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Dr J M K Spalding
(Department of Neurology, United Oxford Hospitals)

The Autonomic Nervous System and the Circulation

In discussing the autonomic nervous system and the cirulation I will deal particularly with some of the ways in which the reflex control of the circulation can be interrupted by neurological disease and how such interruptions can be recognized.

Tests for Activity of Circulatory Reflexes

There are many ways of testing whether the circulatory reflexes are active. Each of the tests serves a different purpose, but most of them involve supplying some stimulus which is known to produce a certain result in normal subjects. A particularly useful stimulus is *Valsalva's manœuvre* (Valsalva 1707), that is to say a sudden rise in the intrathoracic pressure. It is usually produced by the subject voluntarily taking a deep breath and expiring against a closed glottis, but if the patient cannot co-operate a similar effect can be produced by inflating the patient's chest artificially. The effect of Valsalva's manœuvre on the circulation, in particular its effect on the arterial blood pressure, can be observed in a number of ways. The raised intrathoracic pressure interferes with venous return and the arterial blood pressure falls. In the normal subject (Fig 1A), however, reflex vasoconstriction develops and the blood pressure begins to rise although the intrathoracic pressure remains elevated. When the intrathoracic pressure is released the blood pressure shows an overshoot above the original level due to persistence of the reflex vasoconstriction. In a patient whose circulatory reflexes have been interrupted by neurological disease, a 'blocked' response occurs (Fig 1B). When the intrathoracic pressure is raised the blood pressure falls steadily away without any period of recovery, and when the intrathoracic pressure returns to normal again the blood pressure rises only gradually with no overshoot. The record in Fig 1B came from a patient, N W, who is referred to again later but this kind of record is obtained from any patient with severe interruption of circulatory reflexes, for instance from cervical cord injury, tabes, diabetes, or cerebrovascular accidents.

Another stimulus whose effect on the arterial blood pressure can usefully be observed is *change of posture* from the horizontal to the vertical, or near vertical, position. In normal subjects the blood pressure remains about the same or sometimes rises or falls slightly. In patients who have lost their circulatory reflexes, however, tipping produces a fall in blood pressure which may be precipitous especially in those whose neurological lesion is recent.

In a patient who has blocked circulatory responses it may be that the *resistance vessels*, mainly arterioles, are not being appropriately adjusted by reflexes, and these can be tested if the blood pressure is known and if the blood flow is known, for instance by measuring the blood flow with a plethysmograph. It may also mean that the *capacity vessels*, mainly veins, are not being appropriately reflexly adjusted. Capacity vessels govern the amount of blood which is allowed to pool instead of returning to the heart.

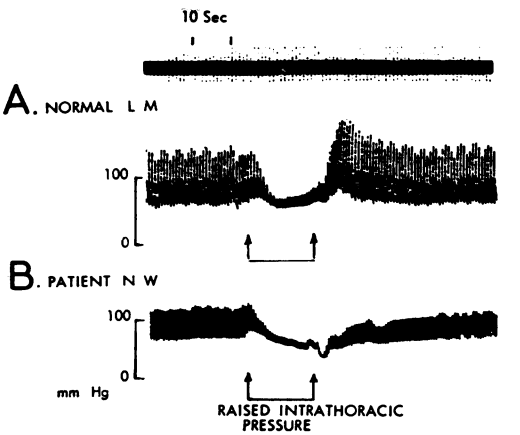

Fig 1 A, *normal, and* B, *blocked response of arterial blood pressure to Valsalva's manœuvre. (Reproduced from Johnson* et al. *1966, by kind permission)*

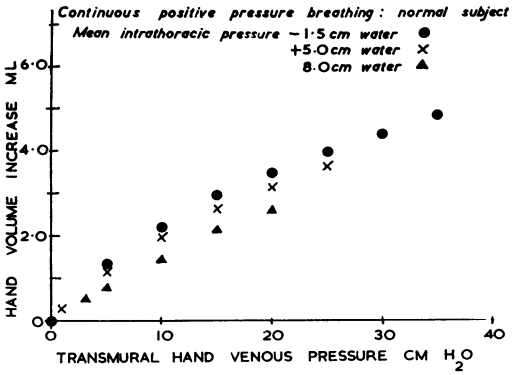

FIG 2A

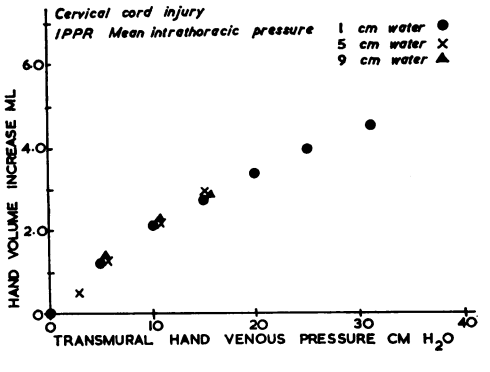

FIG 2B

Fig 2 *Relationship of increase in hand volume to increase in venous pressure. In a normal subject* (A) *a sustained increase in intrathoracic pressure is accompanied by a decrease in the distensibility of the capacity vessels. In a subject with a severe cervical cord injury* (B) *change in intrathoracic pressure is accompanied by no change in venous distensibility. (Reproduced from Watson 1961, by kind permission)*

Reflex activity of capacity vessels is measured by inserting a cannula into a limb vein and placing the segment of the limb which contains the cannula into a plethysmograph. When a distensible cuff on the limb proximal to the plethysmograph is blown up to occlude the venous return, blood flows into the limb, and its volume is measured by the plethysmograph. At the same time the pressure in the veins rises and is measured through the cannula. It is then possible to plot the increase in the volume of the hand against the increase in pressure and this gives a measure of the distensibility of the vessels. In a normal subject the venous distensibility alters readily in response to a rise in intrathoracic pressure whether acute (Sharpey-Schafer 1961, Watson 1962*a*) or sustained (Fig 2A), to sleep (Watson 1962*b*), to drugs (Sharpey-Schafer 1961, Watson 1962*c*, *d*, *e*; Watson *et al.* 1962, Barraclough & Sharpey-Schafer 1963), to change in circulatory blood volume (Sharpey-Schafer 1961, Watson & Seelye 1962) and to alarm. However, in a patient with a neurological lesion affecting the function of the sympathetic nervous system these changes do not take place (Fig 2B) except in response to certain drugs including adrenaline and noradrenaline which act directly rather than through the sympathetic nerves (Watson 1962*f*).

This, therefore, is one way in which a subject who may have reflex circulatory disturbances can be investigated. He can be examined to determine whether his circulatory reflexes as a whole are present, and if they are not whether the trouble lies in the resistance vessels or in the capacity vessels. Usually it lies in both, but there are some conditions in which they react differently, and there are a very large number of conditions which have not been investigated in this way.

If circulatory reflexes are impaired, the patient can also be examined in a different way, for reflexes have afferent, central and efferent parts. In tabes dorsalis, for instance, circulatory reflexes are interrupted on the afferent side (Sharpey-Schafer 1956). In old age and cerebrovascular accidents (Appenzeller & Descarries 1964, Johnson *et al.* 1965) and in poisoning by barbiturates and other drugs (Barraclough & Sharpey-Schafer 1963) central lesions cause loss of circulatory reflexes. The efferent pathways can be cut within the central nervous system by a high spinal cord lesion and in the peripheral nerves in polyneuritis.

What tests will distinguish whether the lesion is afferent, central or efferent? It is not easy to test the afferent pathway and the usual practice is to test the efferent pathway. If it can be demonstrated that the efferent pathway is intact and yet the reflexes are lost it is assumed that the lesion is in the afferent or central areas. There are several tests of activity of the *efferent pathway*. One is to observe the arterial blood pressure when the patient is exposed to a very loud noise, such as a starting gun. Another is to give him mental arithmetic such as serially subtracting 7 from 100 and urge him to do it as fast as he can. Either noise or mental concentration may produce a rise in blood pressure in a normal subject. If it can be demonstrated in a patient with blocked circulatory reflexes that such a rise occurs the efferent pathways must be working and one can therefore conclude that the lesion lies in the afferent pathways or central connexions.

The trouble with these tests is that quite often in normal subjects these stimuli do not produce hypertension so that if in a patient hypertension does not occur in response to noise or mental arithmetic, it cannot be concluded that there is a

lesion in the efferent pathway. The alternative is to test sweating. A heat cradle is placed over the patient's trunk and he is warmed until the central temperature has risen at least 1°C. He should then sweat, and if he does not it is usually correct to conclude that there is a sympathetic lesion in the efferent pathways. If there is such a lesion, it may be preganglionic (either immediately or within the central nervous system) or postganglionic. Postganglionic fibres can be tested by applying faradism to the skin or injecting acetylcholine intradermally. Either of these procedures produces an axon reflex in postganglionic fibres which results in sweating and pilo-erection in the neighbourhood (Barany & Cooper 1956). If these axon reflexes are present in a patient known to have an efferent sympathetic lesion, the lesion must be proximal to the ganglia. A recent example of the application of such tests is patient N W, mentioned above and fully reported elsewhere (Johnson *et al.* 1966). He was a man of 54 who for four and a half years complained of fainting when he stood up, consciousness returning when he lay down. Records of the blood pressure demonstrated that he had orthostatic hypotension and that he had lost his circulatory reflexes (Fig 1B). He also mentioned that he ceased to sweat at the time his symptoms began and we confirmed this. The acetylcholine test suggested that postganglionic fibres were intact, so it seemed probable that he had an efferent sympathetic lesion proximal to the ganglia. The patient died and Dr D R Oppenheimer showed that the cells in the intermediolateral columns of the dorsal spinal cord, that is the cells of the preganglionic fibres, were greatly diminished in number.

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Dr R H Johnson
(*Department of the Regius Professor of Medicine, Radcliffe Infirmary, Oxford*)

The Autonomic Nervous System and Body Temperature

The maintenance of body temperature depends upon a balance between heat loss and heat production.[1] The mechanisms by which heat loss and production are regulated are very similar; each may be regulated in two ways: (1) By reflexes from peripheral temperature receptors in the skin: the reflex pathway probably passes through the brain and its activity may be determined by the level of central temperature. (2) By means of receptors within the brain which respond to changes in blood temperature.

Heat Loss

In man loss of heat may be regulated either consciously by putting clothes on or taking them off, or by means of homeostatic mechanisms involving regulation of skin blood flow or sweating. The conscious control of clothing depends upon the appreciation of cutaneous temperature only. The lack of appreciation of a low central temperature was illustrated in investigations upon patients with spinal cord transection. The central temperature was lowered by immersing the feet in cold water. This procedure allows the skin innervated from above the level of the lesion to remain warm. In spite of the shivering which occurred the patients said they did not feel cold. When questioned two of them said they could not be certain whether they were shivering or had an attack of nerves (Johnson & Spalding 1966).

Both vasomotion and sweating are dependent upon the dual control of a reflex and a central temperature receptor mechanism. Animal evidence has shown the importance of the anterior hypothalamus in the control of heat loss mechanisms.

Reflexes from the skin causing vasodilatation and vasoconstriction: When radiant heat is applied to the trunk vasodilatation may begin in the hand within as little as 15 sec and may proceed in spite of a falling central temperature (Kerslake & Cooper 1950, Cooper & Kerslake 1954). The reflex appears to be dependent upon pathways above the C6–7 level of the spinal cord and therefore probably through the brain. This was concluded from observations on hand blood flow in patients with cervical cord transection

[1]Strictly speaking heat production by shivering is mediated by motor nerves but is included so that temperature regulation may be kept in proportion