A SINGLE VIBRISSAL COLUMN IN THE FIRST SOMATOSENSORY CORTEX OF THE MOUSE DEMONSTRATED WITH 2-DEOXYGLUCOSE

J. CHMIELOWSKA and M. KOSZUT

Department of Neurophysiology, Nencki Institute of Experimental Biology
Pasteura 3, 02-093 Warsaw, Poland

Key words: vibrissal column, somatosensory cortex, mouse, 2-deoxyglucose

Abstract. Single functional column activated by stimulation of C3 vibrissa was visualized in the mouse somatosensory cortex with 2-deoxyglucose autoradiography. The column was cylindrical in shape and extended through the entire cortical thickness. The darkest labeling was found in layer IV, over the anatomical C3 vibrissal barrel. The functional column stretched horizontally over parts of adjacent barrels. A zone of low 2-deoxyglucose uptake surrounded the densely labeled area and covered the rest of the posteromedial barrel subfield.

Vibrissae, the long sinus hair of the face, are important tactile organs of many mammals (10). In some rodents the sensory pathway from the vibrissae to the somatosensory cortex has unusual cytoarchitectonic structure at each of its levels. In the trigeminal nuclei, the ventrobasal nucleus of thalamus and in the first somatosensory cortex the neurons are grouped into discrete cellular aggregates (1, 9, 10, 13). The orderly arrangement of the large vibrissae on the muzzle (five rows of five whiskers) is mimicked by this peculiar cytoarchitecture — the cellular aggregates are also arranged in rows, each corresponding to the row of vibrissae. At the cortical level these structures, observable in layer IV of the first somatosensory cortex of rats and mice, were given the name of vibrissal barrels and the region where the largest barrels, corresponding to the long mystacial vibrissae were found was called
postero medial barrel subfield (PMBSF) by Woolsey and Van der Loos (13). A one-to-one correspondence between barrels and contralateral vibrissae was found in the single unit recording by Welker (11).

The discreteness of the vibrissal pathway, which isolates the input from one whisker, transferring the punctuate receptor organ into punctuate cortical representation, helped in visualization of a single vibrissal cortical column in a rat with 2-deoxyglucose (2DG) autoradiography, a method for mapping functional activity of the brain (2-4, 8). We describe here such cortical column in the mouse, based on a vibrissal barrel of different neuronal structure than that of the rat (13).

The 2-deoxyglucose experiment according to Sokoloff et al. (8) was done on 3 mice. The animals were restrained on a padded block and all vibrissae, except the centrally situated whisker 3 of row C on both sides of the muzzle were clipped close to the skin. Stimulation of the vibrissae was manual (by stroking with a fine brush in all directions) in two mice and mechanical (deflecting in the rostral direction with 8 Hz frequency) in one animal. The stimulation begun 2 min before the intraperitoneal injection of [14C] 2-deoxy-D-glucose (New England Nuclear, specific activity 15 μCi/mmol) 16 μCi per 100 g body weight in 0.3 ml saline. After 45 min of stimulation the animals were killed by an overdose of chloral hydrate and gently perfused through the heart with 3.3% formaline in phosphate buffer. The brains were dissected and frozen in isopentane cooled on dry ice. Two brains were positioned so that the plane of the section was tangential to the barrel field in the cortex and one was sectioned in the coronal plane. The 20 μm sections were cut on the cryostat (Slee) at −18°C picked up on room-temperature coverslips and quickly dried on a hot-plate (65°C). The sections were put on X-ray film into X-ray cassettes and exposed for two weeks. The autoradiograms were developed for 5 min at 18°C in X-ray film developer. The sections were later counterstained with thionine for histological identification of the barrels (2).

We found that stimulation of a single vibrissa, whether manual or mechanical, produces a focal dense labeling in the somatosensory cortex. On autoradiograms of tangential sections (Fig. 1) the spot of increased 2DG uptake was observable in all cortical layers, being faint in layer I and lower layer VI. The darkest labeling was found in layer IV. By superimposing the autoradiograms with the histological sections from which they were obtained it was found that the localization of the area of increased 2DG uptake corresponded to the site of the C3 barrel, that is to the barrel which is the cortical representation of the C3 vibrissa. The area of heavy labeling could therefore be considered to be a functional cortical column, centered on the appropriate barrel.
The column extended beyond the sides of the C3 barrel into the septa and parts of the adjacent barrels, particularly C2 and C4. Thus we suggest that the postulated (11) one-to one relationship between the peripheral receptor and the cortical barrel should be weakened. Our results confirm the electrophysiological data which found that there

Fig. 1. Autoradiogram of tangential 20 μm section through right hemisphere at the level of layer IV showing the densely labeled C3 vibrissal column. White arrows indicate the borders of the surrounding light zone.

Fig. 2. Autoradiogram of coronal 20 μm section showing one labeled C3 vibrissal column in each hemisphere. Black arrows point to the columns, white arrows indicate the borders of surrounding light zone.
is a divergence of activation from a single vibrissa and that it is greater along the row of barrels than across the rows (6, 7). Similar relation between the dimensions of the vibrissal column and barrel was found in the rat (5). On the autoradiograms obtained from the sections taken in the coronal plane the entire functional cortical vibrissal column could be observed (Fig. 2). Again, histological verification found that the labeled column overlied the C3 barrel and extended into parts of adjacent barrels. The column had a cylindrical shape, with darkest labeling corresponding to layer IV level. This shape was different from the spindle shaped vibrissal C3 column observed in the rat (3, 4).

On both transegential and coronal sections a lighter zone, with 2DG uptake lower than in the other parts of the cortex was observed, around the activated column. The borders of this zone were found to correspond to the borders of PMBSF. Small barrels in the anterior part of the barrel field were situated outside that zone and had higher intensity of labeling. This lighter zone was observed around the column in cortical layers IV to VI. Its appearance could be due either to the fact that all whiskers except C3 were cut off and the activity of their cortical representation was reduced or to the suppressive influence of the only stimulated vibrissa over the activity of the rest of PMBSF.

The vibrissal cortical system of the mouse is a good subject for functional activity mapping. Its anatomical discretness at all stages of the ascending sensory pathway facilitates the study of functional circuitry. The possibility of identifying easily the exact locus of cortical representation of the peripheral receptor should help in understanding the functioning of the cortical column. Experiments with improved resolution of the 2DG technique, by using the tritiated isotope, are in progress.

The authors are indebted to Peter Hand for a generous gift of 14C 2-deoxyglucose. The project was supported by the Polish Academy of Sciences grant No. 10.4.01.1.


1 A lighter zone surrounding the activated functional column was also observed on autoradiograms of coronal sections by H. van der Loos (personal communication).


Accepted 14 December 1983