MORPHOLOGICAL CHANGES IN THE NERVOUS SYSTEM DURING EXPOSURE TO VIBRATION

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Because of new technological developments in industry the possibility of exposure of the workers to vibration has increased. Vibration affects various organs and systems of the body and can give rise to pathological changes bearing the name of vibration disease. Most authors consider that lesions of the nervous system are among the more important aspects of this disease [1-3].

As long ago as in 1907 it was found [4] that during exposure of rabbits to intensive vibration the animals develop disturbances of the lymphatic and blood circulation and degeneration of nerve cells and reactive changes in the neuroglia in the lumbar region of the spinal cord which was subjected to vibration. More recently, reports have been given [5-8] of changes in various parts of the spinal cord and peripheral nerves.

This paper describes the results of an experimental morphological investigation carried out to probe more deeply into the influence of vibration on the nervous system.

EXPERIMENTAL METHOD

Experiments were carried out on 27 rabbits. The right hind limb of the animals was exposed to the action of local vibration (frequency 40 cps, amplitude 1.35 mm) for 3 h daily. To produce the vibration a special apparatus was used, constructed at the Leningrad San.-Gig. Medical Institute and consisting of a vibrator producing sinusoidal oscillations in a vertical direction, and a frame for attachment of the animal. Several series of experiment were carried out with different durations of exposure (9, 14, 29, and 90 days), after which the animals were sacrificed by air embolism and the tissue of the nervous system extracted for pathological examination. An additional series of experiments was carried out on 4 rabbits, exposed to vibration daily for 3 months, then not subjected to any form of treatment for the next 4 months, after which they were sacrificed.

Histological investigations were made of the sciatic, tibial, peroneal, and plantar nerves of the right (exposed to vibration) and left hind limbs, the muscles and skin of the leg and foot, various divisions of the spinal cord with the roots and spinal ganglia, and also the brain.

The material was stained by the methods of Nissl, Van Gieson, Cajal–Favorskii, Bielschowsky–Gros, Weigert, Marchi, etc.

EXPERIMENTAL RESULTS

Observations on the behavior of the rabbits showed that during the first 2-3 days of their stay attached to the frame the animals were excited, restless, and tried to free their paws, but on the following days they showed some degree of restlessness only from time to time. After the experiment the animals became still, and the right hind limb dragged as they moved about.

After 10-12 days most of the animals developed a bald patch on the heel of the right foot, and after one month four of the animals developed bleeding ulcers at this place. In the other animals edema of the right paw and atrophy of the muscles of the leg and the plantar muscles were observed. These trophic disturbances in the region of the right hind limb persisted throughout the experimental period. After discontinuing the vibration, they gradually disappeared (the ulcers healed, growth of the hair on the bald patch increased, the muscles of the right leg and foot increased in bulk).

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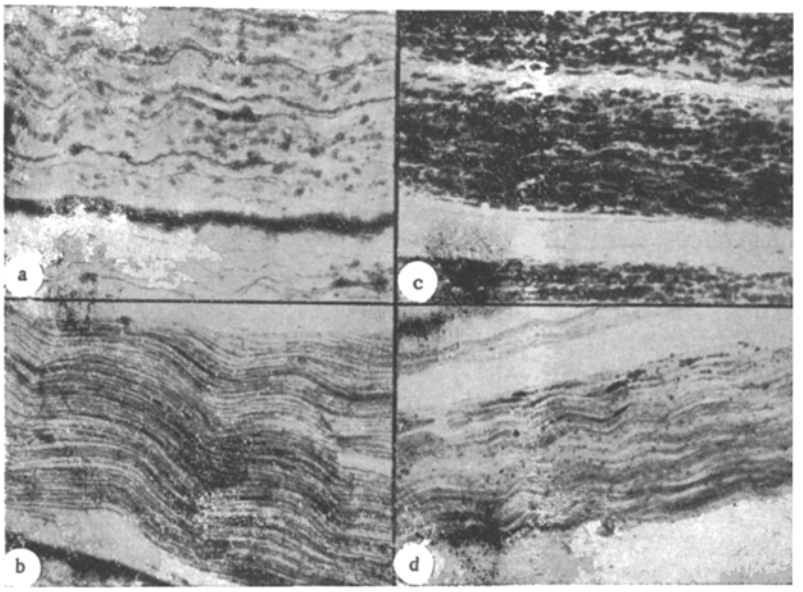

Fig. 1. Changes in the tibial nerve after exposure to vibration for 47 days. a) Decrease in the number of axons in the bundles of nerve fibers of the right tibial nerve; b) axons in the left tibial nerve; c) breakdown of myelin in the nerve fibers of the right tibial nerve; d) increase in the number of Elzholz's bodies and fragments of disintegrating myelin in single nerve fibers of the left tibial nerve. Impregnation with silver by the Cajal-Favorskii method (a and b) and stained by Marchi's method (c and d). 110×.

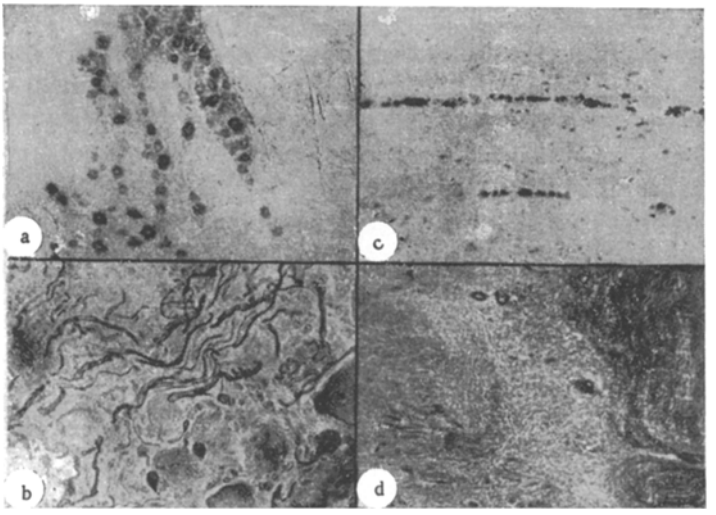

Fig. 2. Changes in sensory ganglia and the spinal cord after exposure to vibration for 50 days. a) Reactive changes in the nerve cells of a right lumbar ganglion displacement of the nucleus, accumulation of chromatophilic material around the nucleus); b) reactive changes in the dendrites of the neurons of a right lumbar ganglion (spherical swellings on the dendrites); c) degeneration of individual nerve fibers in the lateral columns of the spinal cord; d) small hemmorhages around the blood vessels in the gray matter of the spinal cord. Nissl's method (a), impregnation with silver by Cajal-Favorskii method (b), Marchi's (c) and Mallory's (d) methods. Magnification 100× (a), 450× (b), 200× (c), and 110× (d).

On microscopic investigation of the sciatic nerve and its branches to the right leg and foot of the rabbit, obvious signs of neuritis were observed. Individual nerve fibers showed degeneration and others showed periaxonal changes.

The caliber of the axons was irregular, and thick and swollen axons appeared, breaking up into fragments and granules. Areas of degenerated axons, intensively impregnated with silver, were found in the form of twisted fragments inside droplets of disintegrated myelin. In some bundles of nerve fibers the number of axons was greatly reduced (Fig. 1a).

In the initial stage of the degenerative changes in the myelin the number of Elzholz's bodies increased, and subsequently in the enlarged cytoplasm of the Schwann cells, spheres and drops of disintegrated myelin of different shapes and sizes appeared, giving a black or gray color on staining (Marchi; Fig. 1c). Depending on the intensity of the injury to the nerve fiber, the disintegration of the myelin was localized (segmental) or it extended throughout the distal portion of the nerve fiber.

Inflammatory changes were found in the sheaths of the nerves in the distal portions of the right limb of the rabbits with marked trophic changes and ulcers or edema of the foot.

A totally different picture was observed in the nerves of the left foot, not exposed to vibration. The axons in the bundles of nerve fibers remained intact (Fig. 1b) but the outlines of some of them were irregular and they were intensively impregnated with silver. The number of Elzholz's bodies showed a slight increase. Only occasional nerve fibers were found with signs of segmental demyelinization (Fig. 1d).

The neuritis was more severe in the nerves of the distal portion of the rabbit's hind limb: the plantar, tibial, and peroneal nerves, and less severe in the sciatic nerves.

In the muscles and skin of the right leg and foot, disintegration of individual nerve fibers and endings into small fragments was observed. Other medullated fibers showed periaxonal changes.

In the spinal sensory ganglia of the corresponding segments, reactive and degenerative changes were found in the nerve cells: displacement of the nucleus to the periphery, accumulation of chromatophilic material around the nucleus (Fig. 2a). In some preparations spherical swellings were seen (Fig. 2b). The changes in the nerve cells were more marked in the sensory ganglia on the right side.

In the central and dorsal roots, some of the medullated fibers showed signs of segmental demyelinization.

In the gray matter of the spinal cord, moderately severe reactive changes were found in the nerve cells of the ventral horn: an irregular distribution of chromatophilic material, displacement of the nuclei, hyperchromatosis.

In the conducting tracts of the white matter of the spinal cord the segmental demyelinization and degeneration of individual fibers were moderately severe (Fig. 2c).

In the sheaths of the sensory ganglia and the meninges of the spinal cord the blood vessels were dilated and congested. Small hemorrhages were found in the gray matter of the spinal cord (Fig. 2d).

In the brain and meninges hyperemia of the blood vessels was present, and acute swelling of individual nerve fibers was found in the olives, the cortex of the hippocampus, the Purkinje cells of the cerebellum and the nuclei of the cranial nerves.

Exposure to local vibration of definite parameters thus led to the development of lesions in both the peripheral and central nervous systems of the rabbits. Neuritis of the sciatic nerve was found, especially in the distal portions of the limb.

In the corresponding segmental centers (the spinal sensory ganglia and the corresponding segments of the spinal cord) reactive and degenerative changes of the nerve cells were present, with death of some of them, and also a well defined reaction of the neuroglia.

Degeneration of some nerve fibers in the lateral and dorsal columns of the spinal cord was observed. In the brain the vessels were hyperemic and the neurons showed reversible changes of the acute swelling type. The most severe lesions of the nerve fibers were observed 1.5 months after the beginning of exposure to vibration. After 3 months the number of nerve fibers in the initial stage of degeneration was very small and the predominant features were the presence of marked disintegration of the affected fibers and signs of regeneration of individual fibers.

In the rabbits exposed to vibration for 3 months and then rested for 4 months, besides degenerative changes in the nerves, regenerative processes were observed and these varied in their course depending on the degree of development of the neuritis.

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