heart rate was calculated with a heart rate counter by measuring R-R intervals in electrocardiogram recorded with conventional lead I. Respiratory rate was got by recording the shift of air temperature in the air way. The isolated jejunum of 1.5cm in length was suspended under 3 g tension along the longitudinal axis in the Tyrode's solution (NaCl 136.9, KCl 2.68, $CaCl_2$ 1.80, $NaHCO_3$ 11.9, NaH_2PO_4 0.42, $MgCl_2$ 1.05, Glucose 5.55 mM) bubbled with oxygen gas. The longitudinal contraction was detected by a strain gauge transducer (Nihon Koden, SB-1T). All parameters were recorded simultaneously on a paper running at a speed of 2.5cm per minute of UV oscillograph (Sanei-5L).

RESULTS

A) Experiments with a dog

In this experiment, the gastrointestinal motility was numerically evaluated by measuring the length of the mechanogram recorded in each 4 minutes. By measuring the length of mechanogram in a certain period, changes in the motilities due to changes both in amplitude and frequency of the rhythmic contraction could be evaluated. And relative motilities were expressed by percentages of those at the normal core temperature of the animal (in case of the dog, 38°C, and 39°C in the rabbits, Prosser, 1961). One anesthetized dog was exposed to hot air of about 45°C. As shown in Fig. 1-A, during heat exposure, rectal temperature increased from 39.5°C to 42°C at a rate of

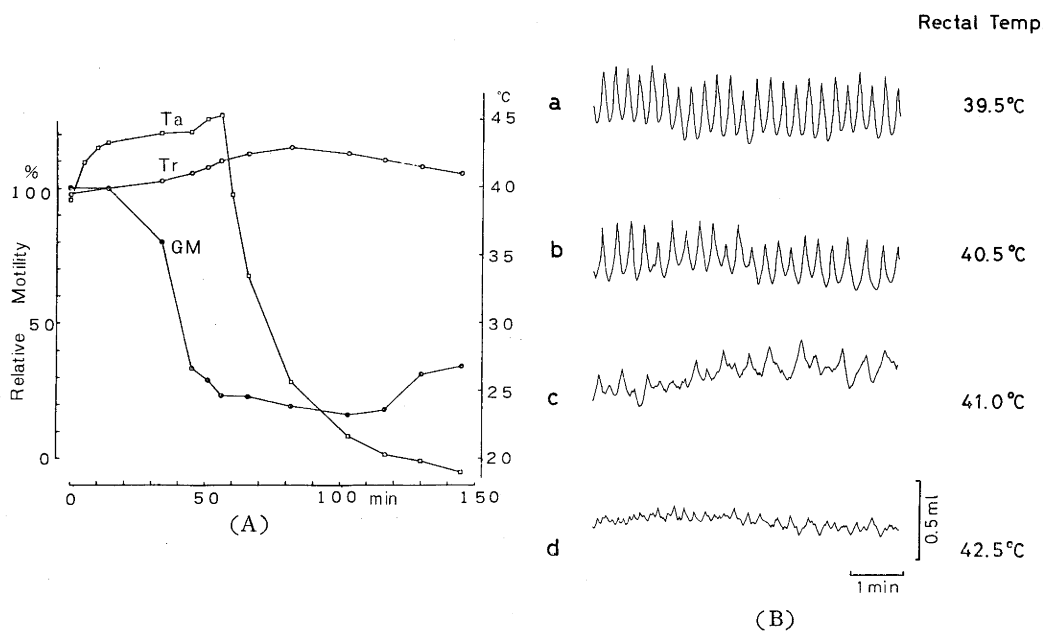

Fig. 1. Changes in gastric motility and rectal temperature when air temperature was changed from heat (42°C–45°C) to neutral (20°C–25°C) temperature in a dog (A), and peristaltic waves at various rectal temperatures during heat exposure (B). Abbreviations in figure are as following. Tr: rectal temperature, Ta: ambient air temperature, GM: gastric motility as relative value in comparison with the motility at 39.5°C of rectal temperature.

2.5°C per hour and then air temperature in the chamber was changed to neutral temperature of a range of 20°C–25°C. The rectal temperature still rose to 43°C after the end of heat exposure, and then it began to fall at a rate of 1.9°C per hour. The gastric motility decreased with the rise of rectal temperature during heat exposure. In comparison with the motility at 39.5°C of rectal temperature, relative motilities were evaluated as 100.4% at 40°C of rectal temperature, 80.2% at 40.5°C, 33.2% at 41.0°C, 29.4% at 41.5°C and 22.7% at 42.0°C, respectively. And an increase in the gastric motility with the fall of rectal temperature was observed during exposure to neutral air temperature. Relative gastric motilities were 15.9% at 42.5°C of rectal temperature, 17.4% at 42°C, 30.8% at 41.5°C and 33.5% at 41.0°C, respectively. Fig. 1-B demonstrates the gastric movements at various rising rectal temperatures in heat exposure. As shown in this figure, regular peristaltic waves were observed at 39.5°C and 40.5°C of small shift from the normal core temperature (Fig. 1-B, a and b), while irregular waves were observed at 41.0°C and 42.5°C of larger shift from the normal core temperature (Fig. 1-B, c and d). This inhibited motility was recovered with the fall of rectal temperature in the neutral air temperature.

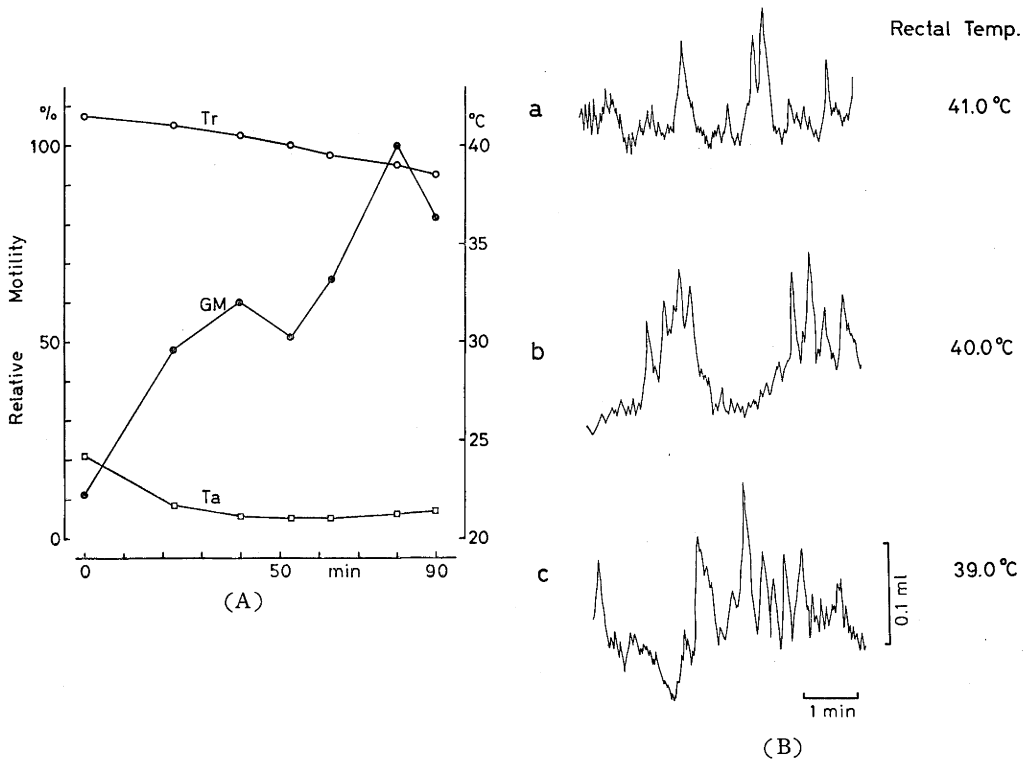

Fig. 2. In neutral air temperature, change in gastric motility and rectal temperature in a hyperthermic rabbits due to heat exposure (A), and gastric movements recorded at various rectal temperatures (B). Gastric motility was shown as relative values in comparison with the motility at 39°C of rectal temperature. Abbreviations; the same as shown in Fig. 1.

B) Experiments with rabbits

Three rabbits were exposed to hot air of 42°C −45°C and then to the neutral air of 20°C −25°C for recovery. During heat exposure the rectal temperature gradually increased at a mean rate of 3.2°C per hour (n=2), and during the recovery phase the rectal temperature decreased. As demonstrated in dog's experiment, the similar results of decrease in gastric motility with the rise of rectal temperature were observed in the experiment of rabbits. In comparison with the motility at 39.0°C of rectal temperature, mean relative gastric motilities during 4 minutes of two rabbits were 91.1% at 39.5°C of rectal temperature, 86.6% at 40.0°C, 89.3% at 40.5°C, 55.0% at 41.0°C and 54.6 % at 41.5°C, respectively. On the other hand, an increase in the gastric motility with the fall of rectal temperature was observed. As an example, changes in rectal temperature and gastric motility during recover phase from hyperthermic condition were demonstrated in Fig. 2-A. The mechanograms of gastric movement with various falling rectal temperature are shown in Fig. 2-B, where an increase in the gastric motility during recovery phase from hyperthermic condition is demonstrated. In this case relative mo-

tilities with various falling rectal temperature were 11.2% at 41.5°C of rectal temperature, 47.5% at 41.0°C, 60.3% at 40.5°C, 51.3% at 40.0°C and 65.5% at 39.5°C, respectively.

C) Experiments with the isolated rabbit's jejunum

In order to analyze the direct effect of temperature on the alimentary canal, change in the rhythmic contraction of the isolated rabbit's jejunum were investigated in the various temperatures in the organ bath. The temperatue in the organ bath was stepwise changed from 30°C to 44°C at the rate of 2°C/3 min. A typical example is demonstrated in Fig. 3, where a decrease in motility of the isolated jejunum was observed with the rise of temperature in the organ bath.

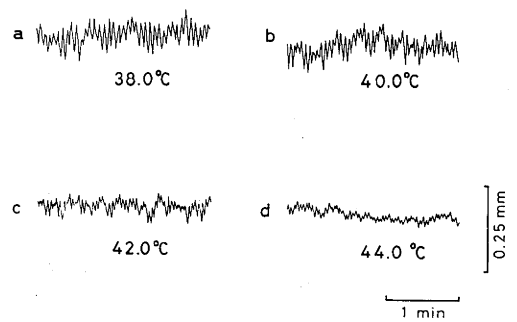

Fig. 3. Rhythmic contraction waves of the isolated rabbit's jejunum at various temperature of the bath solution.

In comparison with motility during one minute at 39.0°C of bath temperature, relative motilites were in this case, 100.7% at 38.0°C of bath temperature, 99.3% at 40.0°C, 67.1% at 42.0°C and 37.2% at 44.0°C, respectively.

DISCUSSION

When animals were exposed to severe heat air under anesthetic condition, a decrease in gastric motility with the rise of core temperature was observed and after the end of heat exposure, an increase in gastric motility with the fall of core temperature was observed. The decrease in gastric motility was correlated with the raised core temperature. If heat stress on the periphery, that is, skin or mucosa, is the most important factor which induces the change in the gastric motility (Freude and Ruhmann, 1926), its change might be expected at just beginning of air cooling in the dog experiment. But the motility started to increase after one hour from the end of heat exposure with adequate decrease in the rectal temperature. Under this experimental condition, therfore, it was suggested that peripheral thermoreception may not play an important role for this change in the gastric motility.

By exposure to hot environmental temperature, the decreases both in food intake (reviewed by Hamilton, 1967) and in gastric motility (Mayer and Sudsaneh, 1959) were reported. On the other hand, under normal environmental condition, spinal cord heating decreased both food intake (Spector and Cormarèche, 1971; Lin *et al.*, 1973) and gastrointestinal motility (Tsuchiya *et al.*, 1974). These facts suggest that pripheral and central warm signals may have inhibitory influences on feeding behaviour and gastrointestinal motility. These are the indirect effects of temperature on the gastrointestinal

control mechanism in the central nervous system. Furthermore, temperature may directly affect on the gastrointestinal control mechanism. It is well known that gastric function is inhibited in febrile state due to pyrogen injection. It was suggested from experiments with dogs and sheep that medulla oblongata and vagal nerves were essential for gastric inhibition during fever with pyrogen (Meyer and Carlson, 1917; Leek and Miert, 1971). It was reported that pyrogen of small doses induced the gastric inhibition without fever (Nechels *et al.*, 1942., Olson and Nechels, 1954). Therefore, it is interstring to compare the mechanisms concerned with the gastric inhibition under the hyperthermic condition with and without pyrogen.

In the experiment using the isolated rabbit's jejunum, the motility was affected by the temperature change of the organ bath. At the bath temperature equivalent to the range of severe hyperthemia, the decrease in the intestinal motility was observed. These facts suggest that hyperthermia may directly affect the movement of the alimentary canal.

Wood (1970) showed that spontaneous electrical activity of single neurons in Auerbach's plexus of the cat's jejunum was considerably resistant to hypoxia, but was very sensitive to temperature. This finding suggests the direct effect of temperature on the enteric neurons. Possible explanation of the gastrointestinal inhibition during hyperthermia could be proposed as follows; a) direct and indirect effects of temperature itself on the gastrointestinal control mechanism in the central nervous system, and b) direct effect of temperature on the organ, the alimentary canal itself.

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暑熱暴露による高体温の胃腸運動に及ぼす影響

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高温暴露時に食欲不振及び胃腸運動障害がおこる事が知られているがその機序は充分に明らかにされていない。そこで本研究では、麻酔したイヌ及びウサギを約45℃の高温暴露し，高体温に至る過程の胃運動の動態及び、ウサギ空腸片の収縮運動に対する浴液の温度の影響を検討した．
麻酔したイヌ及びウサギを高温暴露するとゴム球法で記録された胃運動は直腸温の上昇とともに減弱し，その後の中性温暴露による直腸温の下降とともに回復した．この直腸温変化にともなう胃運動の変化は可逆的であった．ウサギ摘出空腸片の律動収縮は高体温に相当する浴液の温度域において減弱した．
以上の結果から，高温暴露による高体温時の胃腸運動の抑制機序には，高体温の胃腸運動調節機構に対する間接的な作用と、胃腸管そのものへの直接作用が考えられる．

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