# COMPARISON OF INTRACARDIAC AND INTRAVASCULAR TEMPERATURES WITH RECTAL TEMPERATURES IN MAN [1, 2]

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A study of intracardiac and intravascular temperatures was undertaken with the thought that such measurements might provide further information concerning the mechanisms which normally maintain body temperature within its narrow limits and also that they might help to explain the deviations from normal temperature in certain disease states. Whereas the temperature of the peripheral tissues may vary widely, homeothermic man maintains the temperature of the deep tissues, or of a critical deep tissue, fairly constant under widely varying conditions of heat loss and heat gain (2). The identity of the critical deep tissue is not completely understood but a considerable body of evidence places it in the diencephalon and in normal man small variations in its temperature are thought to initiate compensating mechanisms which return the temperature of the body to the homeothermic norm. Generally, rectal temperature has been considered to indicate deep tissue, and critical tissue, temperatures but often rectal temperature appears to be a lagging and unsatisfactory index; witness the onset, when the body is heated, of such compensating mechanisms as peripheral vasodilatation and sweating before a rise in rectal temperature has occurred; and conversely, in subjects who are cooled, the presence of vasoconstriction and pilomotor activity before a fall in rectal temperature has taken place. It seemed desirable, therefore, to look for some other index of critical deep tissue temperature.

Considerations of the mixing of blood in the left ventricle, probably in proportion to the volume flow and temperature of the blood from all organs, suggested the temperature of left ventricular blood as representative of deep tissue temperature. The difficulties in such a measurement, together with the likelihood that no significant change in temperature occurs during the transit of blood through the aorta, lead to the substitution of the temperature of the blood high in the femoral artery for left ventricular temperature. The observation (3) that such femoral arterial temperatures consistently fell below simultaneously recorded rectal temperatures, and that rectal temperature lagged behind changes in temperature of femoral arterial blood during changing body temperature, prompted the measurement of more "central" blood temperatures.

It was the purpose of the present study to determine the intracardiac and deep intravascular temperatures in afebrile subjects and thus establish a baseline of values with which future determinations, obtained during abnormal and changing body temperatures, could be compared.

## METHODS

Observations were made on 24 afebrile hospitalized subjects, usually several hours after breakfast and occasionally after an overnight fast. Most of the determinations were made at ambient temperatures between 77° F. and 84° F. and with the subjects nude, except for a loin cloth. During the few observations made at lower room temperatures the subjects were covered with one sheet.

All temperatures were measured potentiometrically with naked-junction, copper-constantan thermocouples and a Leeds-Northrup, Type K2, potentiometer. The temperatures in the chambers of the right heart and in the deep vessels leading to the right heart were measured by a thermocouple (copper wire gauge 30, constantan wire gauge 30) threaded to the tip of a standard, 8F, intracardiac catheter. This was a roving thermocouple, introduced in varying succession by the technique of cardiac catheterization (4), and under fluoroscopic control, into the right heart and connecting vessels. In determining a temperature with this thermocouple, it was not moved to a new location until three successive read-

[1] Read in part at the Thirty-third Annual Meeting of the American Physiological Society, Detroit, Michigan, April 21, 1949 (1).

[2] This study was supported by a grant from the Baruch Committee on Physical Medicine.

ings, made over a period of five to 10 minutes, checked each other.

All other thermocouples were kept stationary after they were positioned properly. Femoral arterial and femoral venous blood temperatures were obtained by indwelling, plastic-sheathed, thermocouples (copper wire gauge 42, constantan wire gauge 30) threaded through Cournand needles previously inserted into the corresponding vessels high in the groin (3, 5). The thermal junctions of these thermocouples extended in the lumen of the vessels for a distance of 5 to 6 centimeters beyond the needle tips and probably reached the junction of the femoral with the iliac vessels. Rectal temperature, 3 inches above the anal orifice, was determined by a single thermal junction (copper wire gauge 30, constantan wire gauge 30) presenting on the lateral wall of a suppository-shaped, hard-plastic applicator. Subcutaneous temperatures immediately beneath the skin, and intramuscular temperatures at a depth of 1½ inches below the skin surface, were determined in the lateral aspect of the thigh by means of gauge 22 needle thermocouples (copper wire gauge 42, constantan wire gauge 30). Because of their small masses all thermocouples had rapid response times, usually 95% of full deflection in 10 to 15 seconds. At the close of each experiment the calibration factor of each thermocouple was determined for that experiment.

## RESULTS

The data for a typical observation period are plotted in Figure 1, which shows the relationships of the various intracardiac and intravascular temperatures to each other, and to rectal temperature. These relationships are shown more definitively in Table I and in Figure 2, wherein the data for all of the observations are analyzed with reference to the rectal temperature at the time. The data are consistent and indicate several thermal gradients.

The temperatures in the right heart (atrium and ventricle) and pulmonary artery (main stem and

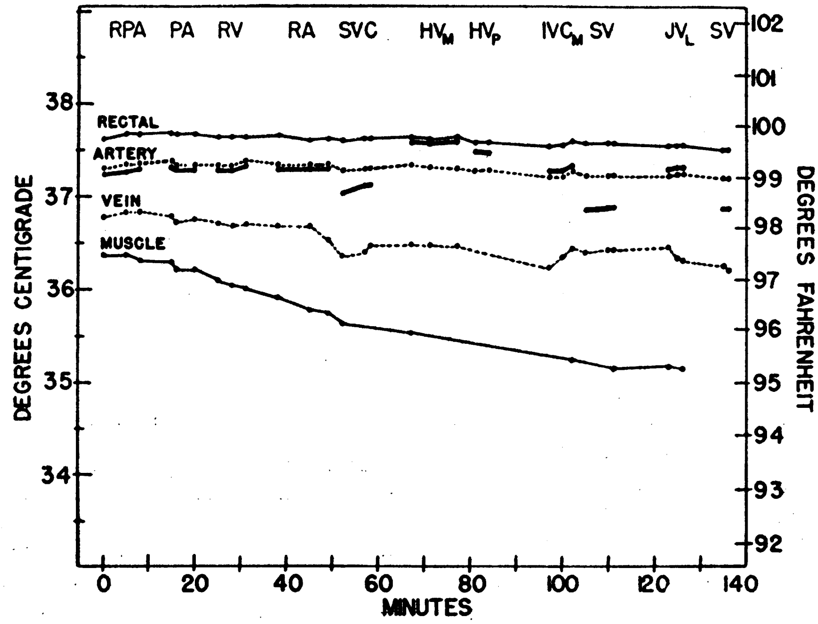


Fig. 1. Observations from a Typical Experiment Showing the Relationships of Intracardiac and Intravascular Temperatures to Each Other and to Rectal Temperatures (Afebrile Subject)

The lines from above downward indicate in turn, rectal temperature, femoral arterial temperature, femoral venous temperature and intramuscular (thigh) temperature. The heavy, disconnected, solid bars indicate the temperatures obtained with the catheter thermocouple in the locations indicated directly above by the letters at the top of the graph. In this and subsequent figures these letters indicate: RPA, right pulmonary artery; PA, main stem of pulmonary artery; RV, right ventricle; RA, right atrium; SVC, superior vena cava; SV and SC subclavian vein; $J_L$ and $JV_L$, jugular vein, low; $J_h$ and $JV_h$, jugular vein, high; $IVC_L$, inferior vena cava, low; $IVC_m$, inferior vena cava, mid-portion; $IVC_h$, inferior vena cava, high; $H_p$ and $HV_p$, hepatic vein near vena cava; $HV_m$, hepatic vein, mid-liver; $H_d$ and $HV_d$, hepatic vein deep in the liver; AV, axillary vein.

TABLE I

*Analysis of the deviations of intracardiac and intravascular temperatures from rectal temperature in afebrile subjects*

| Location of catheter thermocouple | Number of patients | Difference between "catheter" temperature and rectal temperature* | | | |
|---|---|---|---|---|---|
| | | Mean °C. | Standard deviation °C. | Fisher t value | Probability† P |
| Right Pulmonary Artery (RPA) | 16 | −0.27 | 0.17 | 6.24 | 0.01 |
| Pulmonary Artery Main Stem (PA) | 13 | −0.26 | 0.15 | 6.19 | 0.01 |
| Right Ventricle (RV) | 17 | −0.23 | 0.14 | 6.57 | 0.01 |
| Right Atrium (RA) | 24 | −0.26 | 0.13 | 9.96 | 0.01 |
| Superior Vena Cava (SVC) | 19 | −0.35 | 0.16 | 9.01 | 0.01 |
| Subclavian Vein (SV) | 21 | −0.58 | 0.22 | 11.55 | 0.01 |
| Jugular Vein, low ($J_L$) | 15 | −0.22 | 0.15 | 5.51 | 0.01 |
| Jugular Vein, high ($J_h$) | 4 | −0.01 | 0.04 | 0.22 | 0.80 |
| Inferior Vena Cava, low ($IVC_L$) | 7 | −0.26 | 0.22 | 2.84 | 0.02 |
| Inferior Vena Cava, high ($IVC_h$) | 10 | −0.22 | 0.18 | 3.63 | 0.01 |
| Hepatic Vein, near Vena Cava ($H_p$) | 6 | −0.09 | 0.10 | 1.88 | 0.10 |
| Hepatic Vein, deep in liver ($H_d$) | 6 | −0.03 | 0.04 | 1.84 | 0.10 |
| Femoral Artery (FA) | 22 | −0.22 | 0.15 | 6.66 | 0.01 |

* Minus indicates catheter temperature less than rectal temperature.
† Due to the small size of the samples, P values are not expressed smaller than 0.01 even though the P often calculated to a considerably smaller value.

right branch) were practically identical, essentially equal to femoral arterial temperature, and less than rectal temperature by an average of 0.25° C. (0.45° F.). Analysis shows that this difference between right heart and rectal temperature, though small and with a sizable standard deviation, is nonetheless statistically significant (Table I) because the intracardiac temperatures so consistently fell below rectal temperature (Figure 2).

Progressively lower temperatures were recorded as the thermocouple was moved from the right atrium into the superior vena cava and into the subclavian vein, where the temperature averaged 0.6° C. (1.1° F.) below rectal temperature (Figure 2). Statistically, the temperatures in both of these vessels are significantly below rectal temperature (Table I). In the inferior vena cava there were inconstant variations from right atrial temperature but on the average the temperature at all levels was approximately equal to that in the right atrium (Table I, Figure 2).

Two sites contributing blood of higher temperature to the circulation were noted, the brain and the liver. As the tip of the thermocouple passed from the subclavian vein into the common jugular vein, even for a distance of only a few centimeters, the blood temperature rose sharply from a relatively low value to a value equal to right heart temperature ($JV_L$, Figure 1). High in the jugular vein, approximately in the jugular bulb, the temperature was still higher, well above right heart temperature and equal to rectal temperature (Table I, Figure 2). Similarly the temperature of hepatic vein blood exceeded that of the inferior vena cava and equalled rectal temperature (Table I, Figure 2). The observations on hepatic and jugular blood temperatures were few in number but analysis suggests that these temperatures are probably the same as rectal temperature (Table I).

In brief, rectal temperature was slightly higher than the intracardiac and deep intravascular temperatures here measured, except that high in the jugular vein and deep in the hepatic vein the temperatures equalled rectal temperature.

In 20 afebrile subjects the temperature in the femoral artery was found to be similar to that in the right heart (Table II, Figure 3). Moreover, femoral arterial temperature was essentially the same as the temperature in most of the deep vessels. However, in the hepatic vein, and high in the jugular vein, the temperature was higher than femoral artery temperature and in the superior vena cava and subclavian vein the temperature was lower (Table II, Figure 3).

The differences between rectal and right heart temperatures were so small in afebrile subjects that for practical purposes the two temperatures may be considered to be the same. The few preliminary observations thus far made indicate that such a similarity may not be the case when body

TABLE II

*Analysis of the deviations of intravascular and intracardiac temperatures from femoral arterial temperature in afebrile subjects*

| Location of catheter thermocouple | Number of patients | Difference between "catheter" temperature and femoral artery temperature* | | | |
|---|---|---|---|---|---|
| | | Mean °C. | Standard deviation °C. | Fisher t value | Probability† P |
| Pulmonary Artery Main Stem (PA) | 16 | −0.03 | 0.07 | 1.36 | 0.2 |
| Right Ventricle (RV) | 17 | −0.01 | 0.06 | 0.46 | 0.6 |
| Right Atrium (RA) | 20 | −0.03 | 0.07 | 1.84 | 0.1 |
| Superior Vena Cava (SVC) | 17 | −0.11 | 0.08 | 5.83 | 0.01 |
| Subclavian Vein (SV) | 18 | −0.36 | 0.16 | 9.15 | 0.01 |
| Jugular Vein, low ($J_L$) | 11 | +0.02 | 0.12 | 0.62 | 0.5 |
| Jugular Vein, high ($J_h$) | 4 | +0.15 | 0.21 | 1.26 | 0.3 |
| Inferior Vena Cava, low ($IVC_L$) | 4 | −0.08 | 0.17 | 0.85 | 0.5 |
| Inferior Vena Cava, high ($IVC_h$) | 9 | +0.03 | 0.13 | 0.58 | 0.6 |
| Hepatic Vein, proximal ($H_p$) | 3 | +0.11 | 0.10 | 1.56 | 0.3 |
| Hepatic Vein, deep ($H_d$) | 4 | +0.26 | 0.05 | 9.37 | 0.01 |

* Plus indicates catheter temperature higher than rectal temperature; minus, catheter temperature less than rectal temperature.
† See footnote, Table I.

temperature departs from the homeothermic norm. The data plotted in Figure 4 were obtained in a febrile patient with slowly resolving pneumonia and show a very sizable difference (0.8° C., 1.4° F.) between rectal and right heart temperatures. Furthermore, in five febrile patients with rectal temperatures ranging from 38.2° C. to 40.0° C. (100.7° F. to 104.0° F.) the differences between right heart and rectal temperatures were 0.2°, 0.4°, 0.6°, 0.7° and 0.8° C. Right heart temperature

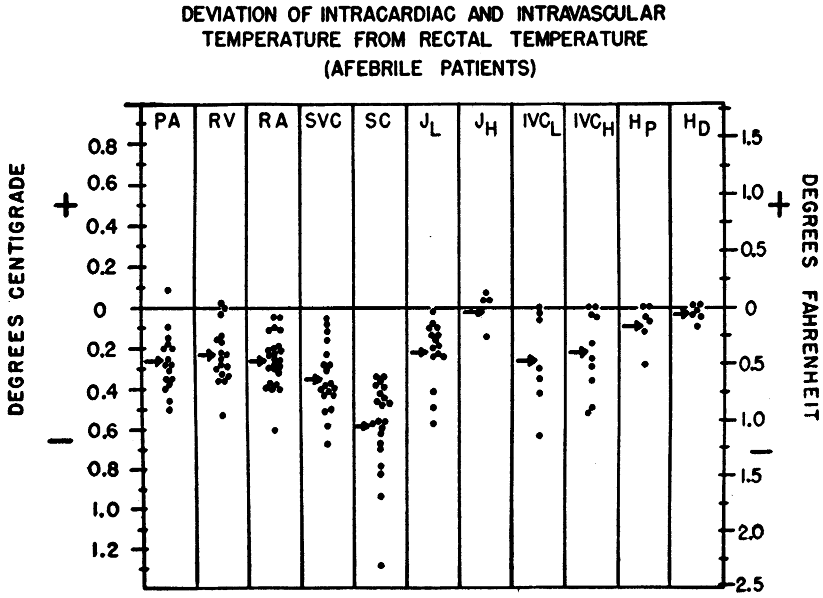


FIG. 2. INTRACARDIAC AND INTRAVASCULAR TEMPERATURES PLOTTED WITH REFERENCE TO THE SIMULTANEOUSLY OBTAINED RECTAL TEMPERATURE AS A BASE (AFEBRILE SUBJECTS)

Each dot represents a comparison in one subject between rectal temperature and the intravascular temperature indicated by the letters at the head of the respective columns. Each heavy horizontal arrow represents the average of the corresponding group of dots.

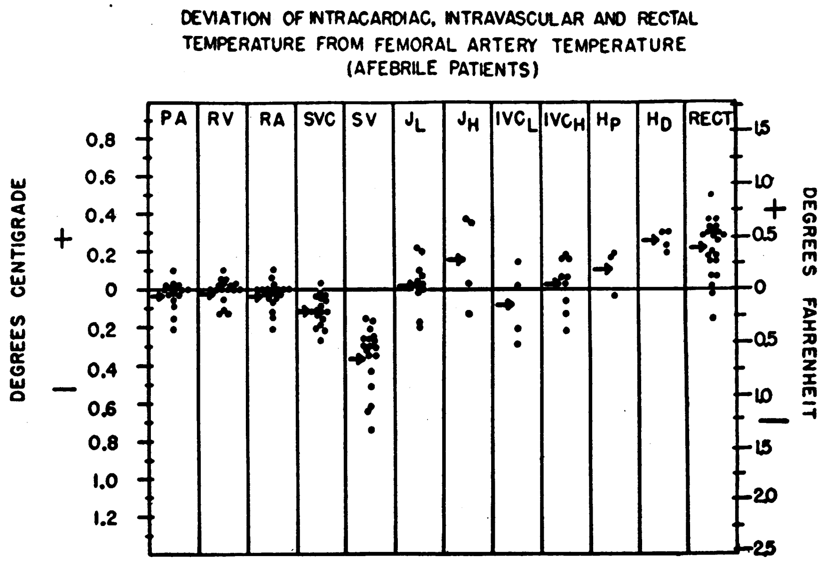


FIG. 3. INTRACARDIAC, INTRAVASCULAR AND RECTAL TEMPERATURES PLOTTED WITH REFERENCE TO THE SIMULTANEOUSLY OBTAINED FEMORAL ARTERIAL TEMPERATURE AS A BASE (AFEBRILE SUBJECTS)

Details as in Figure 2.

was always less than rectal temperature and the difference was greater in the patients with the higher fevers. In all five patients the relationships of the various intravascular temperatures to each other and to rectal temperature were the same as in afebrile subjects, and again, femoral arterial temperature was the same as right heart temperature.

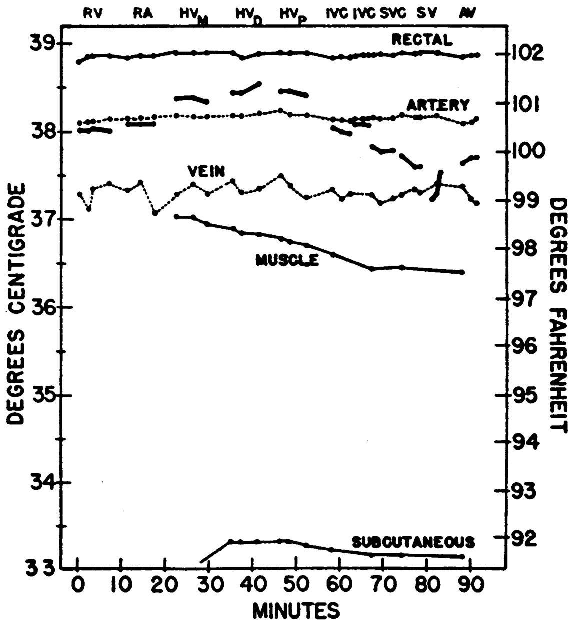


FIG. 4. RELATIONSHIP OF INTRACARDIAC AND INTRAVASCULAR TEMPERATURES TO EACH OTHER AND TO RECTAL TEMPERATURE IN A FEBRILE PATIENT WITH SLOWLY RESOLVING PNEUMONIA

Details as in Figure 1.

## DISCUSSION

The data indicate a small, but consistent, gradient of increasing temperature in the larger veins as they approach the heart. The gradient is steeper in the thorax than in the abdomen where, at times, it is not demonstrable. Sharp rises in temperature above these gradients occur within veins which drain organs considered to have increased metabolic heat production. The liver and brain are shown to be such organs.

It was not anticipated that femoral arterial temperature would be the same as right heart temperature. When previous observations (3) showed that femoral arterial temperature fell below rectal temperature, the supposition was held that right heart temperature probably equalled, or exceeded, rectal temperature and that the lower femoral arterial temperature was due to the cooling of blood within the lungs (assuming again that blood does not change in temperature during transit through the aorta). Since right heart and femoral arterial temperatures are essentially the same, it follows that heat loss from the lungs is *relatively* so small with respect to the large volume of blood which flows through the lungs that the temperature of the blood is not altered by an amount which can be determined by the methods here used.

Since the temperature of right heart blood was consistently less than rectal temperature, and since this difference was small, a systematic variation in the thermocouples was carefully looked for, but excluded. The consistency of the temperature pattern and the statistical analysis lead us to conclude that the difference between right heart and rectal temperature, though small, is a real one. Since the measurements were not made at controlled ambient conditions the significance and constancy of this small difference may be questioned, for it is well known that the temperatures of various portions of the body may vary considerably at different environmental temperatures and humidities. In this regard attention is called to the relatively narrow range (7° F.) of the ambient temperatures, all of which were in a zone comfortable for the nude subject. Furthermore, regardless of the variations in temperature and humidity within this range the relationship of the rectal and intracardiac temperatures was always the same, with respect to both the direction and the degree of difference.

It seems reasonable that there should be a difference between rectal and right heart temperatures since one gives the temperature of a single organ whereas the other is influenced by thermal contributions from all organs. It seems reasonable, too, that femoral arterial temperature should be similar to intracardiac temperature, since both determinations are measurements of mixed blood temperature. Furthermore, differences between intracardiac, intravascular and rectal temperatures of the magnitude and direction here reported have been demonstrated in animals; originally by Claude Bernard (6), who introduced thermometers into the heart and various vessels, and more recently by Horvath, Rubin and Foltz (7) who used intravascular thermocouples introduced under fluoroscopic control.

Although the differences between right heart temperature and rectal temperature were not sufficiently large to be of practical importance in afebrile subjects, these differences assume significance in two respects; in febrile patients and in considerations of the physiology of thermal homeostasis. In preliminary observations on febrile patients, right heart temperature at times fell so far below rectal temperature that the differences between the two cannot be dismissed. Further studies of thermal gradients within the vascular tree during fever may serve to clarify the factors responsible for maintaining the febrile state.

In regard to thermal homeostasis, attention has focussed on two temperatures; the average deep tissue temperature and the temperature of that "critical" tissue, believed to be located in the hypothalamus, which triggers the thermoregulating mechanisms which return body temperature to the homeothermic norm. Present concepts generally hold that both of these temperatures are measured by rectal temperature. This supposition appears open to question. The observations here reported confirm that variations in temperature exist even deep within the body core and this precludes the temperature of a single organ as the measure of *average* deep tissue temperature. An integrating measurement or a calculated average value seems more likely to indicate this temperature. Furthermore, evidence is not at hand to prove that the temperature of the rectum is the same as that of the critical tissue, particularly during conditions of changing body temperature.

Intracardiac temperature, and its equivalent femoral arterial temperature, appears to represent a "vascular" integration of the various individual temperatures to give an average blood temperature. This temperature seems to approach *average* deep tissue temperature more closely than any other single measurement but, because of the thermal contributions from the peripheral tissues, it may not be the same as average deep tissue temperature. Since the critical tissue temperature is the temperature of an organ, it is not likely that it would be indicated by an integrated temperature such as intracardiac temperature. Nevertheless, intracardiac and femoral arterial temperatures should have considerable significance in thermal homeostasis since the temperature of the blood as it enters, and affects, the critical tissue in the hypothalamus is more apt to be indicated by these temperatures than by any other measurement now made. Only the temperature of the blood in the afferent artery to the critical tissue would have greater significance and this is a measurement not now available.

The above considerations, based on the data presented, are suggested for the afebrile subject in thermal equilibrium. It remains for future study to determine whether the relationships between intracardiac, intravascular and rectal temperatures here reported, and the considerations drawn therefrom, also hold under the more critical conditions of changing body temperature, when thermoregulatory mechanisms are actually called into action.

## SUMMARY

1. Measurements of the temperature in the right heart, in the deep vessels leading to the right heart, in the femoral artery and in the rectum of 24 afebrile subjects showed:

(*a*) there is a gradient of increasing temperature in the larger veins as they approach the heart,

(*b*) temperatures within the right heart and pulmonary artery are equal, and the same as the temperature high in the femoral artery,

(*c*) rectal temperature exceeds intracardiac and deep intravascular temperatures by a small but significant amount,

(*d*) temperatures in the veins draining the liver and brain are higher than the temperatures in the veins into which they drain, and equal rectal temperature.

2. The differences between rectal and intracardiac temperatures are not of such magnitude as to be of clinical importance in afebrile subjects.

3. Preliminary observations suggest that during fever rectal temperature may exceed intracardiac temperature by a significant amount, up to 0.8° C. in one patient.

4. The data suggest a review of those concepts of thermal homeostasis which hold that rectal temperature represents either the average deep tissue temperature, or the temperature of the critical tissue which initiates thermoregulating mechanisms.

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