EFFECTS OF EXPERIMENTAL EXPOSURE TO HIGH-FREQUENCY WHOLE-BODY VERTICAL VIBRATION ON THE NERVOUS SYSTEM OF ANIMALS

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The clinical manifestations and pathohistological changes in the nervous system of dogs, rabbits, and cats exposed to the acute and chronic action of whole-body vertical vibration (50 Hz, 0.8 mm, 105 dB, 4 h) were studied. In the acute experiments extensive and universal circulatory disorders developed: regional angiospasms, cerebral edema, acute swelling of ganglionic cells, vasopareses, confluent diapedetic hemorrhages into the brain and viscera. These were interpreted as reflex dyshemic disturbances of traumatic origin. In the chronic experiments, with a gradual increase in the parameters and duration of vibration marked adaptation of the neurocirculatory processes was observed initially; this was followed by the development of degenerative changes in the nerve cells and nerve trunks and changes in synaptic ultrastructure. The clinical and morphological changes observed can be explained by the development of traumatic (vibration) disease of the brain and the accompanying ascending traumatic polyneuritis.

Protection of the human body against the effects of vibration is a problem of some urgency today. Experimental, clinical, and morphological investigations of the nervous system of animals exposed to whole-body high-frequency vibration are so far few in number. The unique form of vibration disease arising through exposure to whole-body high-frequency vertical vibration has been described by a few workers [1-5].

To study the pathogenesis and sequelae of the effects of vibration special experiments were carried out with an appropriate morphological control.

EXPERIMENTAL METHOD

Acute and chronic experiments were carried out on dogs, rabbits, and cats. Whole-body vertical vibration (50 Hz, 0.8 mm, 105 dB) was used as the stimulus. The experiments were carried out in a chamber in which an experimental M-70 vibration bench was installed, and a metal cage with four compartments secured to it. Each dog was placed in a separate compartment of the cage, where they were kept in a vertical or vertically inclined position, or sitting in the usual position, standing on their hindlimbs, and so on. The rabbits were placed in their ordinary position. The animals could move about in the cages. To differentiate between the action of vibration and the mean- and high-frequency noise with an intensity of 90-100 dB accompanying it, control animals (dogs, rabbits, and cats) also were placed in the chamber, but at a distance of 1-1.5 from the vibration bench so that they were exposed only to the action of noise. Before the experiment began the animals were accustomed to their surroundings. Before and after each experiment the clinical condition of the animals (general condition, individual organs, nervous system), their behavior, the state of their excretory function, and their weight were studied.

Ordinary and special (Pickworth, Campos, etc.) staining methods were used in the histological investigations.

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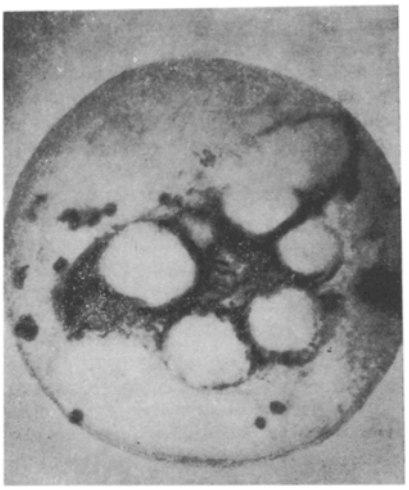

Fig. 1. Nucleus of the hypoglossal nerve in a dog. Marked vacuolation of the cell following chronic exposure to whole-body vibration.

EXPERIMENTAL RESULTS

Acute Experiment. Four dogs weighing 10-14 kg and six rabbits were exposed to vibration. The experiment continued for 4 h without interruption. The animals behaved quietly. The dogs 2.5 h after the beginning of vibration became lethargic and sleepy. After vibration has been discontinued (at the end of the experiment) the dogs showed marked general weakness, shortness of breath, tachycardia, profuse salivation and perspiration, drowsiness, and a well-marked phenomenon of "waxy rigidity of the muscles": the animals remained in whatever curious position they were put into passively. If an attempt was made to put them on their feet the animals staggered, their gait was ataxic, they did not respond to nociceptive stimulation, and hyperreflexia was observed. One dog developed intestinal bleeding. The animals regained their original state 1.5-2 h after the end of the experiment. Only one dog was thirsty and indifferent to food throughout the 24 h after the experiment. The experimental rabbits at first were restless and tried to find a way out of the cage, but later they fell into an inhibited state; toward the end of the experiment two rabbits died while the others were extremely lethargic, they did not respond to a pinprick, and their pulse and respiration rates were sharply increased. The tendon, periosteal, and defensive reflexes of the lower limbs were increased. The pulse and respiration rates returned to normal 30 min after the experiment but the animals remained lethargic, would not eat, and they were sacrificed on the 3rd day after the experiment. No pathological changes were found and there were no changes in the clinical picture of the control animals.

Postmortem examination of the rabbits which died during the experiment showed widespread venous stasis, focal hyperemia of the brain, and extensive hemorrhages into the gray and white matter. In one case a subarachnoid hemorrhage was found into the hypothalamo-infundibular region. On histological investigation of the brain foci of perivascular edema and edema of the nerve cells were found in different parts, especially in the brain stem. The walls of the blood vessels were edematous. Under the influence of a single exposure to whole-body vibration lasting 4 h clinical and morphological changes consisting of generalized disturbances of the blood and CSF circulations were produced.

Chronic Experiment. In these experiments 4 dogs, 2 rabbits, and 4 cats were used (with 1 dog, 2 rabbits, and 2 cats in the control). The experimental conditions were the same but to study the powers of adaptation of the nervous system the duration of exposure to vibration was increased to 10 days. Experiments were carried out for 4 h daily. Depending on the state of the animals, intervals of 1 or 2 days were arranged. The experiment continued for 3-4 months. During the first days of the experiments only increased thirst and briskness of the tendon and periosteal reflexes were observed. After 2 weeks the dogs became lethargic, sleepy, and indifferent to food. The rabbits moved slowly and clumsily. Three weeks from the beginning of the experiment the animals became ill: the dogs ceased to howl or to respond to being called or to their surroundings, they were asthenic, their movements were slow and uncoordinated, they showed marked ataxia, and their tendon and periosteal reflexes were increased and were elicited from a wider area. Nociceptive sensation, which at first was reduced in the hindlimbs and head, later became absent over the whole body, and liquid stools were observed periodically. Trophic disorders appeared 1.5 months after the beginning of the experiment: edema, hyperemia, infiltration of the conjunctiva. Accidental scratches on the limbs and trunk turned into sluggishly healing ulcers. After the end of 2 months some of the animals ceased to respond not only to conditioned, but also to unconditioned stimuli. The dogs did not leave their kennels, they took hardly any food, and they moved unwillingly. During the experiments one dog and one rabbit developed a state resembling collapse with the features of clinical death: the animal drooped lethargically on the floor of the cage, its eyes wandered, the pulse disappeared, the ears and limbs became cold, reflexes were depressed, atony of the muscles developed and respiration ceased. By the end of the experiments the dogs had lost up to 2 kg in weight and the rabbits and cats up to 300-500 g. The state of the control animals was unchanged.

PATHOHISTOLOGICAL INVESTIGATIONS

Postmortem examination of the experimental animals revealed a state corresponding to chronic edema of the tissues. The brain tissue was permeated with a large quantity of fluid and was less dense. In some places the looseness of structure of the brain tissue made it possible to make out individual bundles of fibers of white matter clearly. In various parts of the cerebral hemispheres and in the brain stem, especially at the base, focal hemorrhages could be seen, while in some places the ganglionic cells and swollen vacuolated cells showed gross changes of shape, sometimes curious. The response of the glia was considerably increased. Hyperchromatosis of the nerve cells was found in the spinal ganglia and degenerative changes in the peripheral nerves (Fig. 1).

In the investigation of the ultrastructure of the cells attention was focused on the state of the axon endings. Concentration of synaptic vesicles in some areas, often in the center of the synapses, was found. The number of vesicles was actually slightly increased, but their arrangement was unusual, and they appeared to be compressed. The layers of myelin in the axon were clearly seen to be broken up.

It can be concluded from the results of these experiments that a gradual increase in the intensity of vibration up to the level used in the acute experiments was accompanied by adaptation of the nervous system to the experimental conditions: slight abnormalities appeared only after 2-3 weeks, more marked changes 2-3 months after the beginning of vibration. The clinical picture on the whole can be interpreted as vibration disease developing in the manner of a traumatic disease of the brain and traumatic ascending polyneuritis.

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