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CT of the Normal Brain in Preterm Infants

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Twenty-two normal preterm and 10 full-term infants were studied by cranial computed tomography. The study included correlation of the gestational age and birth weight to the ventricular size, brain size, and the area of the sylvian fissure. The most relevant parameters were the bifrontal diameter, bifrontal index, and the transverse diameter of the brain. The incidence of visualization of the sylvian fissure diminished with gestational age. Density measurements revealed the high cortical sections had a higher average density than the whole brain sections. The parietooccipital region showed an increasing average attenuation during the preterm period until term.

One of the most important features of the perinatal period is the high incidence of central nervous system insult. This is particularly true in preterm infants [1]. There are a few reports describing the normal dimensions of the brain and their relation to the gestational age [2], but no age-dependent criteria are yet available for objective evaluation of normal and abnormal findings for the brain in premature infants. With computed tomography (CT), we tried to define the normal morphologic pattern of the brain of preterm infants and compare it with the normal full-term pattern.

Materials and Methods

We reviewed the CT scans of 22 preterm and 10 full-term infants reported as normal from among 100 CT head scans of high-risk neonates from the neonatal unit of Cairo University Hospital in Egypt. All cases were examined within 4 days after birth and thereafter followed for a minimum of 2 weeks to exclude the possibility of intracranial affection. A full clinical appraisal (including birth weight, head circumference, and gestational age [3]) was obtained for each infant.

The babies were divided clinically into three groups: (1) seven cases, 29–33 weeks gestation (very premature); (2) 15 cases, 34–37 weeks gestation (premature); and (3) 10 cases, 38–41 weeks gestation (full-term).

CT scanning was done by the second generation ACTA scanner 200 F.S. Sections were 8 mm thick with 8 mm increments at 10° from the orbitomeatal line. No sedation was needed to perform the scanning.

In all cases the size of the brain was assessed by measuring the transverse and longitudinal diameters of the cerebrum. The sylvian fissure was measured at its widest part. The quadrigeminal cistern was measured across its anteroposterior diameter. Lateral ventricles were assessed by measuring the widest part of the bifrontal horns. The bifrontal index figures were obtained by dividing the bifrontal horn diameter by the coronal diameter of the brain at that level. The bicaudate index figures are the dividend of bicaudate diameter/coronal diameter at that level. The bioccipital index is the dividend of bioccipital horn diameters/transverse diameter at that level. The brain density in Hounsfield units was measured by computing the mean density of the brain tissue in four intermediate slices and comparing that figure with the mean density in the highest two sections of the brain, which we assumed represented the cortex or gray-matter density. The densities in different regions (i.e., frontal, parietal, and occipital) were calculated and compared with those of the brainstem region by the means of regions of interest (ROIs) of not less than 70 pixels.

Results

Size of the Brain

The mean transverse diameter of the brain was found to correlate significantly with the various gestational age groups at the levels $p < 0.05$ and $p < 0.002$ (table 1). A linear coefficient correlation of $r = 0.83$ was found between the transverse diameter of the brain and birth weight (fig. 1). The relation between skull circumference and transverse diameter of the brain was found to be highly significant ($r = 0.93$; fig. 2). The mean longitudinal diameter of the brain was found to be insignificant in relation to gestational age in the very premature infants (less than 34 weeks); however, this correlation was significant for infants born from 34 weeks to full term ($p < 0.002$; table 1). The longitudinal diameter of the brain significantly correlated with the weight of the infants ($r = 0.87$) and weakly correlated with the skull circumference ($r = 0.6$; fig. 3).

Sylvian Fissure and Quadrigeminal Cistern

The incidence of visualization of the sylvian fissure diminished with gestational age (table 2). There was no significant correlation between the size of the sylvian fissure or the quadrigeminal cistern and the gestational age or birth weight. The subarachnoid space could not be diagnosed as dilated in any of the cases.

Ventricles

A significant linear coefficient correlation was found between the gestational age and both the absolute length of the bifrontal horn diameter and the bifrontal index figure ($r = 0.76$, $r = 0.7$; figs. 4 and 5, respectively). The bifrontal index was found to be significantly correlated with the birth weight ($r = 0.8$; fig. 6). However,

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TABLE 1: **Transverse and Longitudinal Diameters of the Brain and Widths of Sylvian Fissure and Quadrigeminal Cistern According to Gestational Age**

Term of Pregnancy in Weeks (No. of Cases)	Transverse Diameter (mm)	Longitudinal Diameter (mm)	Sylvian Fissure (mm)	Quadrigeminal Cistern (mm)
29–33 (7):				
Range	63–69	88–106	35–103.6	3.6–5.4
Mean	66.3*	90.8	55.9	4.0
SD	±2.5	±12.3	±22.3	±1.5
34–37 (15):				
Range	62–87	86–99	17.2–162	3–9
Mean	71*	90.5*	61.6	5.4
SD	±6.3	±65.0	±38.1	±1.8
38–41 (10:)				
Range	82–104	97–133.2	37–64.8	3–6.4
Mean	87.4*	105.6*	54.1	5.0
SD	±8.8	±10.5	±11.9	±0.1

* = Significant.

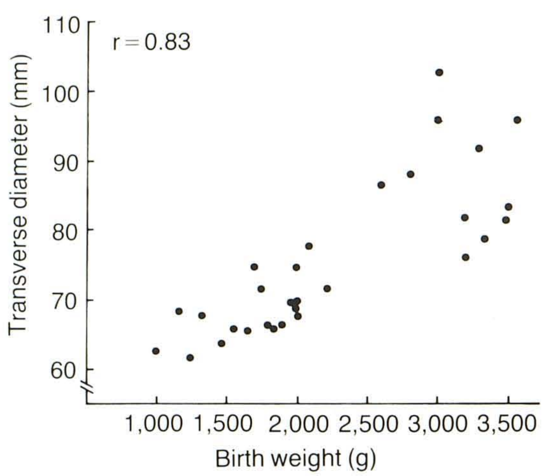

Fig. 1.—Relation between birth weight and transverse diameter of brain.

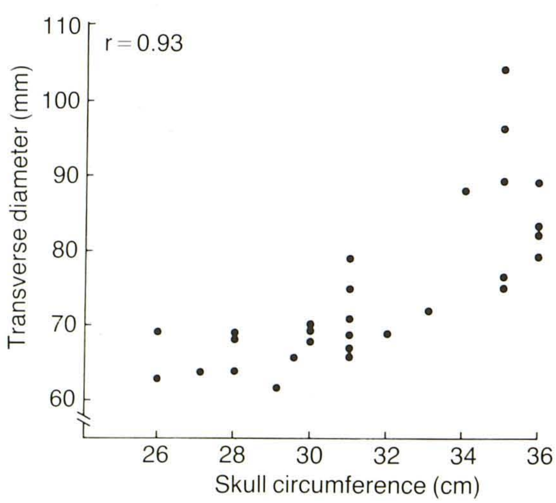

Fig. 2.—Relation between skull circumference and transverse diameter of brain.

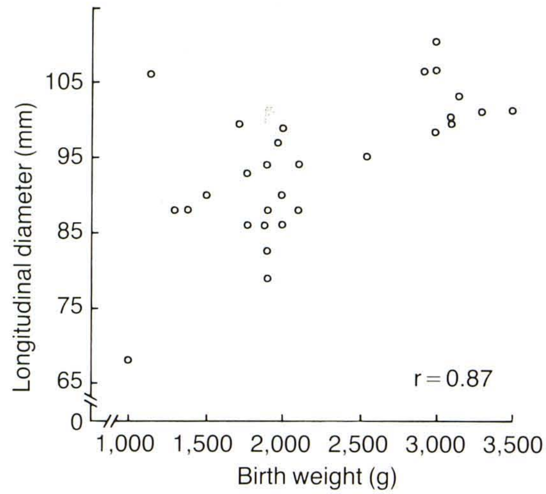

Fig. 3.—Relation between longitudinal diameter of brain and birth weight.

TABLE 2: **Percentage Visualization of Third and Fourth Ventricles, Sylvian Fissure, and Quadrigeminal Cistern**

Term of Pregnancy (wks)	Sylvian Fissure	Quadrigeminal Cistern	Third Ventricle	Fourth Ventricle
29–33	100.0	71.4	71.4	71.4
34–37	80.0	93.0	53.3	60.0
38–41	40.0	100.0	60.0	70.0

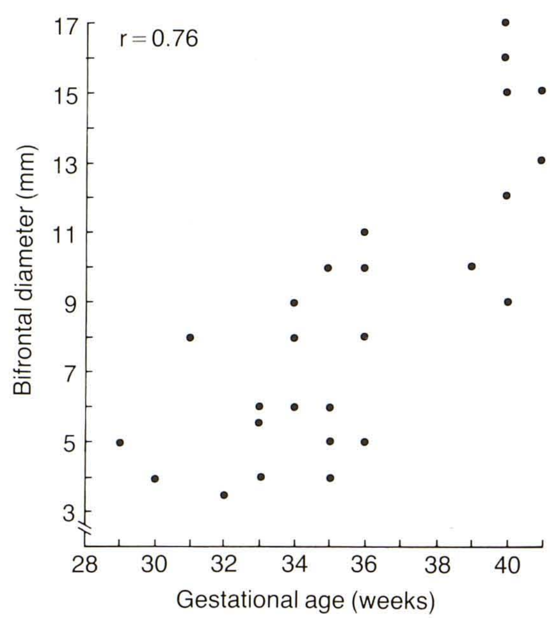

Fig. 4.—Relation between gestational age and bifrontal diameter.

this correlation with the absolute width of the bifrontal horn diameter was insignificant. No significant correlation was found between the bicaudate or bioccipital diameter and the gestational age or birth weight. The percentage of visualization of third and fourth ventricles in all cases is summarized in table 2. There was no significant

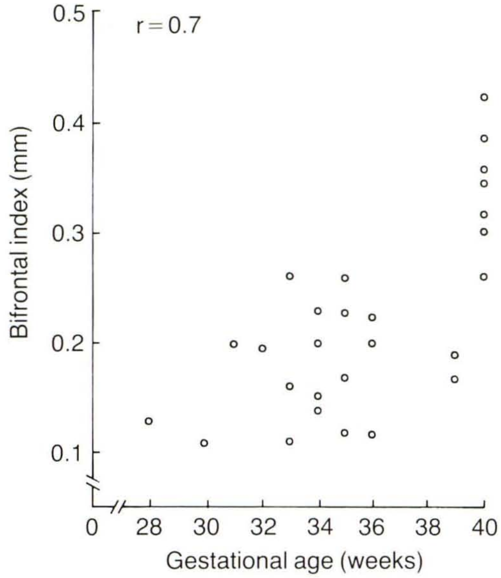

Fig. 5.—Relation between bifrontal index and gestational age.

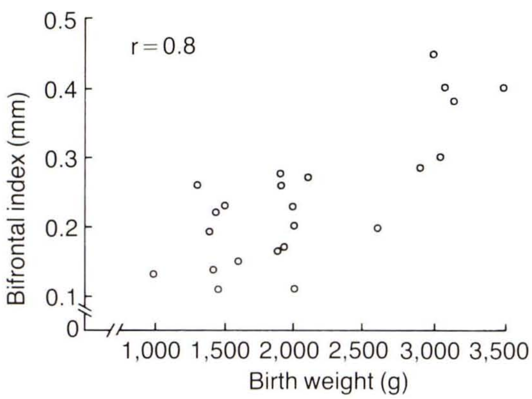

Fig. 6.—Relation between bifrontal index and birth weight.

correlation between the size of the third and fourth ventricles and the gestational age or birth weight.

Density of the Brain

There was a constant difference between the mean density of the brain in the high cortical sections (which might represent the gray matter) and that of all other sections (which represents the whole brain density) in all groups from 29 to 41 weeks. This mean differential density did not increase by gestational age or birth weight.

Discussion

Few CT reports are available on age-related changes in the brain of the preterm neonate. Baron et al. [4] and Fukuyama et al. [5] studied some measurements of the brain of full-term infants at various postnatal ages. Picard et al. [2] reported the cerebral CT appearance of preterm infants. Quencer et al. [6] measured the density of the brain in newborn baboons.

In our study, the mean transverse diameter of the brain was found to be highly correlated with head circumference, gestational age, and birth weight; but the mean longitudinal diameter of the brain was found to correlate significantly with birth weight and gestational age only after age 34 weeks. We therefore suggest that transverse diameter of the brain provides a better parameter to evaluate the increase in the size of the brain; however, Picard et al. [2] have also noted the progressive regular increase in the length of the cerebral hemisphere with gestational age.

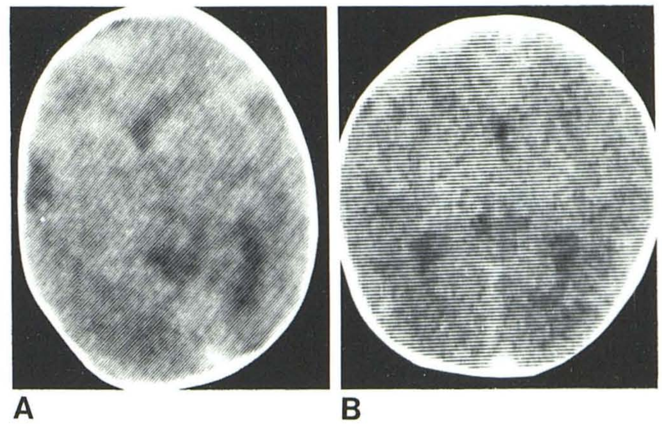

Fig. 7.—**A**, Preterm, 29 weeks. Nonhomogeneous brain density. Asymmetric frontal horns, widened sylvian fissure and quadrigeminal cistern. Subarachnoid space not visualized. **B**, Preterm, 34 weeks. Slightly homogeneous brain density. Frontal horns barely measured. Occipital horns capacious and symmetrical. Widened quadrigeminal cistern. Narrow nonvisualized subarachnoid space.

Sylvian Fissure and Quadrigeminal Cistern

Our finding of diminished visualization of the sylvian fissure with increasing age might be explained anatomically by the development or growth in size of the temporal and parietal lobes. However, the insignificant correlation between the size of the sylvian fissure and birth weight or gestational age could be attributable to the difficulty of and inaccuracy in detecting density variations at the borders of the sylvian fissure. Moreover, measurements of the area of the sylvian fissures vary greatly (from 17.2 to 162 mm^2), which could invalidate the statistical correlation.

The subarachnoid space was not detected in any case. This observation contradicts other authors [2, 5] who have reported the width of the subarachnoid space in preterm and full-term infants. This and other cerebral features of preterm neonates are shown in figure 7.

Ventricles

The positive correlation of the bifrontal index of the lateral ventricles with age and weight of infants, and the negative correlation of the absolute bifrontal horn diameter with the weight of the infants indicate that growth of the lateral ventricle is in relation to the age and not the weight of the infant. We may therefore consider the bifrontal index as one of the most accurate methods of assessing the development of the brain. The absence of a significant relation for the bicaudate and bioccipital indices with birth weight or age might be explained in part by the difficulty of measuring the short bicaudate diameter, and the marked variability and asymmetry of the posterior horns of the lateral ventricle.

Brain Parenchyma

In preterm infants aged less than 34 weeks (very premature), the brain parenchyma appears heterogenous, with patchy areas. This is probably caused by poor differentiation of the brain tissue. We also observed a small difference of the mean density between the two highest sections (cortical slices) and the mean density of all other sections of the brain (which presumably represent the whole brain density).

In this study we considered the brainstem density as the reference for attenuation coefficient comparison in different parts of the brain. Differential density measurements in various parts of the brain in the preterm infant show equal attenuation values for the frontal region and the brainstem. The parietooccipital area shows an average 2.3 Hounsfield units of lower density. At term, the average density of the frontal region is 1 unit lower than that of the brainstem, and that of the parietooccipital area is 1 unit higher. Thus, the average density of the parietooccipital region during the preterm period increased over the average density of the frontal region by more than 4 H. This may be a reflection of the fact that the brain of the fetus differentiates in a caudocephalic pattern until term [7], with the consequent increase in the density of the parietooccipital areas being due to a more active myelination process.

Quencer et al. [6] found that the newborn baboon had a density gradient between the frontal and parietooccipital regions. The frontal white matter was less myelinated and was hypodense compared with the white matter of the parietal and occipital zones. They reported the myelination of the full-term baboon was similar to that of full-term human infants. That the brain of neonates is 90% water may account for the nonhomogeneity and poor demarcation of white and gray matter [8]. We may assume that further differentiation between gray and white matter occurs gradually. Developmentally, the growth of the brain attains only one-sixth of its capacity before term, and human growth spurts are mainly postnatal [9]. Penn et al. [10] concluded that the change in attenuation by CT during the first year of life is due mainly to water shift and decreased water content; the dry components of the brain have only a complementary role. Due to this high water content in the brain of the neonate, we suggest that the water shift has not occurred in the preterm period, and that the attenuation gradient in premature infants is due to the myelination process.

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