Cyclic Heat Loss from the Steady State Skin Surface

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•The amount of heat loss from radiation and convection were calculated from 50 consecutive infrared thermographs of a finger made at 2-sec intervals at a room temperature of 24–26C. The heat loss appeared to show cyclic fluctuations at about 30-sec intervals, similar to those of the simultaneously recorded red blood cell velocities in the nailfold capillary loops of the adjacent finger. The amounts of heat loss in the forehead, finger, and great toe seemed to show grossly synchronized, cyclic fluctuations at about the same interval. This indicated that vasomotion cycles of the skin were at least partially demonstrated by the heat-loss cycles from the skin surface.

Introduction

Vasomotions or cyclic fluctuations of the velocity of the cutaneous vascular flow have been demonstrated in the nailfold capillaries of man.[1,2] The skin surface temperature is largely supplied by the vascular flow to the skin, and the amount of the heat supply in the steady state is expected to be in a constant equilibrium with the amount of heat loss from the skin surface. Therefore, the heat loss will reflect vascular flow to the skin.

In the present study, the amount of heat loss from the steady-state skin surface of the finger was calculated using infrared thermography and was compared with simultaneously recorded red blood cell velocities in the nailfold to explore the effect of vasomotion on heat loss from the skin surface. Heat losses from different parts of the body (forehead, fingers, and toes) were also compared.

Materials and Methods

Simultaneous recordings of the capillary red blood cell velocity in the fifth finger and heat loss in the fourth finger were made in the left hand of 15 healthy adult volunteers, 9 males and 6 females, 24 to 35 years of age. The subjects were examined at a room temperature of 24–26C with a humidity of 40%–60% and air velocity of less than 0.05 m/sec. The subjects were acclimated to the room temperature for 15 min before the thermography procedure.

The recordings were made with or without a tourniquet on the upper arm, and chronological changes of the capillary flow velocity and of heat loss were studied before and after 100 mmHg pressure was released.

Capillary Red Blood Cell Velocity

A capillary microscope* with a special lighting cone,** a high-speed video system,† and a cathode ray tube (CRT) display were used. The video-images, made at 5-msec intervals, were each recorded with the time element, from which the velocities of the arterial and venous limb flows of a capillary loop were determined by dividing the distance of displacement of a plasma gap between red blood cell groups by the time required for the displacement in the CRT display (Figure 1). The subject was seated with the finger placed at heart level on a polystyrene foam board on the microscope stage. Glycerine was used between the nailfold and the lighting cone for observation.

Heat Loss Calculation

The infrared thermography apparatus‡ was equipped with an argon-cooled indium-antimonide detector with a frame-scan time of 0.05 sec with the temperature resolutions set at 0.1 or 0.2C depending on the thermal gradient. Thermograms were stored in a floppy disc, and were later processed by a computer,*** in off-line mode. Fifty consecutive thermograms were recorded at 2-sec intervals for a period of 100 sec at room temperature.

The amounts of heat radiation (Qr) and convection (Qc) from the skin surface were calculated:

$$Qr = de(Ts^4 - Ta^4) \quad [Kcal/h, m^2]$$

$$Qc = Hm(ts - ta) \quad [Kcal/h, m^2]$$

where d is Stefan-Boltzmann's constant (4.88×10^{-8} [kcal/h, m^2, K^4]), e is radiant emissivity of the skin surface, which was 0.99, Ts is absolute skin surface temperature, Ta is absolute ambient temperature, and ts and ta are skin surface and ambient temperatures in °C.[3] Hm is mean natural convective heat conductivity,

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* Nikon.
** Fuji Ind., Inc., Japan.
† MHS-200, NAC, Inc., Japan.
‡ TVS-4300ME, Nihon Avionics Co., Inc., Japan.
*** PC-9801E, Nihon Electric Co., Inc., Japan.