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Spinal sympathetic reflexes in the cat and the pathogenesis of arterial hypertension

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Summary

1. In vagotomized anaesthetized cats with both common carotid arteries occluded, stretch of the thoracic aorta induced reflex increases in arterial blood pressure, heart rate and left ventricular $dP/dt_{max.}$. Similar responses were obtained in cats with spinal transection at the level of the first cervical nerve roots.

2. The hypothesis is advanced that sympathetic excitatory reflexes may contribute to the maintenance of hypertension through positive feedback.

Key words: circulation, neural regulation, positive feedback.

Introduction

The concept of arterial hypertension as a disease of regulation raises the problem of identifying the factors which are responsible for perpetuating the hypertensive state. The remarkable anti-hypertensive efficacy of drugs which interfere with sympathetic functions points to some crucial role played by the sympathetic nervous system. It does not clarify, however, whether there is increased sympathetic activity, an increased vascular responsiveness to a normal sympathetic drive, or whether both factors may participate.

Concerning the hypothesis of a tonically increased sympathetic discharge, two mechanisms have been particularly studied: (i) central neural or psychogenic factors leading to an overactivity of the sympathetic outflow; (ii) adaptation of those neural regulatory mechanisms supposed to counteract the hypertensive state. This latter adaptation has been mostly attributed to a resetting of baroreceptors.

It is the aim of the present paper to suggest the possible involvement of peripheral excitatory neural reflexes in the maintenance of hypertension.

As this suggestion originates from recent experimental data, they will be briefly summarized.

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Methods and results

In anaesthetized vagotomized cats, with both carotid arteries occluded, the walls of the thoracic aorta were stretched without obstructing aortic blood flow by means of a cannula covered by a rubber cylinder (Lioy, Malliani, Pagani, Recordati & Schwartz, 1974). This stretch induced reflex increases in arterial blood pressure, heart rate and the maximum rate of rise of left ventricular pressure ($dP/dt_{max.}$). These responses were abolished by infiltrating the walls of the thoracic aorta with a local anaesthetic.

Similar responses were observed in cats with acute spinal transection at the level of the first cervical nerve roots (C1). Smaller effects were obtained in adrenalectomized cats with an intact central nervous system.

Phenoxybenzamine abolished the pressor response but not the increase in heart rate and $dP/dt_{max.}$. Propranolol drastically reduced the increases in heart rate and $dP/dt_{max.}$ but not the pressor response.

The reflex responses were clearly evident with stretches that increased the aortic diameter by 10%. Increases in aortic diameter of this magnitude are observed when mean aortic pressure is mechanically increased 30–60 mmHg by aortic stenosis.

Strong nociceptive stimuli (such as clamping of the

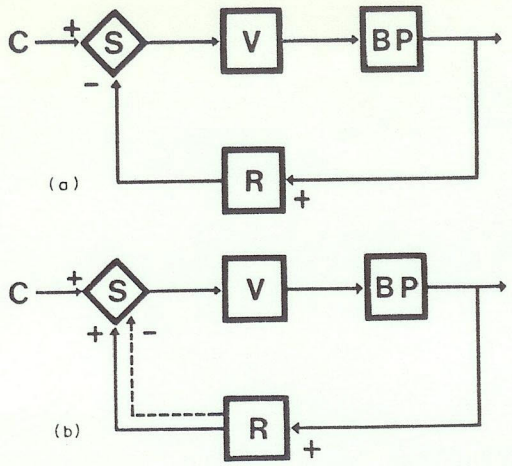

FIG. 1. Schema of suggested mechanisms underlying nervous control of blood pressure regulation. For details see the Discussion section.

paw) were necessary to elicit similar cardiovascular responses.

It was concluded that mechanical stretch of a magnitude likely to occur in physiological conditions initiates reflex increases in sympathetic activity affecting the heart, the peripheral vessels and, probably, the adrenal glands.

Discussion

On the basis of our present understanding of blood pressure regulation (Fig. 1a) stretch of a reflexogenic area (R), simulating a rise in arterial blood pressure, produces a reflex decrease in systemic blood pressure through an inhibition of the sympathetic (S) discharge affecting vascular (V) resistances and thus blood pressure (BP). In this closed loop a negative feedback assures a tonic control of the system regulating the dynamic equilibrium of its operating point (Franz, 1974).

Our experiments, in which supraspinal inhibitory mechanisms were not operative, have revealed spinal excitatory reflexes that seem to exhibit positive feedback characteristics. A stimulus likely to simulate the effects on aortic walls of an increase in mean aortic pressure (Fig. 1b) produces a further rise in systemic arterial pressure by increasing the sympathetic activity. We suggest that these spinal neural mechanisms may contribute to the tonic maintenance of the effects of an increased central command (C, Fig. 1a and 1b). However, it should be pointed out that electrophysiological techniques have detected both excitations and inhibitions induced by a similar aortic stretch on the impulse activity of single sympathetic preganglionic neurons (Pagani, Schwartz, Banks, Lombardi & Malliani, 1974). The coexistence of inhibitory components in spinal sympathetic reflexes is represented by the broken line in Fig. 1(b). These complex properties indicate how much research has to be done before fundamental properties of these reflexes, such as the range of operation, gain, stability and interactions with other regulatory mechanisms, will be even partially understood.

The spinal reflex arc, which is considered the elementary basis of the somatic nervous system, is still often regarded as an unnecessary simplification in the study of the sympathetic nervous system. This may heavily limit our understanding not only of physiology but of pathology as well.

Thus, as an example, one may interpret the 'hyperdynamic beta-adrenergic circulatory state' as a natural condition in which the spinal sympathetic reflexes affecting cardiac function may have a higher than normal activity, eluding inhibitory control from supraspinal centres.

The mechanisms which produce a sustained increase in sympathetic activity may be similar to those which in the decerebrate animal are responsible for gamma-rigidity or spasticity. Sherrington found that spasticity was abolished by deafferentation. Thus it was proved that an augmented central command was not *per se* capable of causing a sustained increase in the postural tonus but that a peripheral spinal loop was necessary for the maintenance of the phenomenon.

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