

CHARACTERISTICS OF ADAPTATION OF CARDIOVASCULAR REFLEXES IN OLD ANIMALS

(UDC 612.833:612.67]-084)

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Translated from *Byulleten' Éksperimental'noi Biologii i Meditsiny*, Vol. 60, No. 8,
pp. 32-36, August, 1965

Original article submitted September 10, 1963

The animal organism must constantly face up to long-acting stimuli arising from both the external and the internal environment. In these conditions, new relationships are formed between the organism and environment, the character of which cannot be determined by application of a transient, measured load. Some of the principles governing these relationships have been determined by the study of adaptation of reflexes [1-4].

The effect of age on the changes in reflex reactions to long-acting stimuli have not attracted the attention of investigators. Yet it may be considered that the study of the changes in the adaptation of reflexes would help to establish the characteristics of adaptation of the organism during aging and to evaluate the age changes in reflex activity.

EXPERIMENTAL METHOD

Experiments were conducted on 56 young (1.0-1.5 years) and 40 old (3.5-4.5 years) rabbits and also on 22 cats (12 aged 2-3 years and 10 aged 8-9 years). During the experiments, the animals were anesthetized with urethane (0.8 g/kg). Urethane was injected intramuscularly. Some of the experiments (23) were conducted on unanesthetized rabbits. The changes in the arterial pressure of the animals were recorded in one carotid artery, and the pneumogram was also recorded. The pressor reflex from the region of the carotid sinuses was evoked by compressing the trunks of both carotid arteries. The depressor reflex from the mechanoreceptors of the isolated carotid sinus was reproduced by raising the perfusion pressure from 100 to 180 mm Hg in different experiments. The chemoreceptors of the isolated carotid sinus and of the intestinal vessels were stimulated by perfusion with solutions of nicotine (10^{-4} , 10^{-5}), sodium sulfide (1% solution) and acetylcholine (10^{-4} - 10^{-9}). Prolonged stimulation of the receptors of the rectum was maintained by inflation of a balloon under pressure. The nerve trunks (aortic and tibial) were stimulated by a current supplied from an electronic stimulator (ISE-1) through a transformer. The transformer had an attachment to remove the constant component of the current supplied by the stimulator.

RESULTS AND DISCUSSION

Weakening of the reflexes during prolonged stimulation of receptive fields and sensory nerves develops more quickly in old animals than in young. This has been shown by the study of exteroceptive and interoceptive reflexes, both in isolation and combined. For example, whereas the time of adaptation of the pressor reflex from the rectum in young animals was 10.5 ± 2.1 min (14 experiments), in old animals it was 4.5 ± 1.3 min (10 experiments). The time of adaptation of the pressor reflex in response to stimulation of the tibial nerve was 10.5 ± 3.2 min in young rabbits (24 experiments) and 2.8 ± 0.8 min in old rabbits (20 experiments).

In young animals, immediately after the initial level of the functions had been regained, prolonged stimulation of the tibial nerve (20-30 min) could be applied without causing any significant change in the arterial pressure. In 11 experiments on old rabbits, sharp changes in the arterial pressure arose in response to prolonged stimulation of the tibial nerve, terminating in a catastrophic fall of pressure and death of the animals.

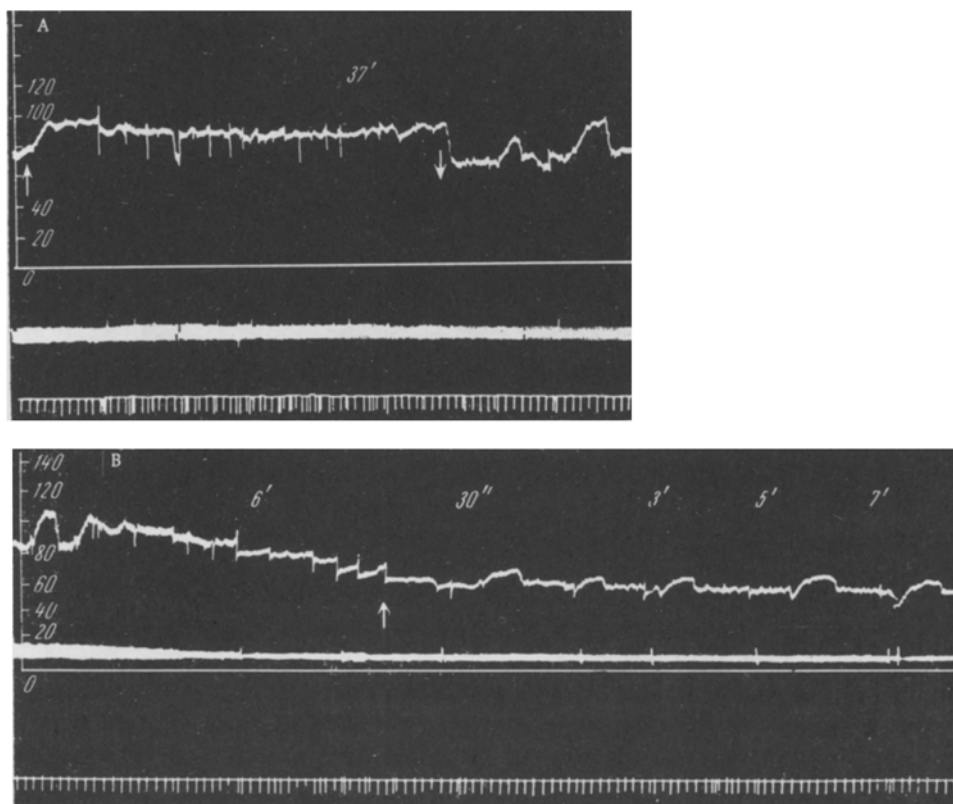


Fig. 1. Age differences in adaptation of the pressor reflex from the mechanoreceptors of the carotid sinus. A) Experiment on a young rabbit. The arterial pressure remains steady at a high level; B) experiment on an old rabbit. Time of adaptation of pressor reflex 6 min. Slow restoration of the initial magnitude of the reflex. Legend (from top to bottom): arterial pressure, zero level, pneumogram, time marker (5 sec). The arrows denote the beginning and end of stimulation.

In experiments on 48 old and young cats and rabbits, the character of adaptation of the pressor reflex from the receptors of the carotid sinus was compared. The time of adaptation of the pressor reflex from the receptors of the carotid sinus in the young rabbits was 20-55 min, and in the old rabbits 5-25 min (Fig. 1).

In the old animals the "Sechenov reaction"—the depressor phase arising immediately following adaptation of the pressor reflex—developed more slowly after removal of the clamp from the carotid artery, but was more prolonged.

Clear age differences also were detected by comparing the depressor reflex arising during perfusion of the isolated carotid sinus under increased pressure.

The adaptation time of the depressor reflex is largely dependent on the magnitude of the perfusion pressure. For example, the adaptation time of the reflexes when the perfusion pressure was 160 mm Hg was 4-5 times longer than when the pressure was 110-120 mm Hg. In the young animals, when the perfusion pressure in the carotid sinus was 150-160 mm Hg, the low arterial pressure was maintained for a very long time (up to 180 min). In the old animals the adaptation time of the depressor reflex was considerably shortened. In most experiments it varied between 5 and 25 min (Fig. 2).

In experiments on 32 old and young rabbits the character of adaptation of the reflexes was compared during stimulation of the chemoreceptors of the carotid sinus by hypoxic and cholinomimetic substances. For this purpose the isolated carotid sinus was perfused with solutions of nicotine, acetylcholine, and sodium sulfide. It is clear, from Fig. 3, that the adaptation time of the depressor reflex during stimulation of the receptors of the carotid sinus of the young rabbit with nicotine ($1 \cdot 10^{-4}$) was 34 min, compared with 3 min 30 sec in the case of the old rabbit.

In the next stage of the investigation the changes in the arterial pressure were compared in response to prolonged

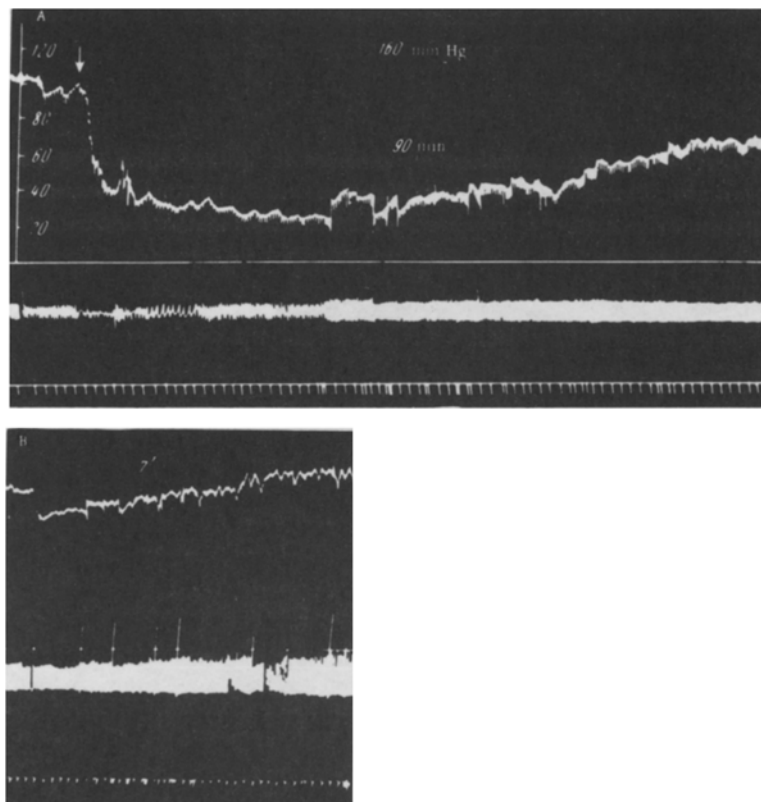


Fig. 2. Age differences in adaptation of the depressor reflex from the mechanoreceptors of the carotid sinus. A) Experiment on a young rabbit. The low arterial pressure was maintained for 90 min; B) experiment on an old rabbit. Adaptation time of depressor reflex 7 min. Legend the same as in Fig. 1.

stimulation of the aortic nerve. In 1908, Bayliss [5] originally noticed that during prolonged stimulation of the aortic nerve of the rabbit the blood pressure remains the whole time at a low level.

This fact has been confirmed by several workers [2]. It has been found that in old animals, in contrast to young, during prolonged stimulation of the aortic nerve the initial level of the arterial pressure was restored fairly quickly.

Shortening of the adaptation time of the reflexes was not observed in all the old animals. It was most often seen in response to prolonged stimulation of the receptive fields of the cardiovascular system itself. When the tibial nerve of the old animals was stimulated, adaptation developed faster in only 12 experiments. In 4 experiments the adaptation time was longer in the old animals than in the young. In 2 of these the arterial pressure fell gradually during prolonged stimulation. However, before the original level had been reached, the 2nd wave of changes in the hemodynamics and respiration appeared, lasting for several tens of minutes in individual cases. In 4 old rabbits the course of adaptation was the same as in the young animals.

In the course of phylogenesis the forms of homeostasis are perfected in animals. Among this type of adaptive reactions arising in the course of evolution may be included the adaptation of reflexes, as a result of which the original level of a function is established, despite continuing stimulation. Meanwhile, conditions exist in which the adaptation of reflexes loses its adaptive, protective character. For this reason, the shortening of the adaptation time of the reflexes in old age, in certain cases, is an important mechanism protecting the aging organism from sudden shocks,

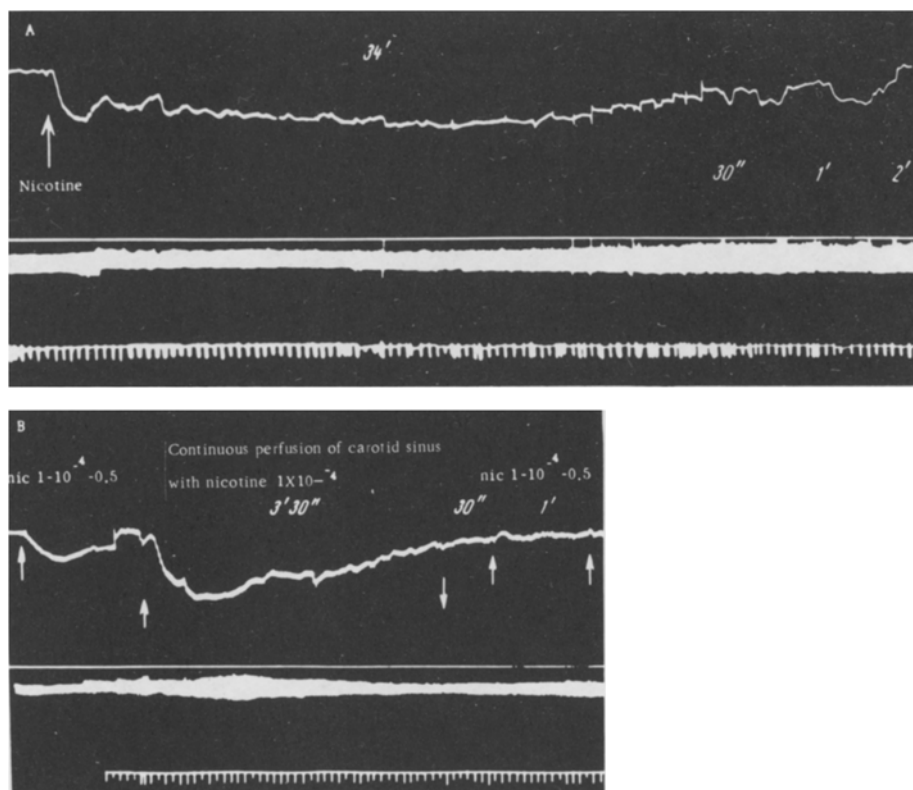


Fig. 3. Age differences in adaptation of the depressor reflex from the chemoreceptors of the carotid sinus. Perfusion with nicotine solution ($1 \cdot 10^{-4}$). A) Experiment on a young rabbit. Adaptation time 34 min; B) experiment on an old rabbit. Adaptation time 3 min 30 sec. Legend the same as in Fig. 1.

while, in others it must be regarded as a unique form of contraction of the range of adaptations of the organism to the environment.

It must be pointed out that the changes in the central nervous system maintaining a definite level of the function in the presence of adaptation of reflexes are unstable in old animals. Prolonged stimulation in such animals may lead to the development of profound depression of the function of the centers, to death of the animal, or to the collapse of a developing process of inhibition and to a permanent increase in the blood pressure.

The prolonged pressor reaction arising during compression of the carotid arteries has been called "acute hypertension" of reflexogenic character. In old animals this type of hypertension is less marked and the blood pressure in it returns to normal more quickly.

Depressor reflexes from the vascular receptors play an important role in the mechanism of maintenance of the normal level of the blood pressure. In young animals these reflex influences, to quote Bayliss, are "practically inexhaustible." In old animals their adaptation develops fairly rapidly, thereby modifying the duration of the hypersensitive reactions at this age.

SUMMARY

Experiments were made on 96 old and young rabbits and 22 cats of various ages to study the age peculiarities of adaptation of cardiovascular reflexes in prolonged stimulation of different extero- and interoceptive fields, as well as of the sensory nerves. In old animals the weakening of reflexes in prolonged stimulation of the rectum, the tibial nerve, the chemo- and mechanoreceptors of the carotid sinus and the aortal nerve had a faster onset. In such animals, prolonged stimulation may produce deep inhibition of the central functions followed by death or failure of the inhibitory process and a stable change in the blood pressure.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.
