Structural Asymmetry of Motor Speech Areas 44 and 45 in Human Cerebral Cortex during Postnatal Ontogeny

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Cytoarchitectonics of motor speech areas 44 and 45 of human brain was studied during postnatal ontogeny. Hemispheric asymmetry of some cytoarchitectonic indexes and volumes of the cortex and the number of neurons in these structures was revealed. The presence of stable and unstable types of morphological markers of hemispheric asymmetry in human brain that change the sign of asymmetry during various periods of ontogeny is hypothesized.

Key Words: *human brain; asymmetry; ontogeny; cytoarchitectonics*

Interhemispheric asymmetry of the brain first studied by P. Broca [6] and other investigators is still of considerable interest. The left hemisphere is involved in speech functions, and the right hemisphere plays the major role in spatial and temporal processes. Functional asymmetry of the brain and neuronal organization of the right and left hemispheres are extensively studied. However, the problem of structural asymmetry of human brain received little attention. There are only few reports concerning the asymmetry of macroscopic structures of human brain and some cytoarchitectonic areas [1-5,7,9]. The following questions remain unclear: which structural signs characterize functional asymmetry of the brain, when they are formed during ontogeny, and whether all cytoarchitectonic markers reflect the interhemispheric lateralization of brain functions?

Here we studied structure and development of motor speech areas 44 and 45 and the motor speech region of the left and right cerebral hemispheres during postnatal ontogeny. Particular attention was given to specific cytoarchitectonic features of Broca's areas in the left and right hemispheres, volumes of motor speech areas 44 and 45, and the number of neurons in these regions at various ages.

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MATERIALS AND METHODS

Serial frontal slices of brain hemispheres of a neonate, children (2, 7, and 12 years), and 30-year-old adult were examined. A total of 11 brains (22 hemispheres) were examined. Slices (20 μ thick) were stained with cresyl violet by a modified procedure (Institute of Brain). Each 40th or 80th slices were examined. The volume of structures and the number of neurons were determined by stereological methods proposed by H. B. M. Uylings [8,10]. The coefficient of tissue shrinkage was considered during the quantitative analysis of results. Boundaries between motor speech areas and adjacent structures were determined using an MBS-9 microscope and then transferred to slice projections. Topographic cytoarchitectonic maps of areas 44 and 45 were reconstructed on the lateral surface of cerebral hemispheres.

RESULTS

Motor speech areas of a newborn were well differentiated. Some signs of asymmetry were observed in studied structures of the left and right hemispheres. In the left cerebral hemisphere, areas 44 and 45 were characterized by more distinct radial stratification and greater width of the cortex and layer III than in the right hemisphere (Fig. 1). Cytoarchitectonics of these structures intensely developed at the age of 2 years. In the left hemisphere (compared with the right hemi-

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sphere), radial stratification was more gracile, and areas 44 and 45 displayed a higher variability in the rostrocaudal direction. At the age of 7 years, cytoarchitectonics of area 45 also exhibited rostrocaudal changes more pronounced in the left hemisphere. In a 7-year-old child, areas 44 were more symmetrical in both hemispheres than areas 45. At the age of 12 years, area 45 in the left hemisphere was characterized by a greater structural variability. Area 44 had a more typical cytoarchitectonics in the left hemisphere than in the right hemisphere, where it was characterized by a higher neuron density and predominance of small cells. In adult, area 45 in the left hemisphere was characterized by a greater width of the cortex, distinct layers and sublayers, and a more gracile radial stratification compared to the left hemisphere (Fig. 2). Cytoarchitectonics of area 45 changed in the rostrocaudal and ventrodorsal directions. The ventrodorsal variant of area 45 was characterized by a more gracile radial stratification and less pronounced horizontal stratification, neurons were elongated, and layer III^3 was less distinct in cross-sections of the cortex. Area 44 of the left hemisphere was characterized by distinct radial stratification, low density of neurons, and clear boundaries between layer IV and adjacent layers. In the right hemisphere, we revealed a cytoarchitectonic similarity between area 44 and adjacent areas, so structures and boundaries between them are difficult to differentiate.

In a neonate, volumes of areas 44 and 45 in the left hemisphere were greater than in the right hemisphere (Table 1). During the period from the birth to 2 years, areas 44 and 45 intensely developed, this development continued to 7 years. Thus, the absolute volumes of areas 44 and 45 in the left hemisphere increased to a greater extent than in the right hemisphere.

At the age of 12 years, motor speech areas 44 and 45 were completely formed, and their volumes in the left hemisphere were greater than in the right hemisphere.

In adult, volumes of cortical layers of areas 44 and 45 in the left hemisphere surpassed that in the right hemisphere (Table 1).

The data suggest that the more advanced development of the right motor speech Broca's area in newborns enables emotional perception of mother and human voices. The intense development of area 45 from the birth to 2 years is due to formation of speech functions (children begin to speak some words and phrases). In our experiments, the Broca's area had greater volume in the right hemisphere. It was probably due to the fact that during the first 2 years of life a

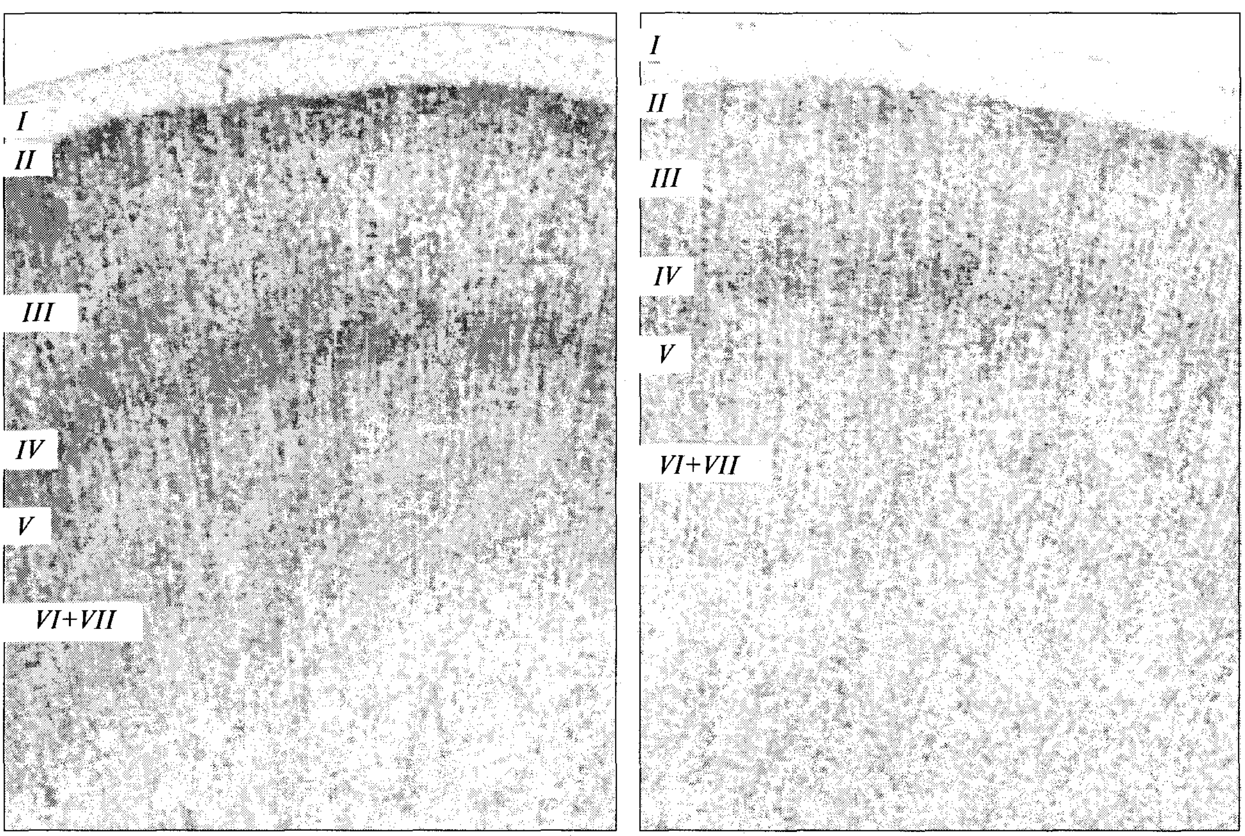

Fig. 1. Cytoarchitectonics of cortical area 44 in newborn. Here and in Fig. 2: left (*a*) and right (*b*) hemispheres; *I-IV*, cortical layers (×45, cresyl violet staining).

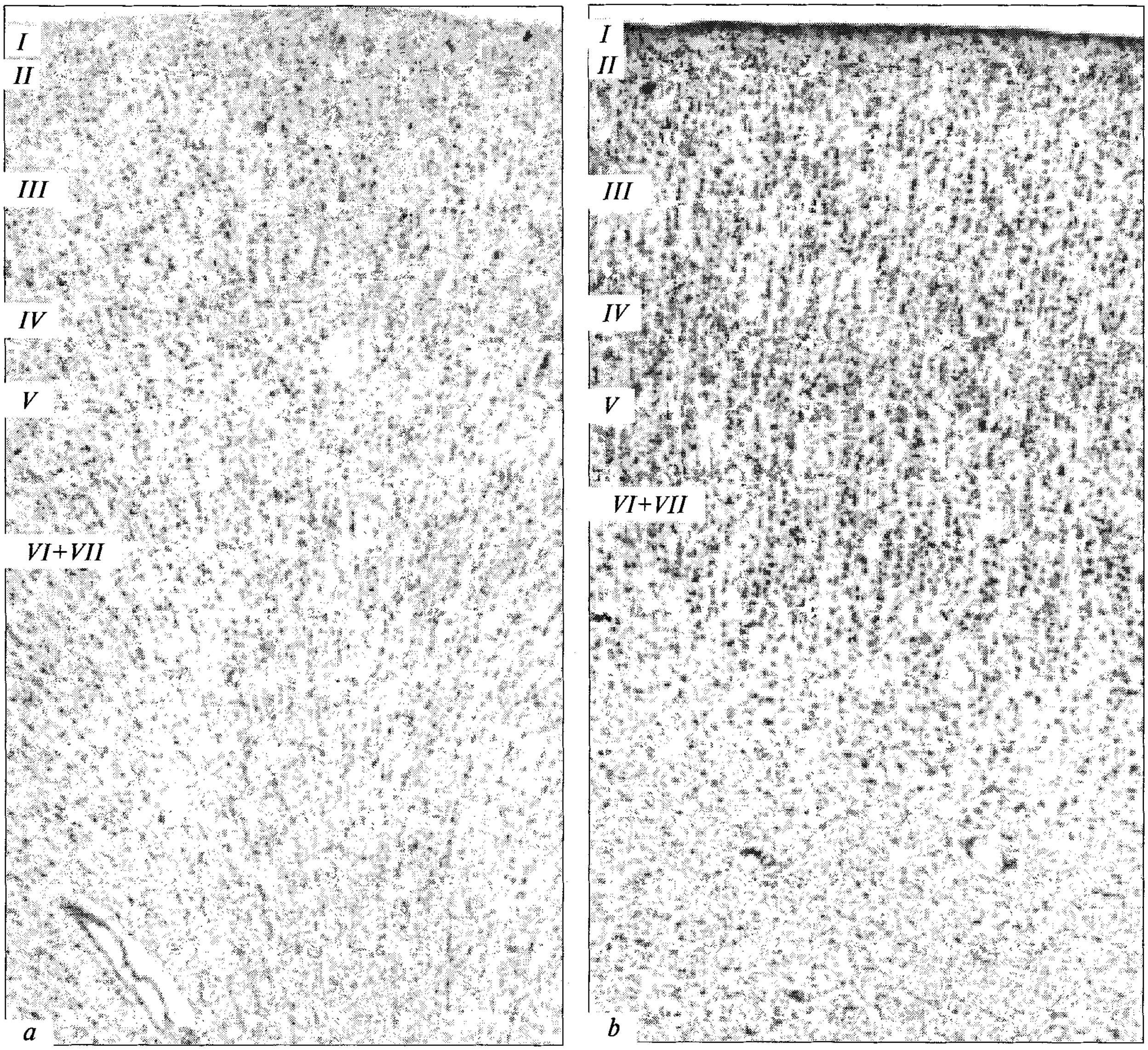

Fig. 2. Cytoarchitectonics of cortical area 45 in newborn.

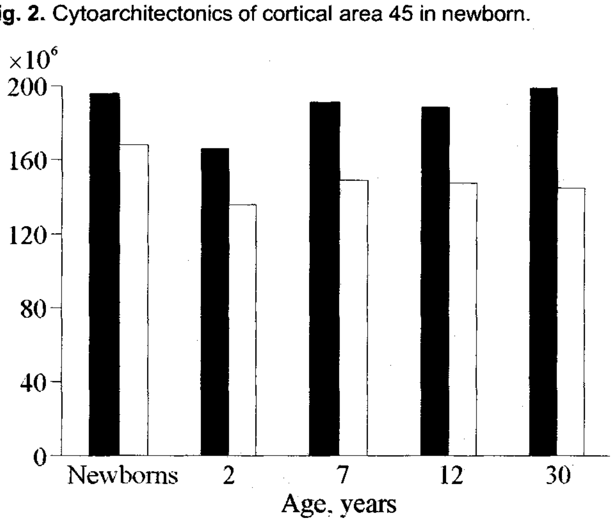

Fig. 3. Number of neurons in area 45 in the left (dark bars) and right (light bars) hemispheres of human brain.

child generally perceives the emotional state of peoples and particular intonations. The first years of life is the stage of differential perception and passive understanding of speech, when the right hemisphere dominates. These data suggest that the right hemisphere is involved in the formation of speech functions. Therefore, the terms "subdominant" and "silent" should not be used in relation to the right hemisphere.

At the age of 2-7 years, area 45 continued to develop, and its volume increased to a greater extent than that of area 44, especially in the left hemisphere. During this period, the left hemisphere plays a more important role, because children above 2 years begins to speak, and their speech serves for verbal communication. This corresponds to the formation of the left-side hemispheric lateralization and motor dominance of the right hand.

At the age of 7-12 years, the development of areas 44 and 45 was not so intensive as before, and their

TABLE 1. Parameters of Motor Speech Areas 44 and 45 in Individuals of Different Age

Age, years	Area 44, cm³		Area 45, cm³	
	right hemisphere	left hemisphere	right hemisphere	left hemisphere
Newborn	1.38	0.81	1.65	1.48
2	1.95	2.15	4.89	3.67
7	2.75	3.09	5.71	6.38
12	3.37	3.76	6.18	8.17
30	3.65	4.15	6.71	9.56

volumes increased insignificantly. It should be emphasized that we revealed left-hemisphere asymmetry of motor speech regions in studied brain samples. Speech functions, image-verbal associations, expressive speech, reading, and pronunciation continue to develop during this period. Thought processes become more objective providing a knowledge about things and their properties. A child recognizes combinations and categories of objects and participates in various types of activity at school, home, and in games.

The number of neurons in cortical areas 44 and 45 of human brain during postnatal ontogeny was higher in the left hemisphere than in the right hemisphere (Fig. 3).

Thus, investigations of the motor speech centers during postnatal ontogeny revealed right hemispheric asymmetry of their volume in newborn and 2-year-old children. At the age of 7 years, the sign of asymmetry changed, and left-side dominance of the volume of Broca's areas was established.

The number of neurons in motor speech areas 44 and 45 is a stable marker demonstrating the left hemispheric dominance during postnatal ontogeny.

Our findings indicate that structural asymmetry of human brain should be characterized by a series of complex parameters.

Two types of morphological markers of human brain hemispheric asymmetry are hypothesized. Type I stable signs of structural asymmetry of the motor speech center are genetically programmed, develop during prenatal ontogeny, and contribute to the left hemispheric dominance of motor speech cortical areas 44 and 45. Type I morphological markers also include more complex structure, distinct cytoarchitectonic boundaries, and great number of neurons in cortical areas.

Type II unstable signs of structural asymmetry probably depend on the development of structures. The volume of cortical formations reflecting structural asymmetry of the motor speech center dominates in the right hemisphere during the early postnatal ontogeny. When the sign of dominance changes, this volume becomes prevalent in the left cerebral hemisphere. These data indicate a mosaic pattern of various markers of brain structural asymmetry and complex processes of formation of cytoarchitectonic hemispheric asymmetry.

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