Blood Respiratory Gases, Lactate, and Pyruvate during Thermal Stress in the Chicken* (32853)

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In mammals subjected to high body temperature, blood pCO_2 decreases and alkalosis appears. Both are factors which tend to decrease respiration. Nevertheless, respiratory ventilation of the hyperthermic animal is well above normothermic levels (1).

Birds are a class of homeotherms which have a different respiratory anatomy, but the effect of anatomical differences on respiratory exchange has not been defined. It is known, however, that minute volume increases in birds with increased body temperature (2). The present report will demonstrate in one species of bird that increased body temperature will cause changes in blood gases, pH, lactate, and pyruvate similar to those found in mammals.

Methods. Adult male white leghorn chickens (1.9–2.9 kg) were restrained and exposed to an environmental temperature of 40°C. The number of birds used for each measurement are indicated in Table I. Body temperature (*Tr*) was monitored with a thermistor placed approximately 10 cm into the cloaca. The *Tr* increased at the rate of approximately 2°C/hour. At normal *Tr* and at *Tr*'s of 43, 44, and 45°C blood samples were drawn from a cannula previously placed in the left carotid artery. All surgical procedures were carried out under local anesthesia.

Blood samples which were analyzed for lactate and pyruvate were drawn into 2-ml syringes, transferred directly to a centrifuge tube containing 2 ml of chilled 10% trichloroacetic acid (TCA), and mixed. The volume of blood was determined on the basis of weight increase assuming a specific density of 1.06 gm/ml for chicken blood. Lactate concentrations were determined by the method of Friedland and Dietrich (3). The method of Friedmann and Haugen (4) was used to determine pyruvate concentration.

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Samples drawn for blood gas and pH measurements were drawn into heparinized syringes and stored in an ice bath until analyzed, usually within 15 min. A Clark-type electrode was used to measure pO_2. A Severinghaus electrode was used for pCO_2. A Metrohm micro pH electrode was used to determine pH. The responses of the three electrode systems were recorded from a Beckman model 160 amplifier. All gases and pH determinations were carried out with the electrode cuvettes in a water bath kept at the temperature of the animal when the samples were drawn.

Results. The increase in minute volume at elevated *Tr* that has been reported previously (2) results in a ventilation rate in excess of that required to maintain CO_2 and O_2 at control levels (Table I).

Arterial pO_2 increased with increased *Tr*. At all temperatures there was evidence of an adequate arterial O_2 tension. Hypocapnia was found at increased *Tr* and could be associated with an increase in blood pH. Arterial blood lactate and pyruvate concentrations increased progressively with increased *Tr*.

Discussion. The panting and increased respiratory minute volume that has been found in hyperthermic chickens (2) involves an increase in alveolar-arterial blood gas exchange. A decrease in arterial blood CO_2 content and an increase in arterial blood pH have been reported in several classes of hyperthermic birds (5,6). Data in the present report support these findings. In addition, our data demonstrate that arterial blood pO_2 is normal or above normal as body temperature increased (7). It is reasonable to assume percentage O_2 saturation of arterial blood is not changed in the hyperthermic chicken. There are no data available for the effects of temperature on the oxyhemoglobin dissociation curve of chicken blood. On the basis of data available for mammals (8) an increase in temperature decreases the amount of oxyhemoglobin at any pO_2 (curve is shifted to the

TABLE I. Mean Arterial Blood pO_2, pCO_2, pH, Lactate, and Pyruvate Concentrations and Correlation Coefficients (R) for Lactate Versus Pyruvate in Chickens During Progressive Hyperthermia.

Body Temp. (°C)	pO_2 (mmHg)	pCO_2 (mmHg)	pH	Lactate (meq/liter)	Pyruvate (meq/liter)	R
41	92 ± 4[a] (6)[c]	26 ± 0.8 (6)	7.46 ± 0.02 (6)	1.96 ± 0.24 (16)	0.153 ± 0.010 (16)	0.68 (16)
43	103 ±11 (5)	—[b]	7.61 ± 0.02 (6)	3.20 ± 0.44 (15)	0.290 ± 0.028 (15)	0.63 (15)
44	111 ± 9 (5)	—	7.67 ± 0.03 (6)	3.74 ± 0.56 (14)	0.326 ± 0.020 (14)	0.29 (14)
45	114 ± 8 (5)	—	7.66 ± 0.03 (6)	4.20 ± 0.36 (16)	0.429 ± 0.035 (16)	0.47 (16)

[a] SE.

[b] —, pCO_2 was less than 15 mmHg.

[c] Figures in parentheses represent number chickens in experiment.

right). Increased pCO_2 also shifts the curve to the right (9). However, arterial pCO_2 decreases by more than 11 mmHg and pO_2 increases by an average of 22 mmHg over the temperature range studied. Both of these factors would increase the percentage saturation. At the very least, percentage saturation would be expected to remain close to normothermic values. The older view of Randall (10) that death of birds at high temperature was the result of acute anoxia is not supported by the arterial blood oxygen data.

At normal body temperature, decreasing the arterial blood CO_2 results in an increase in arterial blood lactate and pyruvate concentrations (hypocapnic lacticacidosis). This observation has been made in mammals (11) and in chickens (12). The increase in arterial blood lactate and pyruvate concentration observed in chickens as Tr increased may be due to the overventilation and the resulting hypocapnia observed rather than a direct effect of high temperature on pyruvate-lactate metabolism. In mammals hypocapnic lacticacidosis has been attributed to change in blood cell metabolism (13). The red blood cells of birds are nucleated and contribute directly to blood aerobic as well as anaerobic glycolysis (9). Increased lactic acid from increased tissue anaerobic glycolysis would not apper as great in well-oxygenated chicken blood because of the aerobic metabolism of the erythrocytes. Some other estimate of anaerobic glycolysis is needed to indicate the source of chicken energy metabolism under hyperthermic conditions.

Summary. Arterial blood pO_2, pCO_2, pH, lactate, and pyruvate concentrations were measured in chickens at normal body temperature and at temperatures of 43, 44, and 45°C. A decrease in pCO_2 and increases in the other components were observed. It was concluded that acute anoxia was not the cause of thermal death in chickens.

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Comparisons of Five Toxicity Parameters of *Serratia marcescens* Endotoxins* (32854)

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Interrelationships between the numerous endotoxic reactions have not been thoroughly investigated. Dissociation of lethality from Shwartzman reactivity in the rabbit has been demonstrated by the administration of large doses of cortisone prior to injection of endotoxin as reported by Thomas and Smith (1). It is generally believed, however, that different endotoxicity parameters are equivalent and may be used interchangeably as measurements of toxic potency. While this may be true for a few measurements under certain experimental conditions, great differences can be demonstrated in other instances, as observations in this laboratory have indicated.

Experiments aimed at investigating the relationship of structure to endotoxic activity have utilized chemically altered preparations. A variety of different biological properties have been measured and compared to the original potency of the preparations prior to chemical alteration of the structure with boron trifluoride, potassium methylate, or pyridinium formate. Differentiation between the biological properties of such preparations was established by diminishing or abolishing some toxic properties, including lethality in mice and rabbits, while maintaining other biological actions, such as stimulation of nonspecific resistance or the adjuvant effect (2). Using milder chemical procedures such as 0.1 *N* NaOH which resulted in partial loss of toxicity, it was observed that while some of the toxicity assays showed no alteration in degree of potency, other methods indicated complete inactivation. These observations initiated the experiments reported here. In these investigations, quantitative comparisons of the five most commonly used endotoxicity parameters were performed on preparations with different degrees of purity or chemical degradation.

Materials and Methods. Endotoxin preparations. A partially purified Boivin-type, trichloroacetic acid (TCA) extracted *Serratia marcescens* endotoxin (3) served as the original preparation which was further treated by different chemical means. A phenol–water purification of the original starting material was prepared according to the method of Westphal *et al.* (4). A type of chemically detoxified endotoxin (endotoxoid-4) was prepared by treating the Boivin-type TCA extracted endotoxin with 0.1 *N* NaOH at room temperature for varying periods of time, followed by neutralization with 0.1 *N* hydrochloric acid to pH 7.0 (5).

Assay methods. (a) The chick embryo (CE) lethality tests using the chorioallantoic membrane (CAM) route of inoculation were patterned after the method of Smith and Thomas (6). (b) The CE lethality tests employing an intravenous (iv) route of injection followed the procedure of Smith and Thomas (6), modified by Finkelstein (7). (c) Mouse lethality of each preparation was measured by injecting graded doses intraperitoneally into 18–20 gm random bred Swiss albino mice. Each dose level was injected into at least five mice at different dilutions and deaths were recorded 12–72 hours following injection. The calculation of median lethal dose (LD_{50}) was made by the method of Irwin and Cheeseman (8). (d) Shwartzman reactivity was carried out by intradermal injection into the shaved abdomen of New Zealand white rabbits

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