MORPHOLOGICAL CHANGES IN CENTRAL AUDITORY STRUCTURES DURING PROLONGED EXPOSURE TO NOISE

A. B. Strakhov, V. I. Korshunova, and N. V. Antakova

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Subcortical and cortical neurons of the auditory system of albino rats exposed for long periods to noise were investigated. Marked morphological changes were found in the neurons in these regions. In the case of exposure lasting from 1 to 7 days the changes were most severe in the auditory cortex, but after longer exposure to noise (15-28 days) the cortical reactions were less marked while in the brain stem the reactions increased progressively.

The writers have shown previously that prolonged exposure to loud noise leads to considerable changes in higher nervous activity, in the electroencephalogram and electrocardiogram, and in hemodynamic indices [7, 8].

The morphological changes in the inner ear under these conditions have been adequately described in the literature [6, 11]. However, only a few investigations have been made of the corresponding phenomena in the central nervous system [2, 4, 5]. In all the investigations cited, the duration of the exposure to noise varied from a few minutes to 2 h.

No data could be found on morphological changes in the structures on the central nervous system following prolonged and continuous exposure to acoustic stimulation.

In the investigation described below an attempt was made to determine the character of the morphological changes taking place in nerve cells during continuous exposure for many days to noise and to identify the levels of the central auditory system at which these reactions are most marked and the regions of the brain where the most enduring changes develop.

EXPERIMENTAL METHOD

Experiments were carried out on 20 albino rats which were exposed to the continuous action of noise the intensity of which was 94 dB when determined by means of the Soviet Sh-3 LIOT noise meter. The frequency characteristics of the noise were determined by a type ASh-2M analyzer. The noise used was of the wide-band type, with a maximum of acoustic energy at frequencies of 1500-3000 Hz, i.e., it could be classed as high-frequency noise.

All the animals were subdivided into five groups, each consisting of three experimental animals, depending on the duration of exposure to noise. The exposures were of 1, 3, 7, 15, and 28 days. An additional 5 rats constituted the control group, not exposed to noise.

The animals were sacrificed immediately after the end of the exposure to noise by rapid decapitation under superficial ether anesthesia. The control rats were dealt with in the same way. The brain was re-

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TABLE 1. Dynamics of Number of Changed Neurons (M ± m) in Different Parts of the Central Auditory System in Albino Rats during Different Periods of Exposure to Noise

Dur. of exp. to noise (in days)	Dorsal cochlear nucleus	Inferior colliculi	Medial geniculate body	Auditory cortex Control
1	17,7±0,9	13,3±1,2	13,7±1,2	15,7±1,8
	32,2±3,0	17,8±6,0	21,1±2,3	36,1±3,0
t	4,7	0,7	2,8	5,8
P	<0,001	>0,2	<0,05	<0,001
3	32,0±5,4	18,5±4,1	19,8±5,2	34,8±5,5
t	2,6	1,2	1,1	3,3
P	<0,005	>0,2	>0,2	<0,02
7	37,7±5,0	35,1±5,2	29,5±3,0	33,3±4,8
t	3,9	4,0	4,8	3,4
P	<0,01	<0,01	<0,01	<0,02
15	47,5±3,4	29,2±4,4	30,7±5,7	29,7±1,4
t	8,5	3,4	2,9	6,0
P	<0,001	<0,02	<0,05	<0,001
28	46,7±6,0	37,7±1,5	39,8±1,1	22,3±3,5
t	4,7	13,9	16,2	1,6
P	<0,01	<0,001	<0,001	>0,1

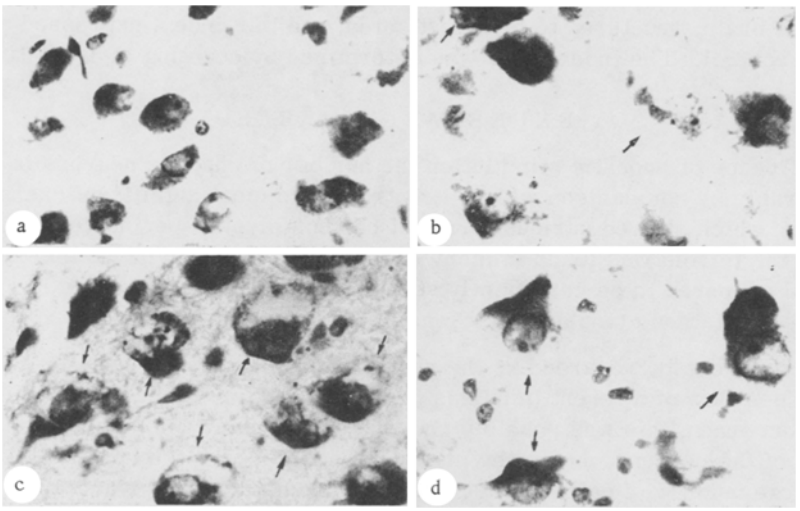

Fig. 1. Changes in neurons of the auditory cortex after exposure to noise for different periods: a) control; b) exposure for 7 days to noise: perinuclear chromatolysis visible in many cells; c) exposure for 15 days to noise: cells with evidence of peripheral chromatolysis and with two nucleoli in their nucleus can be seen; d) exposure for 28 days to noise: number of changed cells is less than at preceding periods. Nissl, 400×.

moved from the skull, fixed in 50° ethanol, and passed through a series of alcohols of increasing concentration, after which it was embedded in paraffin wax. Frontal serial sections were then cut to a thickness of 15 μ. The sections were stained by Nissl's method with 0.1% thionine solution. Subsequently the cells of specific brain structures were studied. The dorsal nuclei of the cochlear nerve (the tubercula acustica), inferior colliculi, medial geniculate bodies, and auditory cortex were investigated. In the structures of the rats' brain bearings were taken from Craigie's atlas [9].

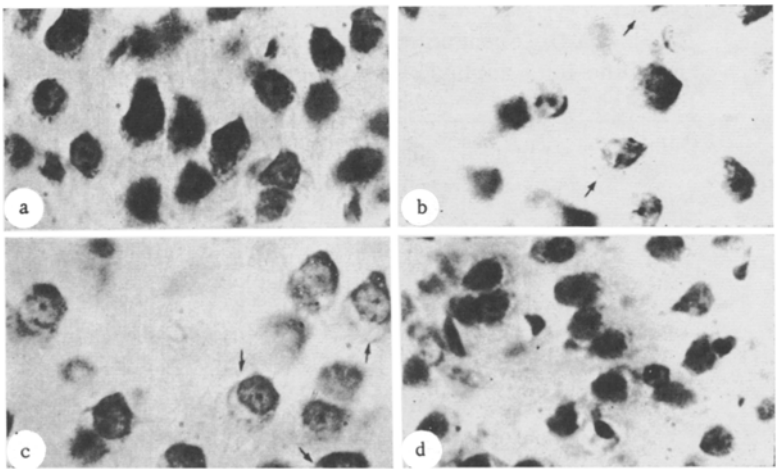

Fig. 2. Changes in neurons in dorsal cochlear nucleus after exposure to noise for different periods: a) control; b) exposure for 7 days to noise: neurons with deformed nuclei and also ghost cells are visible; c) exposure for 15 days to noise: cells with marked chromatolysis and vacuolation of the cytoplasm can be seen; d) exposure for 28 days to noise: segmental chromatolysis visible in many cells. Nissl, 400×.

In the brain of the control animals a certain number of modified neurons could always be found, their presence not being indicative of pathology [1, 4]. For this reason the number of changed cells was determined in each of the brain structures to be investigated, and this index, expressed as a percentage, was compared with the control. The index itself was determined by counting at least 100 neurons in each region.

EXPERIMENTAL RESULTS

Under the influence of acoustic stimulation the number of changed neurons in the experimental animals rose considerably by comparison with the control. The most significant changes were those affecting the Nissl substance, which showed various forms of chromatolysis: perinuclear, peripheral, or total. Segmental lysis of the tigroid was found in many of the cells. In many cases the chromatolysis was so severe that the cell appeared to be very faintly stained, and numerous ghost cells appeared. The number of neurons with deeply stained cytoplasm also was increased.

These phenomena can be regarded as the result of increased functional activity of the cell under the influence of an intense flow of afferent impulses [1, 3, 10]. So far as the increase in number of hyperchromic cells is concerned, this was possibly connected with the development of an inhibitory state in a certain proportion of the neurons, due to the prolonged action of the stimulus. This could also explain the appearance of a large number of cells with peripheral chromatolysis, for according to Klosovskii and Kosmarskaya [3], the development of a state of inhibition of a neuron is accompanied by displacement of chromatin into the perinuclear layers and by its intensive staining.

Besides reactions of the Nissl substance, changes affecting the nuclei and nucleoli also were observed in the experimental animals. The number of cells with the nucleus situated at the periphery was increased, and in some cases the nucleus was fragmented or pycnotic in shape. Cells with 2 or 3 nucleoli were encountered much more often than normally. These were considered to be a sign of restorative processes after the period of increased cell activity.

The changes described above differed in degree in different parts of the brain, largely depending on the duration of exposure to noise.

With shorter periods of exposure to noise (from 1 to 7 days) the most marked morphological changes were found in the auditory cortex, especially in layer II (Fig. 1). The reactions observed in the structures of the brain stem were less clearly defined, although they increased in intensity with an increase in the duration of the period of acoustic stimulation.

With longer exposures to noise (15-28 days) the changes taking place in the cerebral cortex became progressively less marked, while those in the subcortical structures (medial geniculate body, inferior colliculi, dorsal cochlear nucleus) gradually increased in severity (Fig. 2).

The dynamics of the changes in neurons in different parts of the auditory system after different periods of exposure to noise is shown in Table 1.

It must be considered that the intensive influx of afferent impulses into the cortex, giving rise to a traumatizing effect, occurs only during the first days of exposure to noise. Later, as a result of blocking of these ascending influences at the subcortical level, as the writers demonstrated previously by electrophysiological investigations, their influx into the higher levels of the central nervous system is reduced, so that restorative processes can take place in them. On the other hand, the morphological changes arising in the structures of the brain stem become progressively more marked through the continued action of the acoustic stimulus.

These differences in the localization of morphological changes during exposures of different duration to noise and their concentration in the subcortical structures after longer exposures would appear to be of great practical significance.

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