CHARACTERISTICS OF THE HOMEOSTATIC REACTION OF DOGS OF DIFFERENT AGES IN HYPOXIA

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From the past [17, 18] down to the present [8, 12] the resistance of animals of different ages to hypoxia has for the most part been evaluated only under conditions of absolutely lethal exposure.

Researchers [3, 4, 9-11, 13-15] have called attention to the fact that comparisons made for absolutely lethal exposures or doses under the action of hypoxic factors, pharmacological agents, or bacterial toxins cannot serve as reliable criteria of resistance. Thus, the workers of our laboratory have shown that under acute experimental conditions young puppies (16-18 days old) collapse and die at oxygen concentrations in the inhaled air sufficient for mature dogs to maintain marked homeostasis and survive.

In the present work we set ourselves the task of characterizing the resistance of dogs of different ages to hypoxia under so-called chronic observation (without anesthesia) rather than during vivisection, which complicates analysis. The criterion of this resistance was the ability to maintain homeostasis for a more or less prolonged period, as determined from the indices of cardiovascular, respiratory, and thermoregulatory activity.

EXPERIMENTAL METHOD

Our investigations were conducted in a pressure chamber at 23-24°. The animals were lightly restrained. Newborn puppies were wrapped in cotton. The appropriate sensors were fastened to the animal when it was placed in the pressure chamber; the sensor leads were passed through special apertures in the chamber wall, so as not to destroy the hermetic sealing, and connected to a recording apparatus. A lead-II EKG and the respiration curve were recorded on a two-channel oscillograph. The rectal temperature was registered with an electrothermometer. Cardiac activity, respiration, and temperature were recorded continuously for 15-30 min at the beginning of the ascent and then at 15 min intervals. Continuous visual observations were made of the change in cardiac activity, as displayed on an oscilloscope. Some of the animals were permitted to become accustomed to the pressure chamber over a period of several days before the experiment began.

We conducted two series of experiments on 80 dogs of different ages. In the first series the dogs were taken in stages to "altitudes" of 2000, 3000, 4000, and 6000 m, remaining at each level for from 30 min to 2 h. In the second series the animals were rapidly taken to higher "altitudes"—7000-10,000, and 16,000 m.

EXPERIMENTAL RESULTS

The data obtained enabled us to divide the animals under investigation into 3 groups by age. The 1st group comprised puppies up to 15-16 days old, the 2nd group included puppies from 18-20 days to 2-3 months old, and the 3 rd group comprised puppies more than 3 months old and mature dogs. The animals of the 3rd group, in which cardiac activity is regulated primarily by vagal innervation, responded to stepwise ascents to "altitudes" of 2000, 3000, 4000, and 6000 m with a homeostatic reaction divided into two phases, bradycardic and tachycardic.

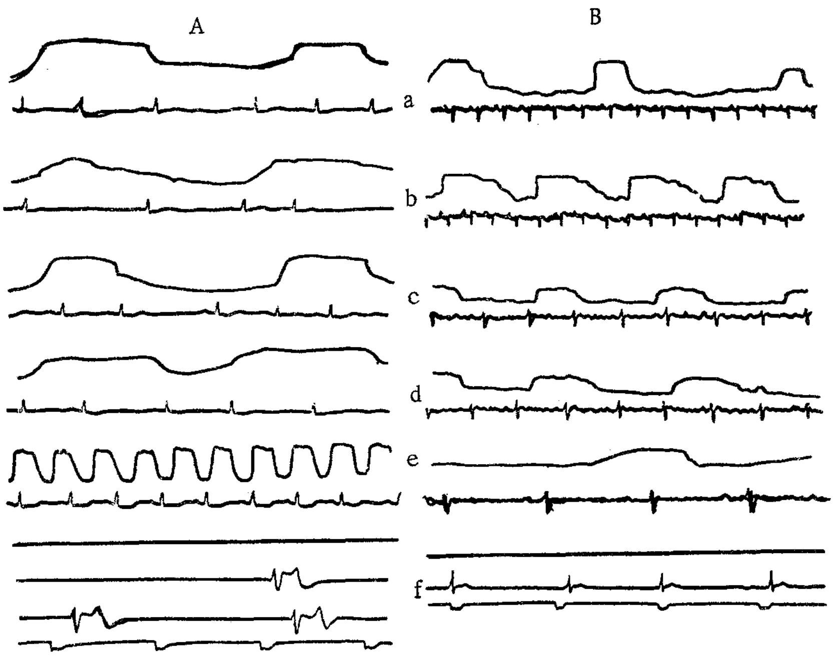

Fig. 1. Respiration curve and EKG of a mature dog (A) and a 5-day-old puppy (B) during stepwise ascent to 2000, 3000, 6000, 10,000, and 12,000 m. A: a) Initial rhythm; b) after 1 h at 2000 m; c) after 1 h at 3000 m; d) after 4 h at 6000 m; e) after 30 min at 10,000 m; f) after 5 min at 12,000 m. B: a) Initial rhythm; b) after 1 h at 2000 m; c) after 1 h at 6000 m; d) after 2 h at 6000 m; e and f) after 3 and 3.5 h at 6000 m.

Figure 1A shows the initial respiration and EKG background (a) for a mature dog. The first phase took the form of maintenance of the initial heart rate (70-90 beats per min) or retardation of the heart rate to 60-50 beats per min (b). In the majority of the experiments respiration was slightly accelerated, from 18-20 breaths per min to 25-30 per min. Body temperature remained almost unchanged. The bradycardic phase was more marked in the dogs preliminarily acclimated to the pressure-chamber setup. During the gradual stepwise ascent to 6000 m the bradycardic phase lasted 4-6 h or longer in the dogs of the 3rd group (c, d). A tachycardic phase set in during the subsequent ascent to 10,000 m: the respiration and heart rates were severely accelerated (e). During the ascent to 12,000-13,000 m the dogs underwent rapid (over 8-10 min) collapse, which took the form of respiratory arrest and reversible cardiac arrest (syncope) followed by the appearance of an atrioventricular rhythm (f, g). Before the dogs died their cardiac activity passed into an automatic rhythm. When mature dogs were taken directly to an "altitude" of 12,000 m the time for which they were able to maintain their homeostatic reaction decreased; collapse was more rapid than during stepwise ascent. Any stay at 12,000-13,000 m was lethal for the dogs of the 3rd age group.

The homeostatic reaction of young puppies (from 1 to 15-16 days old), in which the tonus of vagal innervation has not yet appeared and cardiac activity is regulated by sympathetic innervation [14-17], to hypoxia created by reduced atmospheric pressure differs sharply from that of mature dogs. During a stepwise ascent to "altitudes" of 2000, 3000, and 4000 m under the same conditions such puppies develop only the tachycardic phase. Figure 1B shows a typical experiment on 5-day-old puppy. An acceleration of the heart and respiration rates may be seen in segment b. There was no initial bradycardic phase. According to the indices of cardiac and respiratory activity the young puppies were capable of maintaining homeostasis for 2-3 h during stepwise ascents to "altitudes" of 2000, 3000, and 4000 m. Their body temperature dropped long before the cardiovascular and respiratory indices showed homeostasis to be disrupted. This decrease began after 3-10 min of the ascent, being slight (0.5-1°) at first and then sharper (2-3°) for 2-3 h. During the further ascent to 6000 m the puppies of the 1st age group underwent protracted collapse 2-3 h after the beginning of experiment. There was a gradual decrease in the heart and respiration rates (c, d, e). Respiration stopped before cardiac activity ceased (f). A progressive drop in temperature to 29-28° was observed during collapse. Collapse lasted 2-4 h during the stepwise ascent. When young puppies were rapidly taken to "altitudes" of 5000-8000 m the duration of the homeostatic reaction decreased and collapse set in after 1-2 h. The temperature of these animals decreased more sharply.

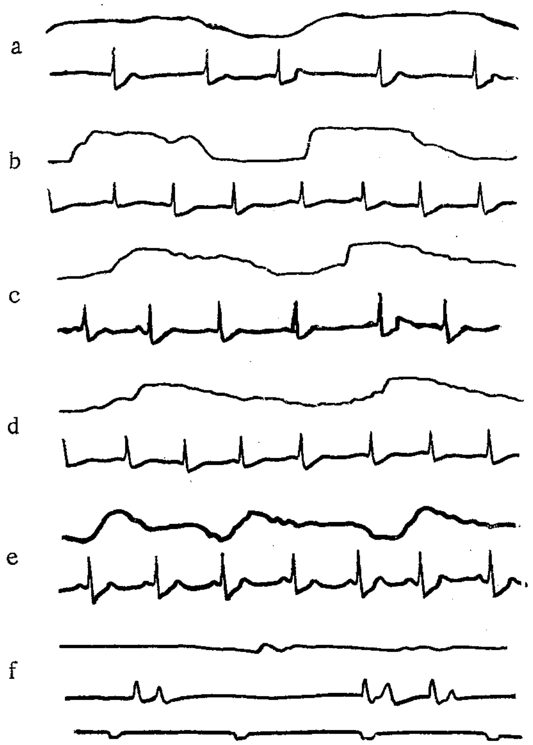

Fig. 2. Respiration curve and EKG for a 2-month-old puppy during stepwise ascent to 2000, 3000, 6000, 10,000, and 12,000 m. a) Initial rhythm; b) after 1 h at 2000 m; c) after 1 h at 3000 m; d) after 2 h at 6000 m; e) after 30 min at 10,000 m; f) after 20 min at 12,000 m.

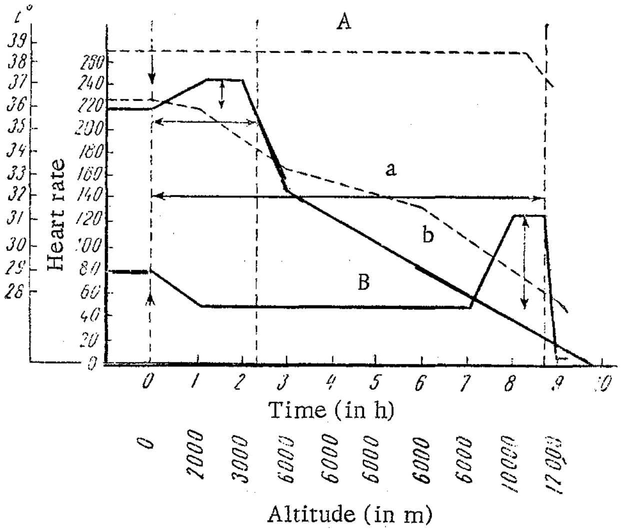

Fig. 3. Schematic representation of changes in body temperature (A) and cardiac activity (B) in mature dogs and young puppies (a and b respectively) during stepwise ascent to 2000, 3000, 6000, 10,000, and 12,000 m. The arrows indicate the beginning of ascent, the vertical line bounded by arrows represents the range of the adaptive reaction, and the horizontal line bounded by arrows indicates the range of resistance. 1) Heart rate; 2) time (in h); 3) altitude (in m).

There was no homeostatic reaction during direct ascent to 10,000 m. The puppies rapidly underwent protracted collapse, while the mature dogs were able to maintain homeostasis for 1-1.5 h at this "altitude". It is important to note that in the puppies of the 1st group the protracted collapse failed to be manifested in symptoms such as syncope and transition to an atrioventricular rhythm. During prolonged exposure complete cessation automatic cardiac functioning may occur in young puppies at an altitude of 12,000-13,000 m. In addition, protracted collapse may occur in such animals during ascents to 16,000 m. On the basis of the data obtained in our laboratory [3, 4, 9-11] we may assume that with sufficiently long exposure young puppies may die of protracted collapse during ascents to an "altitude" (less than 10,000 m) not lethal for mature dogs.

Just as in the puppies of the 1st group, there was no bradycardic phase in the puppies of the 2nd group during stepwise ascents to "altitudes" of 2000, 3000, and 5000 m, despite the appearance of the first signs of tonus in the vagal-innervation center. The homeostatic reaction took the form of an acceleration of the respiration and heart rates. During ascents to 2000-5000 m this reaction lasted 3-4 h, i. e., considerably longer than in the puppies of the 1st group. Body temperature began to decrease later (after 45-30 min) and dropped less sharply (by 0.8-1° at first and by 1-2° over the next 2-3 h) than in the animals of the 1st group. Collapse developed during the ascent to 12,000 m. Syncope appeared, although it was briefer than in the adult dogs, and was followed by transition to an atrioventricular rhythm. This reaction coincided with respiratory syncope. The collapse lasted 30-45 min. Figure 2 shows the typical reaction for puppies of the 2nd age group. Thus, although the homeostatic reaction of the puppies of this group was similar to that of the animals of the 1st group (no bradycardic phase), it lasted longer. The reaction of the puppies of the 2nd group was similar to that of the mature dogs with respect to the character of the collapse. At the same time, the latter lasted longer in these animals than in the adult dogs. The lethal "altitude" for the puppies of the 2nd group was 12,000-14,000 m.

Figure 3 is a schematic representation of the homeostatic reaction to reduced atmospheric pressure in young puppies and mature dogs during gradual stepwise ascents to "altitudes" of 2000, 3000, 6000, 10,000, and 12,000 m. The mature dogs maintained their homeostasis for an extended period, primarily because of the prolonged bradycardic phase, which was characterized as anabolic in our laboratory [5, 16]; this phase ended only on collapse. Under the same hypoxic conditions the young puppies maintained homeostasis for a considerably shorter period. In this connection we must conclude that these animals are substantially less resistant to reduced atmospheric pressure than mature dogs. This is explained by the absence of a bradycardic (anabolic) phase. The range of the tachycardic reaction is small as a result of the high initial activity of the cardiovascular, respiratory, and other systems.

Previous works [13, 14] showed the necessity of differentiating the concept of resistance from those of sensitivity and endurance. In the present work we devoted our principal attention to determining resistance to hypoxia as a function of age from the time for which homeostasis is maintained. At the same time, the results of our investigations have for the most part been confirmed by the data of other authors [1, 2, 3, 5], which indicate that the decrease in atmospheric pressure required for protracted collapse or prolonged survival may be greater for young puppies than for mature dogs. The difference in lethal "altitude" and exposure as a function of age must be attributed to a difference in endurance.

The resistance range within which the organism can maintain homeostasis under reduced atmospheric pressure has not yet been determined as a function of age, although this index is of greater importance than determination of the limits of survival for animals of different ages.

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