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THE STOP-HEAT-FLOW TECHNIQUE FOR ORGAN TEMPERATURES, (U)  
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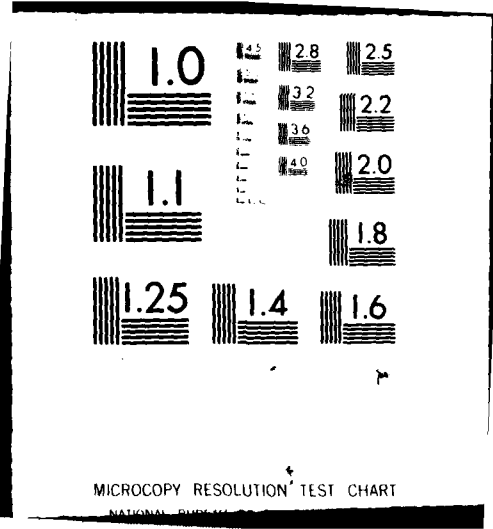
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THE STOP-HEAT-FLOW TECHNIQUE FOR ORGAN TEMPERATURES

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## THE STOP-HEAT-FLOW TECHNIQUE FOR ORGAN TEMPERATURES

We found the need of taking body organ temperatures of small animals after three types of research experiences: 1) It is sometimes necessary to obtain core temperatures of hyperactive free-living small animals such as weasels (Folk et al. 1977). One cannot restrain the animal and obtain a normal rectal temperature because the reading rapidly rises. For example Kendeigh (1945) held a deermouse containing a rectal thermocouple and the body temperature increased over the starting value by 2.2°C in 6 mins. When possible with an abundance of the species needed, it seemed desirable to guillotine them and rapidly take a liver temperature to represent core temperature. 2) We have carried out experiments on organ culture. At times before removing the organs from the exsanguinated animal, it is desirable to take its temperature (Refs. ). 3) Recently our interest has been a search for those organs which contribute extra heat to the cold acclimatized animal. It is estimated that brown adipose tissue contributes 6%, liver 24%, and muscles 50% of this extra heat (Grubb and Folk, 1976). We are in process of searching for the origin of the remaining 20% of estimated heat. Our approach is that of surveying a sample of control and cold-exposed animals by taking temperatures of organs, hoping by this means to expose those organs that are providing more heat than at room temperature. To illustrate that tissue temperatures can be used in this way, we present the temperatures of a series of bats which were moved from hibernation in the cold into a warm room (Brenner, 1975). The room warmed the outside of the dormant

animal and then thermogenesis began (Fig. 1). One would expect the core of the animal to increase the most rapidly but instead the brown fat between the shoulder blades showed a 3° increase over core temperature. Our survey of organs in the cold-acclimatized rodent may expose similar organs which are warmer than non-contributing organs in the body. To obtain accurate readings, we felt that control experiments were needed to explain exactly how such measurements should be made. Our hypothesis is that when a small animal is exsanguinated, the flow of heat to and from organs such as the brown fat, rectum, kidney, and liver, is arrested for a brief time; the investigator has stopped the heat flow. We assume that under these circumstances the four types of organs mentioned behave in the same way. Our postulate is that the interior temperature of the organ does not cool for a brief time, and could not raise its temperature by thermogenesis (perhaps due to histamine or epinephrine release) because blood pressure and blood flow is near zero. The following series of experiments test this hypothesis.

#### METHODS

For obtaining organ temperatures we have used a thermistor in the point of an 18 gauge needle, 7cm long. In most cases we were able to use a Yellow Springs telethermometer reading to 0.001°C, but more recently our readings have been taken to 0.01°C.

The first question of technique is whether, when an animal is freshly opened and one inserts the needle thermistor in an organ such as the kidney, the reading obtained is decreased by a

flow of heat from organ into the needle. In a control experiment we tested this situation. Six rat kidneys were at the surface of a 30°C bath. The needle thermistor was immersed in the bath (warm probe) and readings were taken in each organ. In Table 1 the readings obtained are shown (28.6°C). Next the readings were repeated only the needle was equilibrated at 20°C for 60 secs. between each reading (cool probe). The results were that when the needle probe is approximately 10° cooler than the actual organs, readings are 0.3°C too cool (28.3°C). This leaves the investigator with a choice. Before taking an organ temperature, he can immerse the needle probe in a bath which is approximately the temperature of the organ, or else he can do a control experiment and correct for the effect of the air temperature upon the metal of the needle probe.

### RESULTS

Experiment 1: In the first experiment we found that the procedure of exsanguinating the animal and opening the abdominal cavity was time-consuming. In order to test whether organs were cooling rapidly, we opened the abdominal cavity under anesthesia of each rat in a series. The animals then were guillotined and at 30 secs. the first reading was taken. After the next 30 secs., we could predict a drop of 0.1°C. These results are displayed in Figure 2; the standard error is not of the measurement but represents the different starting liver temperatures of the seven rats. These temperatures were taken by leaving the probe in the animal

during the cooling process. Probably some heat was conducted up the probe and the drop of  $0.1^{\circ}\text{C}$  was an artefact. The experiment was repeated with kidneys..

Experiment 2: One gerbil was sacrificed and the abdominal cavity was opened more rapidly than in Experiment 1. The probe was left in the kidney. At the end of one minute there had been no drop in organ temperature. This was repeated on three rats and the average drop in the second 30-second period was  $0.1^{\circ}\text{C}$ . Once again we felt that the probe which was left in the kidney during the readings was conducting some heat out of the organ. It seemed desirable, then, to use the probe only once and even to remove the somewhat cooled kidney from the body. To do this we designed a hypothetical rat with eight kidneys for the next experiment.

Experiment 3: For several hours eight kidneys were cultured in Ringers solution at  $36^{\circ}\text{C}$ . These kidneys were transferred to the abdominal cavity of a very large exsanguinated rat and the cavity was held closed. Every 30 secs. the cavity was opened, the temperature was taken of one kidney, and this somewhat cooled kidney was removed. We found that during the second 30-sec. period there was no apparent cooling at all, and even a slight rise in temperature. It can be seen in these three experiments that no way could be devised to take a control reading at zero time because the animal had not yet been exsanguinated. It was decided that the only way to obtain satisfactory control readings was to first take temperatures by rectal probes fastened in, and then to exsanguinate the rats. This was done in Experiments 4 and 5.

Experiment 4: The absolute readings of three typical rats out of ten with the rectal probe taped to the tail is displayed in Figure 5. In no case did the removal of blood from the animal cool the rectum; in fact there was a slight rise in temperature during the first minute and one-half in some cases. The results from 10 rats are pooled in terms of differences (Fig. 6). The initial increase in temperature is enlarged on the right hand side of the diagram. From this experiment, one can predict within one minute, a possible rise of  $0.03^{\circ}\text{C}$  and at 1.5 minutes a cooling of  $0.05^{\circ}\text{C}$ . At this point we wished to look for early changes in heat in the liver but determined that the only way was to compare two groups of rats, one under anesthesia and the other exsanguinated. We could not use long-term implanted thermistors to get control values because such work is criticized on the grounds that around the thermistor there may be inflammation or engorgement of capillaries or small vessels. The rectal temperatures and liver temperatures of two groups of six rats were compared. When the blood was removed from six of the rats and rectal temperatures taken there was no difference from the control values taken under anesthesia (Table 2,  $37.3^{\circ}$  vs.  $37.1^{\circ}$ ). The deep liver temperatures showed a slight rise over control values when blood had been removed. These results confirmed Experiments 4 and 5.

To summarize the six experiments, we found little evidence of cooling of organs within one minute after exsanguination is complete. Apparently organ temperatures of the exsanguinated animal for one minute are close to those found in the undisturbed animal as it is walking around or resting.

### CONCLUSIONS

Our hypothesis ~~at the start of this paper~~ was that heat flow in the individual organ can be arrested by exsanguination for a brief time. These experiments show that this brief time is of the order of one minute, and within this time the error of  $T_b$  is no more than <sup>1 or -</sup>  $\Delta 0.1^\circ\text{C}$ . We suggest that the procedure be called the Stop-Heat-Flow Technique for obtaining organ temperatures.

### ACKNOWLEDGEMENTS

We wish to thank Mary L. De Vos for her conscientious assistance with these experiments. This work was supported by The Arctic Institute of North America with the approval and financial support of the Office of Naval Research under contract number N00014-75-C-0635 (Subcontract ONR-455).

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Table 1. The effect of air temperature on a needle thermistor used to take temperatures of six rat kidneys near surface of a 30° bath; warm probe at 30°C, cool probe at 20°C.

<u>Kidney Number</u>	<u>Warm Probe</u>	<u>Cool Probe</u>
1.	29.4	29.1
2.	28.7	28.4
3.	28.7	28.5
4.	28.6	28.4
5.	28.4	28.2
6.	<u>27.7</u>	<u>27.4</u>
Mean	28.6°	28.3°

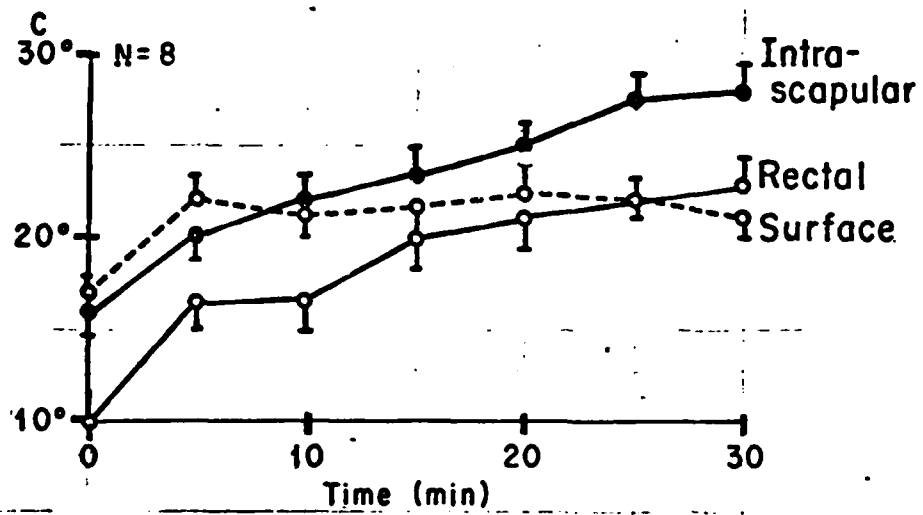
Table 2. A comparison of organ temperatures of six control rats under "Inovar" and six rats using the stop-heat-flow technique ( $\pm$  SEM).

	<u>Stop-Heat-Flow*</u>	<u>Under 'Inovar'</u>
Rectal Temperatures ( $^{\circ}$ C):	37.3 $\pm$ 0.14	37.1 $\pm$ 0.23
Deep Liver Temperatures ( $^{\circ}$ C):	37.0 $\pm$ 0.06	36.4 $\pm$ 0.19
Time to Take 2 Readings (sec.):	63 $\pm$ 1.4	40 $\pm$ 1.9
Rat Weights (g):	96.9	123.9

\* exsanguinated

Fig. 1

$T_b$  of a Bat (The Cluster Bat, *Myotis sodalis*) During Arousal From Torpor (N=8)



**Fig. 2**  
**Control Curve of Deep Liver of Rats**  
**after Exsanguination (N=7)**

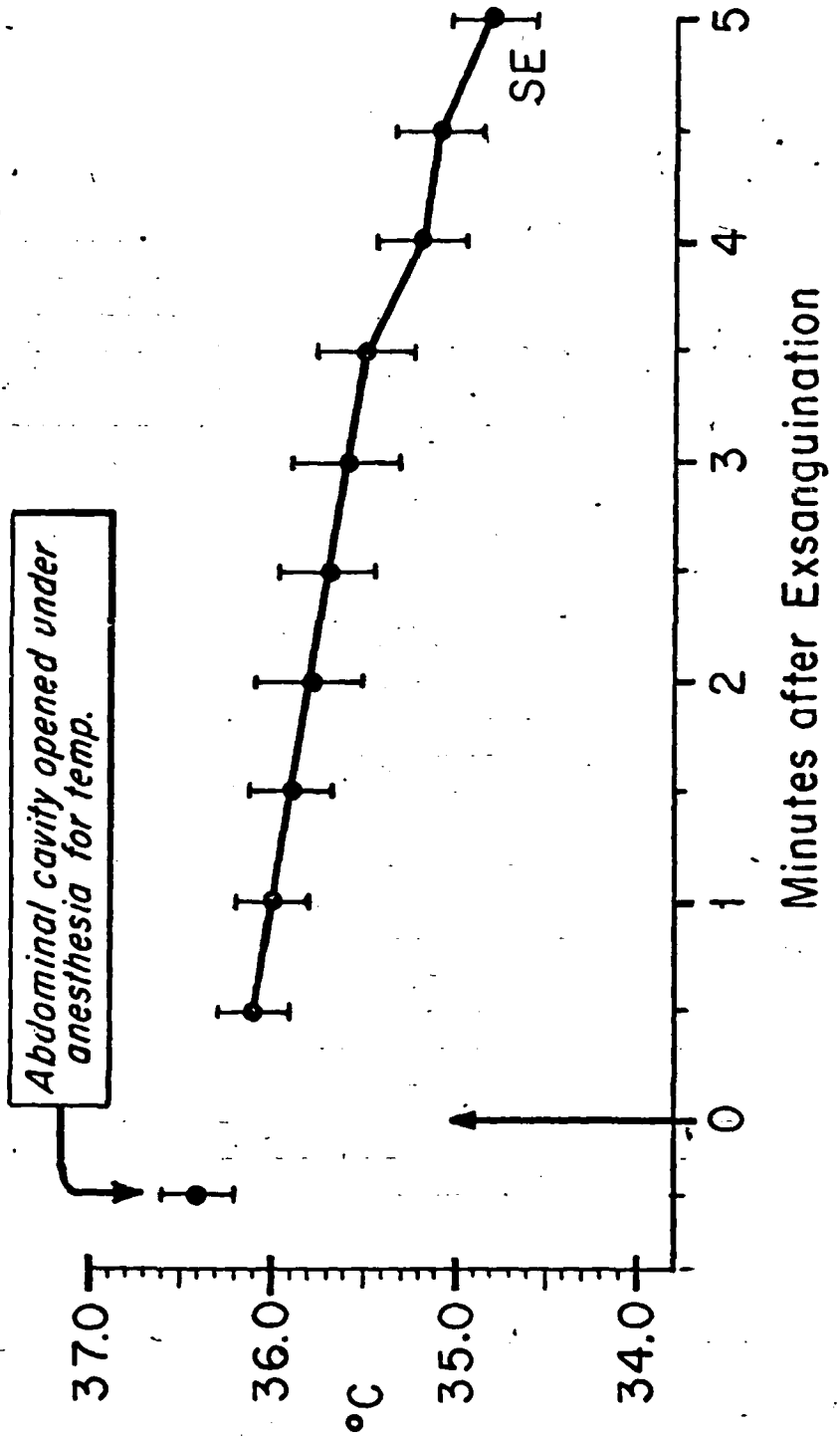


Fig. 3

Stop Heat-Flow of Kidneys

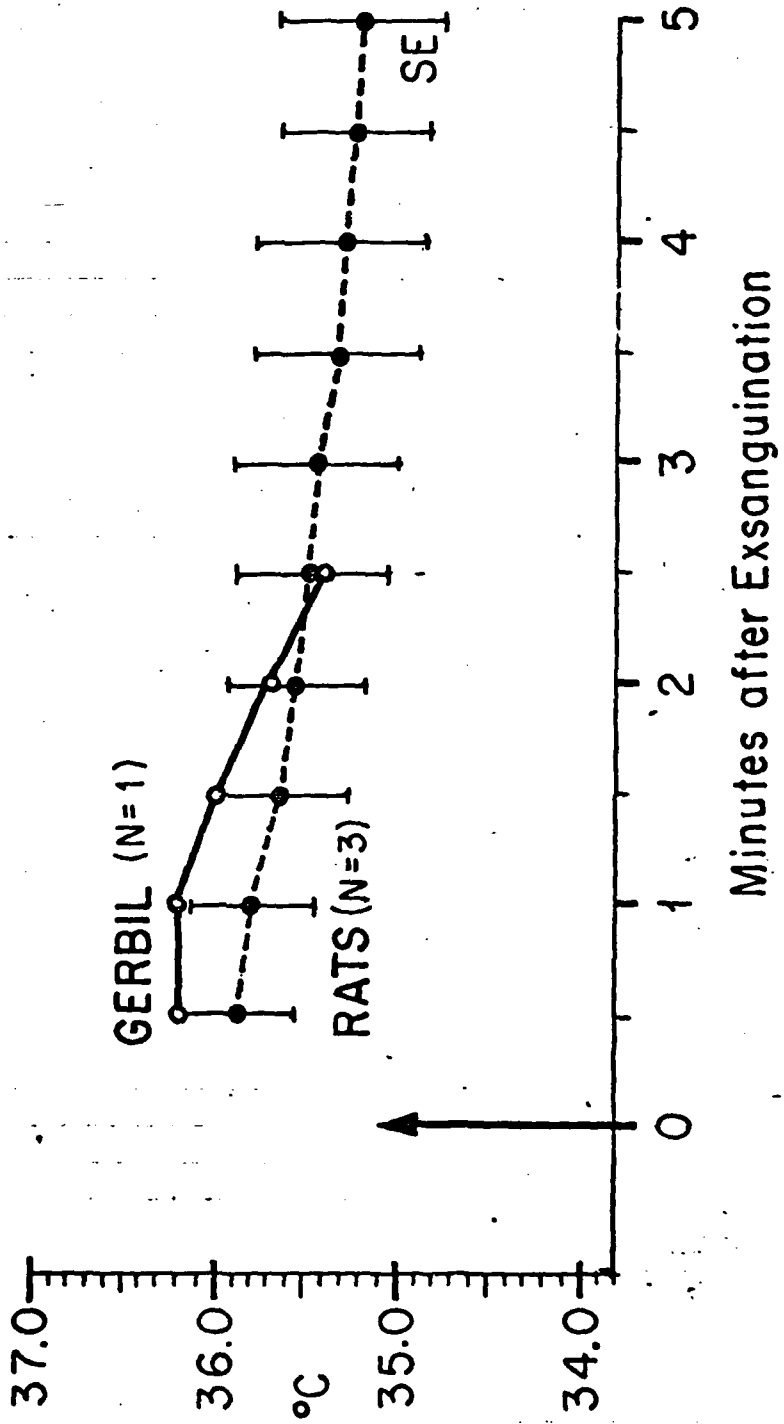
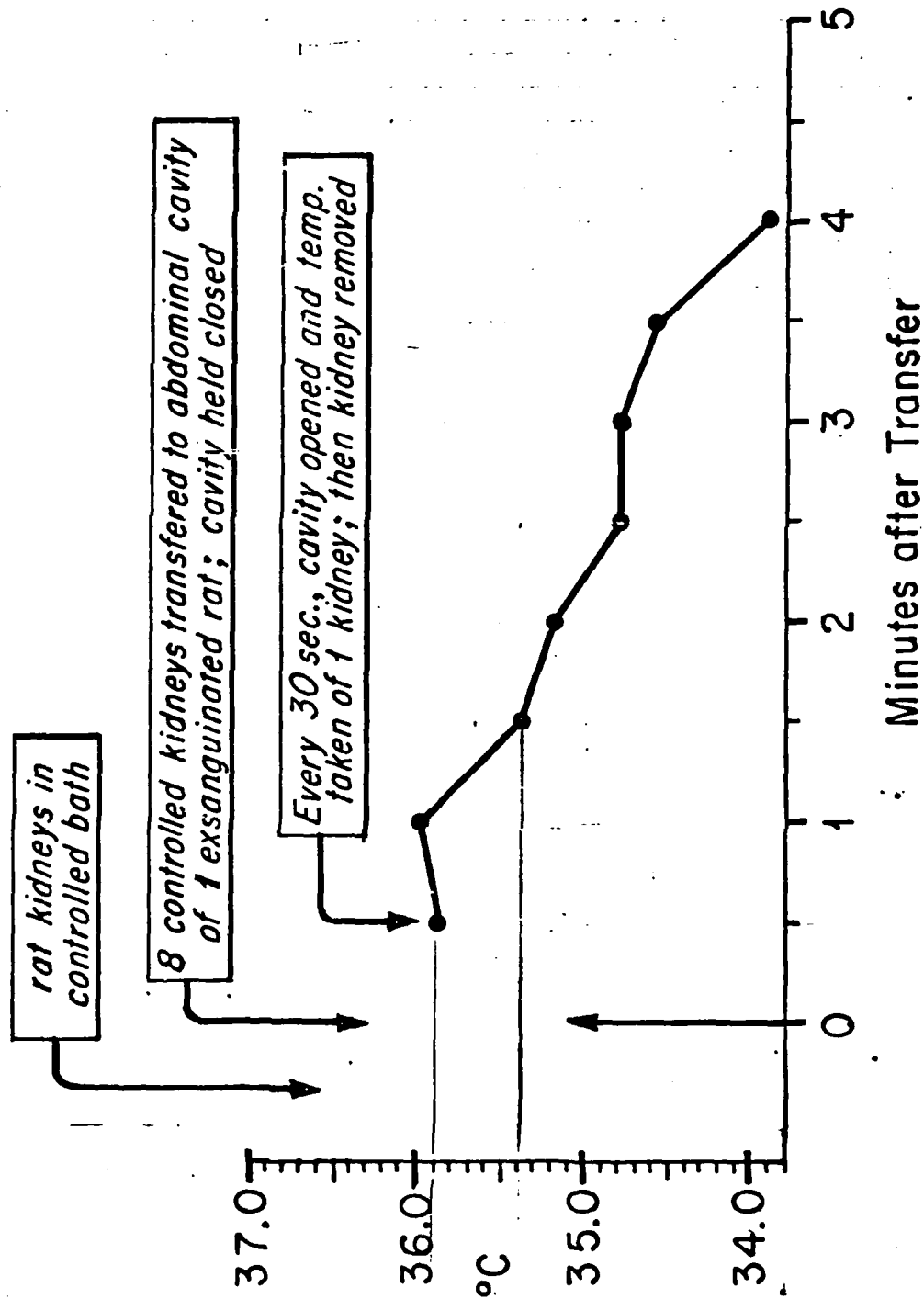


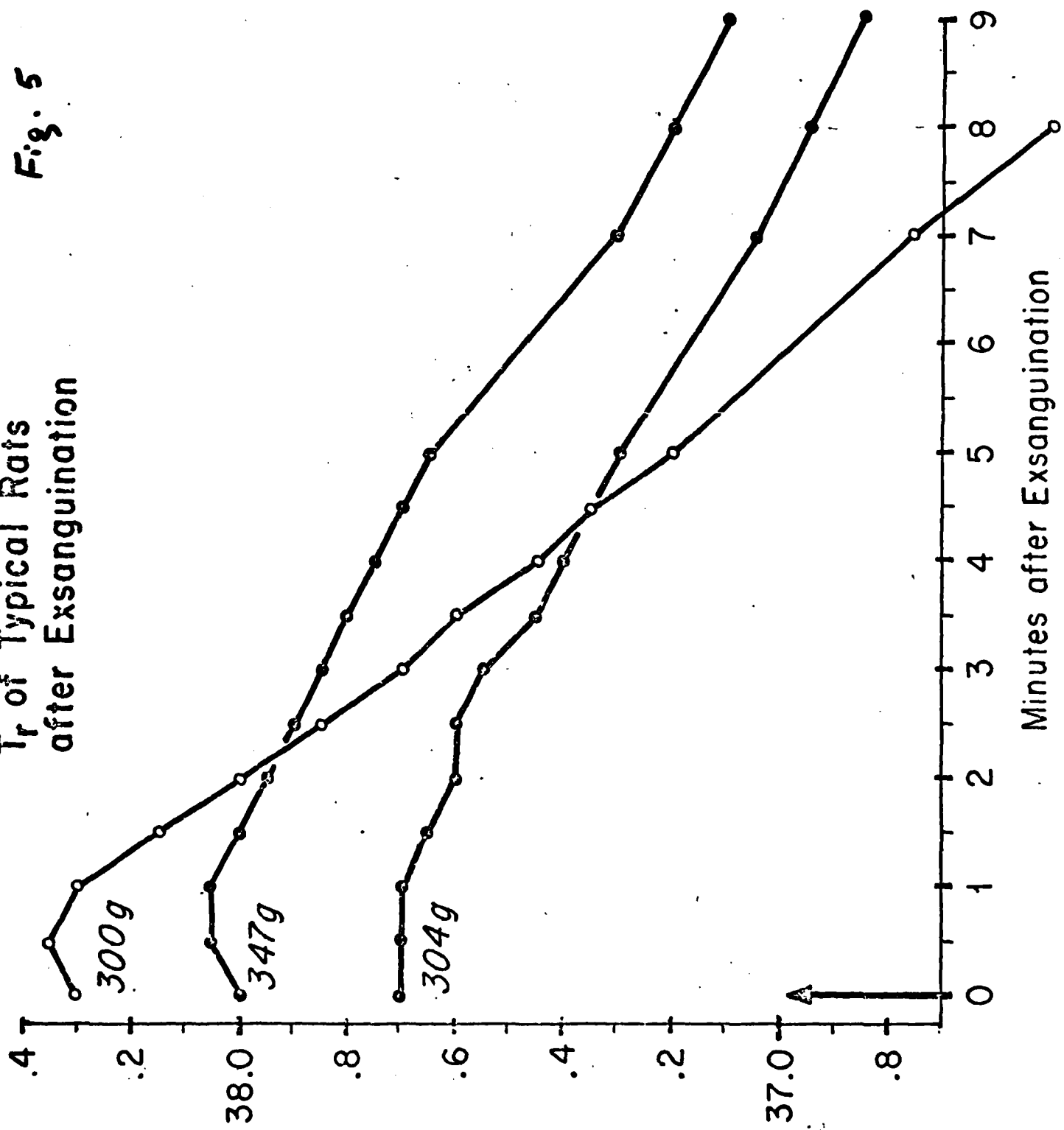
Fig. 4

# Stop Heat-Flow of Rat Kidneys Inserted into Abdominal Cavity of Exsanguinated Rat



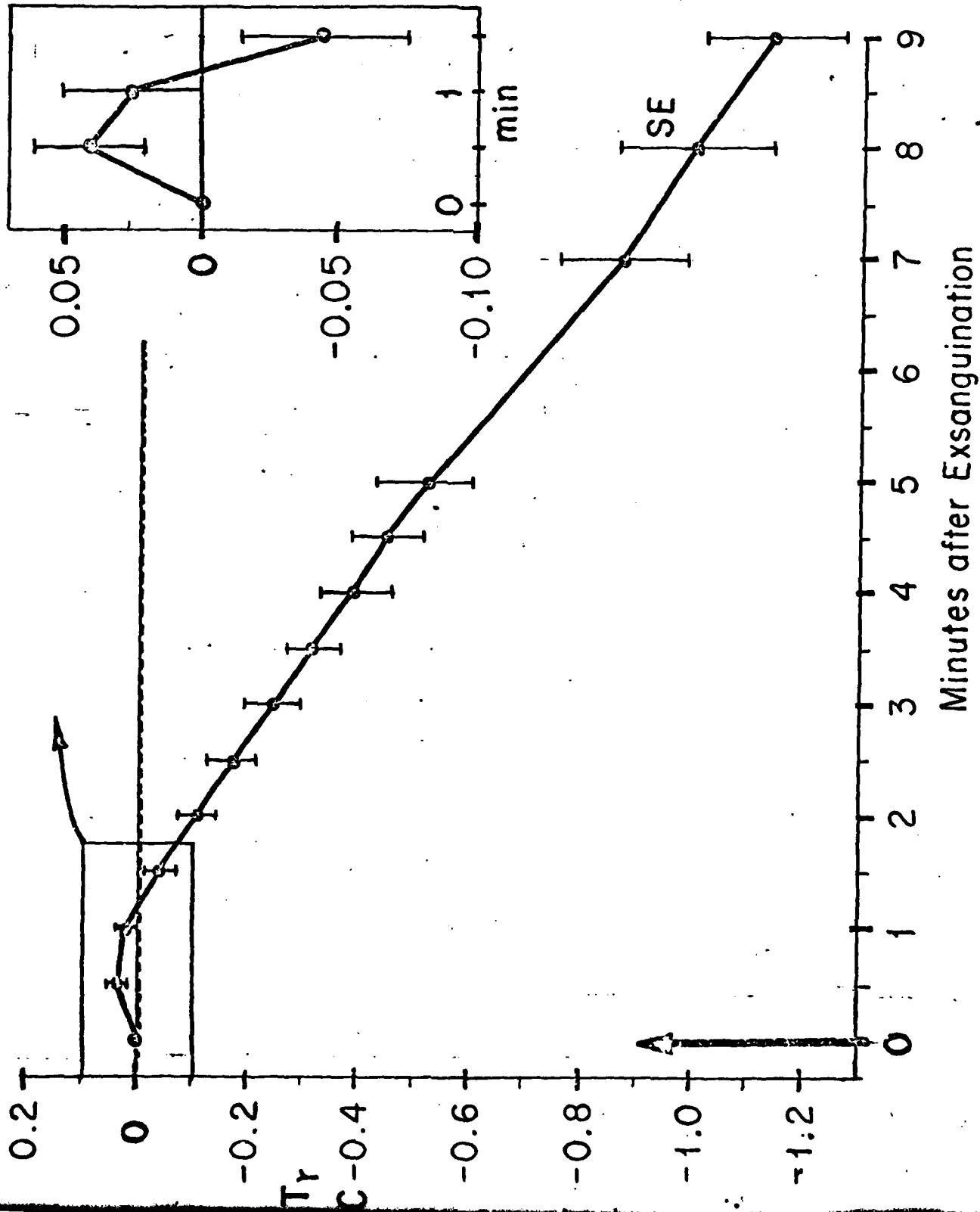
Tr of Typical Rats  
after Exsanguination

Fig. 5



# Mean $\Delta \bar{I}_r$ from Control Rats after Exsanguination (N=10)

Fig. 6



**N  
DAT**