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SECTION MEETINGS

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Some Effects of Hypothermia on the Cardiovascular System and ECG of Cats.* (28812)

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Hypothermia is used clinically as an adjunct to surgery, most frequently in procedures requiring a bloodless field. The myocardium is exposed to new hazards under hypothermic conditions, particularly an increased incidence of ventricular fibrillation. Covino and D'Amato(1) have reported that below 25°C the cardiac conduction velocity decreases without a proportional increase in the refractory period, thus leading to an increased incidence of ventricular fibrillation. If, however, the length of the conduction pathway (size of the heart) is short, the above hypothermic effect will be obviated. For this reason, a species of smaller size (cats) was chosen as the experimental animal and this report deals with the effects of hypothermia on the cardiovascular system of these animals.

Materials and methods. Twenty adult cats were anesthetized with sodium pentobarbital (30 mg/kg intraperitoneal) and placed in a supine position on an animal board. The body weights of these cats averaged 3.4 kg (2.5-4.5 kg). Hypothermia was accomplished by packing chipped ice around the trunk of the animal. Body temperature was measured with a thermistor placed in the esophagus at the level of the heart. Respirations were spontaneous and unassisted although a tracheotomy was performed. A femoral artery was exposed and cannulated to record the blood pressure (Statham pressure transducer). The standard Lead II electrocardiogram was recorded from needle electrodes inserted subcutaneously in

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A portion of the experimental data was collected while the author was an Instructor in the Dept. of Physiology, Boston Univ. School of Med., Boston, Mass.

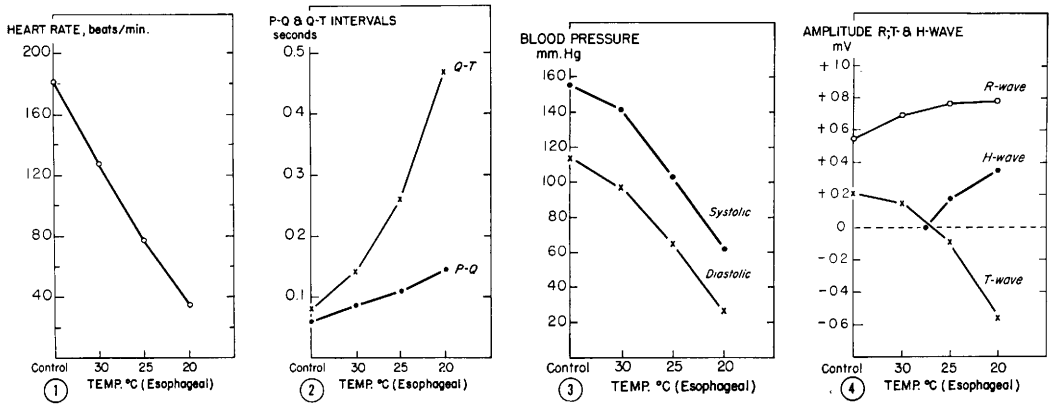

FIG. 1. Effect of hypothermia on heart rate. Average of 20 adult cats.
FIG. 2. Effect of hypothermia on P-Q and Q-T intervals of cardiac cycle. Average of 20 adult cats.
FIG. 3. Effect of hypothermia on blood pressure. Average of 20 adult cats.
FIG. 4. Effect of hypothermia on amplitude of R-, H-, and T-waves of ECG (Lead II). Negative values indicate an inverted wave. Average of 20 adult cats.

each limb. The animals were cooled until asystole or irreversible ventricular fibrillation intervened. No attempt was made to rewarm the animal, nor to defibrillate either with drugs or electroshock.

Results. Fourteen of the animals showed a highly irregular cardiac rhythm prior to death (Table I). This was in the form of numerous ectopic ventricular contractions or bouts of actual ventricular fibrillation. Only 3 of the cats showing an irregular rhythm terminated with irreversible fibrillation, each of the other animals spontaneously reverted back to a normal rhythm. Asystole was the cause of death in 65% of the animals.

The heart rate decreased linearly as shown in Fig. 1. If this line is extrapolated to its intercept with the abscissa, the point of interception is 17.5°C. This closely agrees with the average measured terminal temperature of 17.9°C (Table I). The slower heart rate was due primarily to an increase in Q-T interval of the cardiac cycle (Fig. 2). There also occurred a simultaneous, linear increase in P-Q interval, but not to the extent observed in the Q-T interval. However, statistical comparison indicated all points were significantly greater than control values in Fig. 2.

The blood pressure also showed a continuous decrease (Fig. 3), but not linearly as did the heart rate. Both systolic and the diastolic pressures at 30°C were not significantly different from control values.

There was no significant change in the amplitude of the depolarization (R) wave (Fig. 4). In each case the T-wave was upright in the control records of Lead II, but later became inverted. The amplitude of the inverted T-wave is indicated by the negative values in Fig. 4. Also evident in each animal was the appearance of the hypothermic (H)

TABLE I. Summary of Events at Termination of Experiment.

Animal No.	Pre-terminal events	Cause of death	Terminal temp, °C (esoph)*	Time of exposure (min)
1	ES†	Fibrillation	21.0	138
2	PF‡	Asystole	13.8	283
3	NR§	Fibrillation	18.5	255
4	NR	"	20.4	194
5	NR	Asystole	16.6	240
6	NR	Fibrillation	23.9	125
7	PF	Asystole	18.1	243
8	PF	"	15.3	370
9	NR	"	24.3	150
10	NR	Fibrillation	23.3	180
11	ES	Asystole	15.1	235
12	PF	"	18.1	205
13	PF	Fibrillation	20.4	185
14	PF	Asystole	15.8	305
15	PF	"	16.1	205
16	PF	"	17.4	205
17	PF	Fibrillation	15.3	355
18	PF	Asystole	15.4	395
19	PF	"	14.9	315
20	PF	"	13.9	385
Avg			17.9	248

* Esophageal.
† ES = Extrasystole.
‡ PF = Periodic fibrillation.
§ NR = Normal rhythm.

wave, first appearing at an average temperature of 27.7°C. This was the same temperature at which the T-wave became inverted.

Discussion. The refractory period of cardiac tissue is normally of such duration as to preclude reentry of an action potential into a cell. However, hypothermia causes a reduced conduction velocity, hence it is possible for the refractory period of some cells to be completed before the entire heart has become depolarized and, thus, reentry may occur and lead to fibrillation(1). With hearts of small size, even though conduction velocity be reduced, the distance traveled is short. Therefore the refractory period is sufficient to disallow reentry and thus decrease the incidence of fibrillation. The present investigation confirmed this hypothesis for the most frequent cause of death in cats was asystole and not ventricular fibrillation as is usually the case in larger animals such as dogs(2). Prior to death of the animal various cardiac arrhythmias did occur in many instances, but these were transient in nature and normal rhythms spontaneously reappeared. These arrhythmias all occurred at body temperature below 25°C.

The ratio of heart weight (g)/body weight (kg) has been found to be 7.5 for dogs and 4.5 for cats(3). No comparison has been found in the literature of the actual length of the conduction pathway of these two species of animals. However, this can be inferred from the QRS duration of the ECG which is the time of ventricular depolarization(4). The mean QRS duration in the present report was 21 msec and has been reported by others as 20 msec for cats(5) and 50 msec for dogs (6).

Blasius *et al*(7) have reported the effects of hypothermia on the ECG of dogs and found a linear increase of the P-Q interval and an exponential increase of the S-T interval. This agrees with the above results on cats. However, they found the heart rate to decrease in an exponential manner as opposed to the linear decrease found in cats.

The fact the R-wave did not change significantly is thought to be due to the dependence of depolarization on physicochemical events, whereas repolarization (T-wave) is linked with chemical events and therefore more temperature dependent.

The maintenance of blood pressure in the early portion of the experiment, in the face of a decreasing heart rate, is probably due to a general peripheral vasoconstriction. This would occur with this method of cooling the animal, the peripheral tissue becoming cold more rapidly than the internal organs.

Osborn(8), one of the first to describe the H-wave (also called the "Osborn wave"), said this phenomenon heralded the onset of fibrillation. While the exact cause(s) and significance of this wave are not known, it is not always followed by ventricular fibrillation. The H-wave appeared in each animal of this series of experiments, yet most of the cats terminated in asystole. The observation of the inversion of the T-wave at the same temperature as the first appearance of the H-wave has not been previously reported. The significance of this relationship is not known. It has been reported that the magnitude of the H-wave and the temperature of its appearance may vary with the particular lead system used(9).

Summary. Adult cats were cooled by packing in ice until cardiac failure occurred. Asystole was the most frequent cause of death. The decreased heart rate observed under hypothermia was primarily due to a lengthening of the Q-T interval. Systolic and diastolic blood pressure decreased when body temperature reached 30°C. There was no change in amplitude of the R-wave of the ECG. The T-wave was upright in the control record and became inverted as cooling progressed. The temperature of the first appearance of the H-wave, which was present in each experiment, coincided with the temperature at which the T-wave became inverted.

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Hemodynamic Effects of Renal Transplants in Hypertensive and Control Rats.* (28813)

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From several types of studies it appears that transplantation of a normal kidney reduces arterial pressure in a hypersentitive recipient. In dogs made hypertensive by bilateral nephrectomy and a diet rich in protein and salt, kidney transplants were able to decrease arterial pressure in less than 24 hours, without a decrease in the fluid compartment(1). In 3 patients with renal hypertensive disease, kidney homotransplants from normal twins produced a decrease in arterial pressure. This occurred even when the diseased kidneys were left in place(2). In the rat with arterial hypertension developed by DCA treatment and in the renal hypertensive rat, transplantation of a normal kidney lowered the arterial pressure to normal levels within about a half hour(3).

This report concerns the hemodynamic change responsible for the decrease in arterial pressure produced by a normal kidney transplant in a hypertensive rat. Experiments were done in which we measured the changes in arterial pressure, cardiac output, and resistance in a vascular bed in normotensive and renal hypertensive rats before and after transplantation of a normal kidney.

Methods. Twenty-five male Sprague-Dawley rats weighing between 250 and 410 g were used. Fourteen were made hypertensive by placing a figure-of-8 ligature on one kidney and one week later removing the remaining kidney. In the control animals only the unilateral nephrectomy was performed. Arterial pressure was measured at intervals using the tail microphone method(4). Four weeks following application of the ligature the animals were hypertensive.

From 7 to 9 weeks after the figure-of-8 ligature was placed on the kidney, changes in hind limb resistance and cardiac output caused by transplantation of a normal kidney were studied. Details of the methods are summarized in the legends of Fig. 1 and 2. In 6 hypertensive and 6 control rats the resistance in the hind limb perfused with autogenous blood at a constant rate of 1.5 ml/min was observed. In 8 hypertensive and 5 control animals cardiac output was measured with the thermodilution indicator method. The animals were anesthetized with sodium pentobarbital (40 mg/kg, i.p.), tracheotomized heparinized (10 mg/kg, i.v.). Systemic arterial pressure during the experiment was monitored by a centrally directed cannula in the femoral artery. All the parameters were recorded on a Grass polygraph.

The technique for kidney transplant has been described(3). Coagulation of the blood in the renal vascular tree was avoided by replacing blood with a heparin solution in saline. The ischemic period of the kidney never exceeded 20 minutes. The transplantation procedure caused an immediate random variation in arterial pressure; hence, the 5- to 10-minute period required for this procedure was excluded from the data presented here.

Experimental observations were made as follows: after control period, A, lasting 10-30 minutes, the normal kidney from a donor rat was transplanted to the recipient's femoral

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