

## On the Changes of Blood Gas During Induced Hyperthermia in Dogs

Yuzuru HONDA, Natsuo HONDA  
and Shunsuke ODA

*Dept. of Anesthesiology, Medical College of Oita, Oita*

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The changes of blood gas during hyperthermia induced surface warming were investigated in adult mongrel dogs.

With body temperature elevation, for arterial and venous blood, both pH decreased rapidly beyond 42°C. And oxygen saturation of central venous blood showed remarkable decrease that suggested increase in oxygen uptake in tissues.

### INTRODUCTION

In the malignant hyperthermia, one of the severe complications in general anesthesia<sup>1)10)</sup>, in early stage, a considerably decrease in pH of blood gas is observed as one of its signs, and such decrease is said to be due to an increase in PCO<sub>2</sub> according to increased production of CO<sub>2</sub> in the skeletal muscle. It is also said that such increase in PCO<sub>2</sub> not seldom rises above 80 mmHg and yet precedes the increase in body temperature and that PaO<sub>2</sub> may give rise to an decrease at an early stage and PvO<sub>2</sub> in the central venous blood may also fall down.

Now, in the hyperthermic condition there naturally occurs hypermetabolism, so that it is natural that carbon dioxide production should increase and tachpnea should occur thereby. However, we doubt whether the increase in PCO<sub>2</sub> mentioned above may be so early, and this is why we suspect that such increase may occur either in case of the hyperthermotherapy for the treatment of cancers or in case of the heat stroke. Therefore, the following experiment was made for the purpose of studying how blood gas makes changes in course of the hyperthermia.

## METHOD

Twenty-two adult hybrid dogs weighing 4 to 12 kg were used, induced with Thiamylal (50 mg/kg) and kept on spontaneous respiration after endotracheal intubation.

Then, both inguinal regions were incised after infiltration anesthesia with 2% lidocain and arterial and central venous pressures were measured after respective, femoral arterial and venous cannulations, while with an increase in body temperature, blood samples were taken from these sites for the measurement of blood gases.

Hyperthermia in this case consisted of sinking the animal wrapped in vinyl sheet, to the chest in hot water of 39 to 40°C and bringing the water temperature to 45 to 46°C in 2 to 3 hours.

Body temperature was measured by fixing a probe PD-1 type on the epigastric skin surface, using the deep body temperature monitor apparatus made by Telmo.

During the experiment, arterial and central venous pressure, and ECG were monitored while respiratory rate, minute volume and oxygen uptake were measured.

Blood gases were measured in terms of the body temperature at the time drawn blood, using the ABL-2 made by Radiometer, Co., Ltd.

## RESULTS

1)  $PO_2$ : For the arterial blood,  $PO_2$  showed an increasing tendency with a rise in body temperature, but without statistically significant difference. Also for the central venous blood,  $PO_2$  showed an indication of slightly increasing, but not significantly.

2)  $PCO_2$ : For the arterial blood,  $PCO_2$  showed a gradually decreasing tendency with an increase in body temperature, but showed a slightly increasing tendency for the venous blood.

3) pH: For the arterial blood, pH showed some repetition of increasing and decreasing with an abrupt falling down, and also for the venous blood it showed a remarkable decreasing tendency beyond 42°C.

4) Oxygen saturation: As already reported together with the changes in the respiratory responses, arterial blood saturation had little change while central venous blood saturation decreased with an increase in body temperature and the difference of arterio-venous blood oxygen saturation proved to increase in parallel with an increase in body temperature.

## DISCUSSION

The above results proved to be different remarkably from the data on the malignant hyperthermia mentioned in the introduction. In comparison of our results with those reported in other similar studies, Frankel et al.<sup>2)</sup> showed from the results of measurement

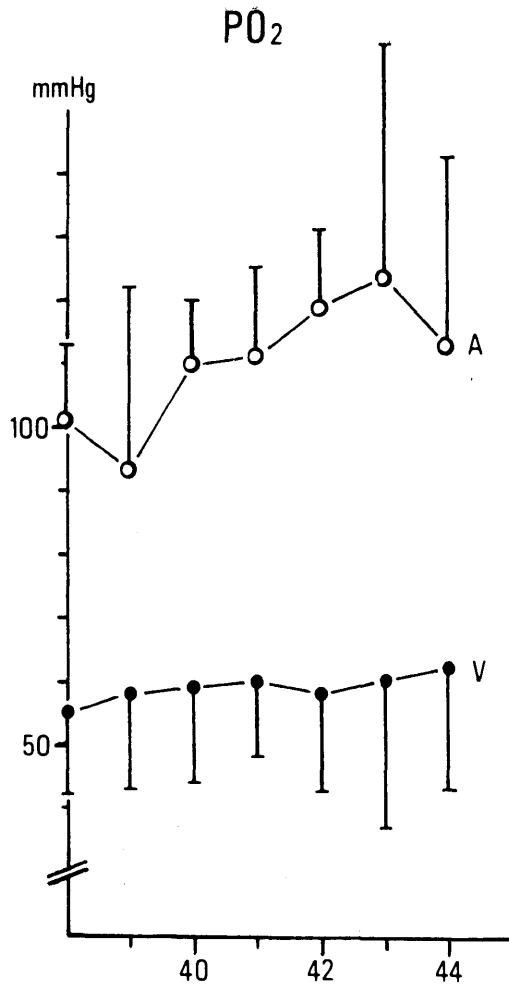


Fig. 1, Average  $PO_2$  at progressively elevated body temperature in dogs. Vertical bars on each mean value indicate standard deviations.

open circle : arterial blood  
closed circle : central venous blood

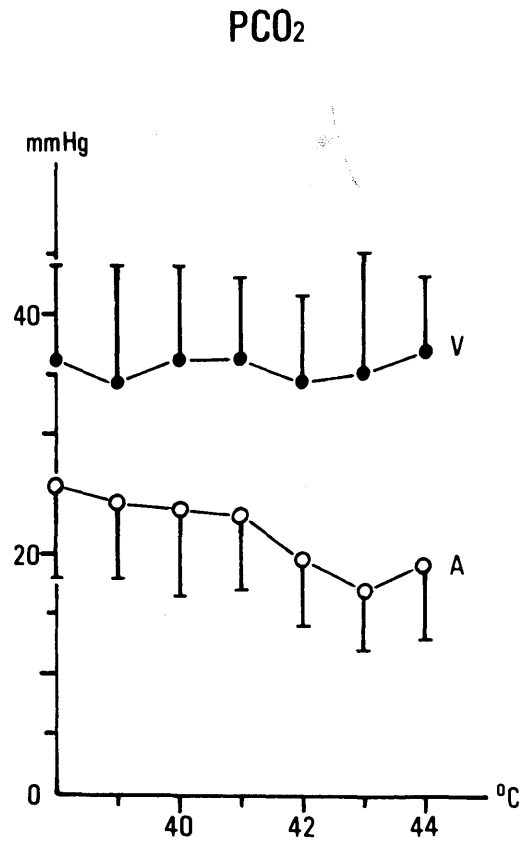


Fig. 2, Average  $PCO_2$  at progressively elevated body temperature in dogs.

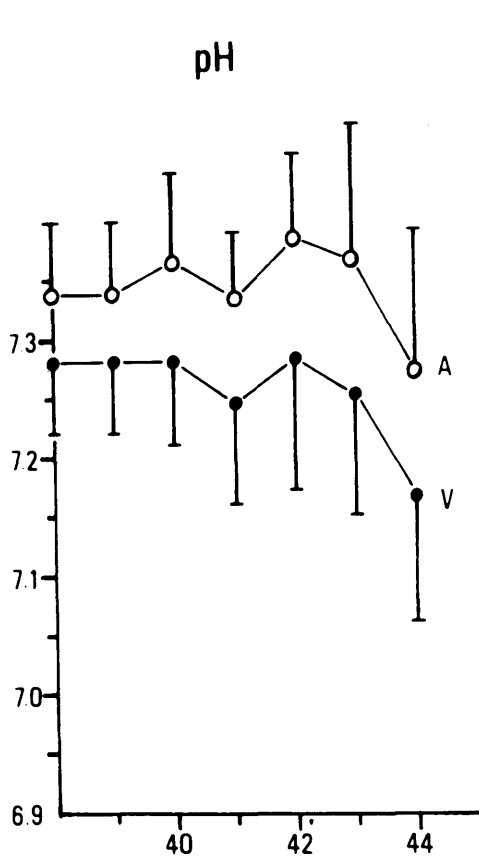


Fig. 3. Average pH at progressively elevated body temperature in dogs.

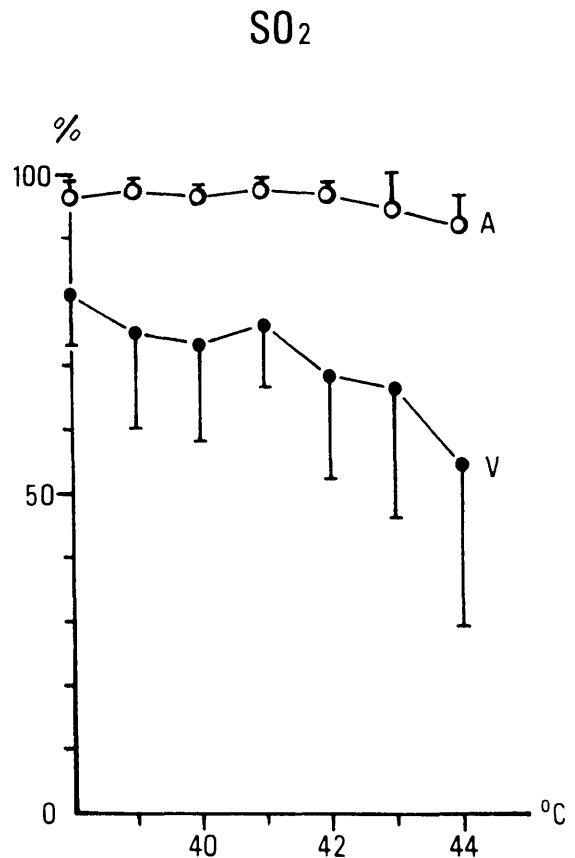


Fig. 4. Mean arterial (open circle) and central venous blood (closed circle) concentration of oxyhemoglobin saturation (Hb sat).

of the arterial blood in dogs that  $\text{PaO}_2$  increased with a rise in body temperature while  $\text{PaCO}_2$ , decreased with a slightly increasing tendency beyond  $42^\circ\text{C}$  and that  $\text{PaH}$  also increased till  $42^\circ\text{C}$  and decreased beyond this temperature, and oxygen saturation had little change. Nemoto et al.<sup>9)</sup> showed similar results.

Frankel and Cain<sup>3)</sup> reported in the measurement of blood gas in artery and superior sagittal sinus (SSS) blood that  $\text{PaO}_2$  showed an increasing tendency,  $\text{PaCO}_2$  decreased,  $\text{PaH}$  showed an increasing tendency till  $42^\circ\text{C}$  with a subsequent decrease, and saturation showed some increase, but with the same changes as so far reported. As for these authors, venous blood measurement was made of SSS, but  $\text{PO}_2$  and saturation had the same changes as ours. These authors reported also that the difference of arterial and venous blood saturations was 32 to 35 % between  $40.9$  and  $42.9^\circ\text{C}$ .  $\text{PCO}_2$  and pH had changes not always the same as ours, and this seems to be in relation with the fact that these authors made measurements in SSS, but not in central venous blood as we did.

Honda et al. made similar studies of 2,4-dinitrophenol (DNP)<sup>5)</sup> and metamphetamine,<sup>6),7)</sup> and the results in the present study were comparatively similar to the changes for DNP. These authors reported that rather the findings for metamphetamine were similar to those for malignant hyperthermia.

Therefore, from the results of the present study, it is possible that the findings of blood gas for the malignant hyperthermia are not due to the hyperthermia itself, but do involve other factors.

It is thought that amphetamine or metamphetamine has great influences on autonomic nervous system and also for malignant hyperthermia the autonomic involvement is related therewith, though not directly responsible thereof. However, Kim et al.<sup>8)</sup> observed an increase in catecholamine in course of the treatment of cancers with hyperthermia and the results from our body temperature elevation make presume an almost similar tendency. If so, either for this surface warming method or the malignant hyperthermia, it is thought that possible factors involved in blood gas include influences of other different elements, to say nothing of increased oxygen uptake due to hypermetabolism accompanying hyperthermia, increased production of CO<sub>2</sub>, changes in the respiratory system, increased catecholamine and so forth, all of which may give rise to different findings of blood gas.

Now, this kind of body temperature elevating method is clinically applied as one of the treatments of cancers;<sup>4)</sup> it is thought that with this method changes as observed in our experiment are possible also in human body with an increase in body temperature, in relation to the findings of blood gas.

Usually, body temperature elevation is performed under general anesthesia, indeed, but especially in case of the controlled respiration in hyperthermia, much attention should be paid to the metabolic acidosis or the hypoxia because of a remarkable hypermetabolism with accompanying increase in oxygen uptake, unlike in normal body temperature.

## CONCLUSION

For the purpose of studying the blood gas in hyperthermia, adult hybrid dogs were used, whose body temperature was risen from 38°C to over 45°C by a water-temperature increasing method, while the arterial blood and central venous blood were taken to examine for blood gases. The results obtained revealed that PaO<sub>2</sub> increased, PaCO<sub>2</sub> showed a decreasing tendency, and PaH and PvH showed a rapid decrease beyond 42°C and that oxygen saturation presented a remarkable decrease in central venous blood, suggestive of an increase in oxygen uptake in tissues.

These findings were differently remarkably from those of the malignant hyperthermia as observed under anesthesia, a fact which made presume not only some hyperthermic influences, but also an involvement of other different factors.

In case of applying this kind of body temperature increasing method to the treatment of cancers and others, adequate care must be taken of possible acidosis or hypoxia because of anticipated hypermetabolism or increase in oxygen uptake in tissues.

This study was presented at the 6th Asian Australasian Congress of Anesthesiologists.

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