Section of Surgery

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Digital Vasospasm [*Abridged*]

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Effects of Cold on the Extremities

Cutaneous Vasomotor Control
Skin is provided with a profuse blood supply to fulfil its role in thermoregulation. In digital skin, blood flow can range from less than 0·5 ml per minute through each 100 ml of tissue during intense vasoconstriction to more than 50 ml with the subject warm. The oxygen requirements of digital skin have been calculated as 0·8 ml of blood per minute (Burton 1961), so even in the normal person vasoconstrictor control is probably powerful enough to reduce the blood supply to the point of anoxia.

The control of blood flow through skin depends partly on central control through sympathetic vasomotor nerves and partly on a direct local effect of temperature. Over the greater part of the body surface cutaneous vasomotor control is mediated by both vasoconstrictor nerves and a vasodilator mechanism, whereas in the extremities only vasoconstrictor control is present (Fox & Edholm 1963, Abramson 1967). Although alterations in vasomotor tone mainly subserve the the needs of temperature regulation, it is perhaps insufficiently recognized that certain psychogenic stimuli can also produce a strong vasoconstriction.

Effects of Local Cooling
With intense cooling of the hands the initial vasoconstriction in the digits is usually followed after a period of minutes by a cold vasodilatation. Lewis (1930) and Grant (1930) showed that the blood flow during cold vasodilatation passes through the arteriovenous anastomoses but the precise mechanism remains uncertain. The phenomenon can still be elicited after sympathectomy and is frequently abnormal in patients with digital vasospasm.

In some apparently normal individuals exposing the skin to water several degrees above zero can produce a cold injury (Edholm *et al.* 1957). The injury develops as an inflammatory reaction in the skin after a latent period of twelve to twenty-four hours and appears to be distinct from frostbite, immersion foot or chilblains.

Sympathectomy for Digital Vasospasm
Sympathectomy of a normal limb produces an immediate and large increase in blood flow, which is, however, short lived, subsiding rapidly during the first couple of days after operation and then more slowly in the succeeding weeks until it is only a little above the pre-operative level (Barcroft & Walker 1949). The mechanism of this return of tone is uncertain but it is probably an important factor contributing to the disappointing and unpredictable late results of sympathectomy for the relief of Raynaud's phenomenon (Buchanan *et al.* 1952, Johnston *et al.* 1965).

De Takats & Fowler (1962) believe that success with sympathectomy is improved by selecting patients who exhibit a particularly active neurogenic component of control and they claim that this is indicated by abnormalities in the EEG. The importance of overactive central neurogenic control, which was suggested by Raynaud (1862, 1864) as the basis for the phenomenon, has been largely discounted since Lewis and others showed that Raynaud's phenomenon could still occur after sympathectomy. There is no doubt that the blood flow response in the hand to changes in local temperature is abnormal in primary Raynaud's disease (Peacock 1958, 1959). However, this does not exclude the possibility that the condition is aggravated in some cases by over-

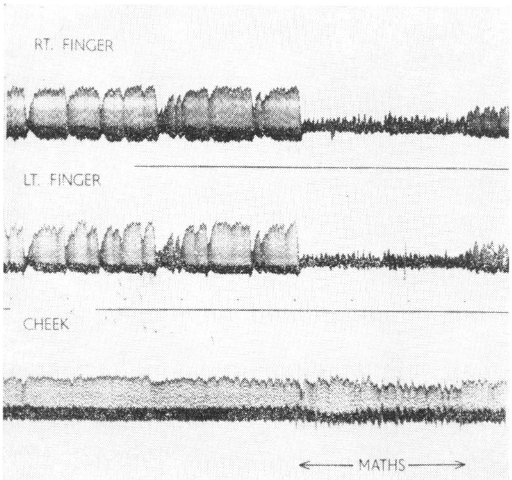

Fig 1 *Pulsimeter recordings from tips of fingers on both hands and the cheek of a normal young male subject at rest in a thermally neutral environment. The typical spontaneous vasoconstrictions in the fingers and the profound vasoconstriction produced by mental arithmetic are shown. A minute marker is visible below the second trace*

active sympathetic control and, if so, it would certainly seem logical to expect such cases to benefit most from sympathectomy. The difficult problem is to find a suitable technique for selecting patients with overactive sympathetic control. It is suggested that a promising approach is to measure the response to a controlled psychogenic stimulus, the effects of raising and lowering local temperature and their interactions with the central release of sympathetic tone by body heating.

Equipment recently designed to enable either the deep body temperature or the skin temperature to be changed and then held at any required level (Fox 1967) could provide the standard conditions required for testing the responsiveness of neurogenic control. The response elicited could be studied using the photoelectric pulsimeter pioneered by Hertzman (1948). An improved version of this instrument has recently been developed (Collins *et al.* 1968) to investigate the blood flow in skin grafts (Muir *et al.* 1968). The device is extremely simple to use and gives a sensitive indication of vasoconstrictor responses in the digits; it does not give a strictly quantitative measure of blood flow and might therefore be combined with venous occlusion plethysmography.

The illustrations show the results of using these two techniques on a normal subject. In the experiment shown in Fig 1 the subject's body and hands were exposed to an environment of 30° C and he felt neither warm nor cold. The traces show the spontaneous variations in finger blood flow and their relative absence in the skin of the face. The subject was asked to concentrate on a simple mental arithmetic problem (subtracting 17 from 400, then 17 from the remainder and so on until told to stop) to demonstrate the intense vasoconstriction elicited by a relatively mild and fairly reproducible psychogenic stimulus. As the body temperature was raised, spontaneous vasoconstrictions in the fingers became less frequent, less pronounced and less prolonged (Fig 2);

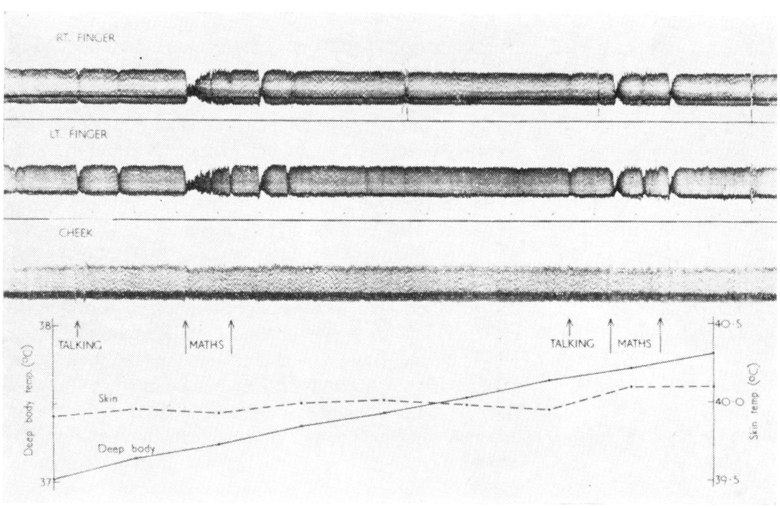

Fig 2 *The same subject as in Fig 1 during body warming. Spontaneous vasoconstrictions are less frequent and marked, and the vasoconstrictor response to talking and maths is progressively reduced*

talking to the subject did not have so much effect and the response to mental arithmetic became less pronounced. Similarly, it can be shown that the response to local cooling becomes less marked as central vasomotor tone is released by raising body temperature.

With these techniques to study the interactions between the two factors influencing the neurogenic component and the effects of local temperature on hand blood flow, the selection of cases for sympathectomy might be improved.

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Frostbite: General Observations and Report of Cases Treated by Hyperbaric Oxygen

Frostbite occurs when the tissues freeze; individuals at risk are those exposed to below zero temperatures (0° F; −18° C) in polar or mountainous regions and in countries where seasonal freezing occurs, and air crew.

In the pre-1920 era of polar exploration associated with the names of Scott and Shackleton, frostbite appears to have been relatively common. However, it is now an uncommon condition except in the case of accidents.

In the Himalayas where temperatures (−50° F; −46° C) and wind velocities (100 miles/h; 45 m/s) comparable with those of polar regions are encountered, there is the added complication of altitude. At normal altitudes, frostbite rarely occurs except when the patient is inadequately clothed due to low intelligence, alcoholism, illness or accident. Though frostbite can occur without general body cooling it may be associated with hypothermia.

Normally mountaineers operate at about 60% of maximum work capacity or 2 litres/min if maximum oxygen intake is 3 litres/min. If for any reason their physical working capacity is lowered they will have to work nearer to their maximal capacity to keep warm (Pugh 1966). If they are unable to keep up heat production, eventually the central core body temperature will fall and they may become gravely ill and die. Cases are recorded in which death has occurred within two hours of the onset of symptoms. At high altitudes, a steady work rate of 2 litres/min is more difficult to maintain and the individual is working nearer to capacity. Oxygen lack also causes forgetfulness and elementary preventive measures may be neglected. Heat loss increases also with overbreathing, as maximal breathing capacity is approached during physical work. Heat production will fall in cases of illness, injury or poor physical condition and the extremities will cool, despite clothing, to the ambient temperature, which, as it is often below freezing, will result in frostbite.

Frostbite, however, is not an inevitable sequel of sub-zero temperatures, at high altitude, in inadequately clad subjects. On the Himalayan Scientific Expedition 1960–1, a Nepalese pilgrim aged 35 spent a number of nights under observation without shelter at altitudes between 15,300 and 17,500 ft (4,600–5,200 m); he was wearing thin cotton clothing and both hands and feet were bare; minimum night temperature was −15° C, yet no frostbite occurred. During this period his diet consisted mainly of tea with sugar. This man normally lived in a village at 6,000 ft (1,830 m) where the night temperature in winter was below freezing and the windows were unglazed; he was therefore well acclimatized to cold. Overnight and daytime investigations suggested that his general metabolism was raised and he underwent a continuous light shivering rather than intermittent violent attacks (Pugh 1963). He also seemed relatively insensitive to afferent cutaneous cold stimuli as he never complained of