Area of lateral ventricles measured on cranial ultrasonography in preterm infants: reference range

Elie Saliba, Philippe Bertrand, Francis Gold, Marie C Vaillant, Jean Laugier

Abstract

Serial ultrasound imaging of the brain was carried out in 87 preterm infants of 27 to 36 weeks' gestational age while they were in the special care nursery and during their first postnatal year. None had evidence of intracranial disease during the neonatal period and 94% had good neurodevelopmental outcome at 2 years of age. Lateral ventricle area measurements were plotted against independent variables including postnatal age and head circumference at the time of the examination. The measurements increased as age and head circumference increased. During the first six weeks of life the mean (SD) postnatal head circumference growth velocity (rate of growth) was 0.53 (0.13) cm/week and the mean postnatal ventricular area growth velocity was 0.39 (0.19) mm²/week.

A reference range for lateral ventricle area values was developed from these serial measurements in infants with documented good short term developmental outcome.

Real time ultrasonography is now used extensively for the detection of cerebral injuries during the neonatal period. There have, however, been few ultrasound studies of the normal size of the lateral ventricles in preterm infants.¹

In this longitudinal study of cranial ultrasound scans, we report direct measurements of the lateral ventricular body measured by the ventricle area. This study was carried out during the first year of life in neurologically normal preterm infants. The purpose of this report is to provide reference values that can be used in the evaluation of these neonates.

Patients and methods

Between October 1984 and July 1986, preterm infants of 27–36 weeks' gestational age, who survived for the duration of the study were followed up prospectively in a longitudinal neurosonographic and clinical study. These infants were of normal weight for gestational age; Apgar score was 7 or more at five minutes. None of them had periventricular or intraventricular haemorrhage, periventricular leucomalacia, or any other abnormality on ultrasound scans carried out during the first two weeks of life, seizures, sepsis or infection of the central nervous system, or hyperbilirubinaemia requiring exchange transfusion. Infants with birth asphyxia, hydrocephalus, or congenital anomaly were excluded from the study. If needed, intensive care was provided in keeping with current concepts of thermal, metabolic, and ventilatory

control. Nutrition in very low birthweight infants was provided by orogastric tube feeding of human milk or formula feed of 2.814 MJ/l.

ULTRASOUND SCANS

Infants were prospectively scanned with an Advanced Technology Laboratory (Bellevue) mechanical sector scanner and 7.5 MHz transducer. Scanning was carried out through the anterior fontanelle in the coronal and parasagittal planes, initially within 48 hours of birth, then daily during the first week of life and thereafter once a week for six weeks. Further scans were carried out serially at 4, 6, and 9 months, and—if the anterior fontanelle was still open—at 12 months. The coronal sonographic plane was used to measure the area of the lateral ventricles at the level of the mid-body in their occipital part just before they diverge. The plane of measurement was standardised by the alignment of the bodies of the lateral ventricles, the hippocampal gyri, and the pons that produce a vertical echogens band between the hippocampal gyri (fig 1). In a previous study we described the neuroanatomical landmarks that give the sonographic correlation to determine this plane. The measurements made at this level showed little interobserver error.²

Measurements were made using a digitising table (Numonics) connected to an Apple IIE personal computer. The instrument was calibrated at each of the five field settings. The images were enlarged by reference to the calibration, and the area enclosed by the lateral ventricles was calculated. Three measurements of the left and right lateral ventricle area were made at each study by a single examiner. The averages of the left and right area from each study were recorded for the analysis. The SEM of the successive measurements were less than 3%, suggesting that the reproducibility of the method was acceptable. The coronal and parasagittal images were examined for evidence of periventricular or intraventricular haemorrhage or periventricular leucomalacia. All images were evaluated independently by two specialists in paediatric ultrasonography.

MEASUREMENTS OF HEAD CIRCUMFERENCE

During each sonographic scan and clinic visit, the occipitofrontal circumference was measured with a paper measuring tape.

NEURODEVELOPMENTAL ASSESSMENT AND FOLLOW UP

Gestational age was determined from maternal

Institut de la Santé
et de la Recherche
Médicale (INSERM),
Unité 316, Tours,
France
Philippe Bertrand
Francis Gold
Marie C Vaillant

Department of Paediatric
Intensive Care
and Neonatology
Elie Saliba
Jean Laugier

Correspondence to:
Dr Elie Saliba,
Paediatric Intensive Care,
CHRU Centre de Pédiatrie,
49 Boulevard Béranger,
37000 Tours,
France.

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dates and by the score developed by Dubowitz *et al.*³ The babies were then examined by medical staff not concerned in the neonatal care at the ages of 4, 6, 9, 12, 18, and 24 months. The follow up examinations consisted of detailed neurological examination and an assessment of development using the Brunet-Lezine psychomotor development scale corrected for gestational age. This test is a French adaptation of the Gesell and Amatruda scale.^{4 5} The items of the Brunet-Lezine test include assessment of posture, oculomotor coordination, language, and sociability. Evaluations of vision and hearing were also made. Neurodevelopmental outcome was classified as: normal; moderate neurological abnormalities (transient abnormality of tone); developmental delay (developmental quotient less than 80); cerebral palsy (spastic diplegia, quadriplegia, or hemiplegia); and neurosensory impairment (auditory or visual impairment). The results of the repeated neurological examinations between 18 and 24 months of age were the criteria for the presence or absence of neurodevelopmental abnormalities.

Figure 1 (A) Coronal ultrasound image at the level of the mid-body of the lateral ventricle; and (B) measurements obtained by digitising the ventricular area.

DATA ANALYSIS

Postnatal growth velocity (rate of growth) of occipitofrontal circumference and ventricular area, which is the slope of growth as a linear function of time of examination for each infant, was calculated. Regressions of occipitofrontal circumference on postnatal age, and of ventricular area on postnatal age, were calculated by considering the slope for each subject and then averaging the slopes. Linear regression analysis ($y=ax+b$) by pooling all the data in the whole sample ($n=87$) was used to evaluate the relation of ventricle area to gestational age, occipitofrontal circumference to postnatal age, and ventricle area to occipitofrontal circumference. Data are reported as mean (1SD), and a probability of <0.05 was accepted as significant.

Results

Eighty seven preterm infants were included in the study. The birth weight, gestational age, and clinical details are shown in tables 1 and 2.

OCCIPITOFRONTAL CIRCUMFERENCE IN RELATION TO POSTNATAL AGE

The relation of occipitofrontal circumference to postnatal age was significant ($r=0.80$; $p<0.0001$; occipitofrontal circumference = 0.44 postnatal age + 28). The average of the slopes was 0.43 (0.12) cm/week. The mean postnatal growth velocity during the first six postnatal weeks was 0.53 (0.13) cm/week.

VENTRICULAR AREA IN RELATION TO POSTNATAL AGE

There was no variation in initial ventricular area as a function of gestational age at birth. ($r=-0.027$; not significant). The mean birth ventricular areas ranged from 7.4 (3.6) mm^2 at 27 weeks' gestation to 8.5 (4.5) mm^2 at 36 weeks' gestation (not significant). For the rest of the study, therefore, ventricular area variation was calculated as a linear function of postnatal age. The mean (SD) at each postnatal age of examination is shown in fig 2. The average of the slopes was 0.34 (0.2) mm^2/week . The mean postnatal growth velocity during the first six postnatal weeks was 0.39 (0.19) mm^2/week . For

Table 1 Birth weights and gestational ages of 87 infants (51 girls and 36 boys)

Birth weight (g)	No of infants	Gestational age (weeks)	No of infants
800-1000	6	27-30	8
1001-1500	19	31-32	20
1501-2000	26	33-34	24
2001-2500	20	35-36	35
2501-3100	16		

Table 2 Details of 87 infants studied

Clinical details	No of infants
Hyaline membrane disease	26
Transient respiratory distress	26
Idiopathic apnoea	23
Patent ductus arteriosus	12
Assisted ventilation	34

the first six postnatal weeks the means (SD) for change/week in ventricular area, compared with the data from the first week, were 1.04 (2.05), 2.8 (2), 3.3 (2.7), 5 (3.7), and 5.84 (4) mm²/week, respectively.

VENTRICULAR AREA IN RELATION TO OCCIPITOFONTAL CIRCUMFERENCE

The relation of ventricular area to occipitofrontal circumference was significant ($r=0.55$; $p<0.0001$; ventricular area=0.75, occipitofrontal circumference=12). Figure 3 shows the regression line and 95% confidence intervals of the mean.

NEURODEVELOPMENTAL OUTCOME

The mean (SD) developmental quotient between 18 and 24 months was 101.7 (5). Five

Figure 2 The mean (SD) of ventricular area at each postnatal age of examination.

Figure 3 Mean lateral ventricular area and head circumference in 87 preterm infants showing the regression line (—) and 95% confidence intervals of the mean (---).

of the 87 children who were initially thought to be normal had developmental delay (developmental quotient=0.77 (0.01)). Five had transient abnormality of tone. None had cerebral palsy or neurosensory impairment.

Discussion

The accuracy of cranial ultrasonographic measurements of brain ventricles has previously been established.^{6,7} There is a close relationship between ventricle size measured by this technique and by computed tomography.⁸ Most of the ultrasonographic studies of normal ventricle size in high risk neonates use transaxial width of the lateral ventricles and brain hemispheres.^{9,10} The static images in these studies were obtained with a linear array transducer that transmits the ultrasound beam through the relatively thin temporoparietal region of the cranial vault in young infants. Using a 7.5 MHz sector scan that produces images with an angle of 90°, we found it difficult to obtain reproducible measurements with similar accuracy to those in the transaxial plane.

To calculate the ratio of transventricular diameter:intracranial hemidiameter, or transcranial diameter, a strong echo of the inner table of the skull is necessary. This is not always possible using real time sector scanning. The explanation lies in the fontanelle size which, in some cases, may not allow adequate transducer contact. Despite widespread use of various types of ratios, we believe direct measurement of the lateral ventricles is more accurate. Growth cannot be monitored reliably using a ratio, and abnormalities of both ventricle and cortex may not show as an abnormality when expressed as a ratio. Furthermore, when ventricular dilatation occurs, there is an increase in volume of cerebrospinal fluid, and linear measurements do not reflect this change. To date there are no data for the measurement of the cerebral ventricular system other than the lateral ventricles. The third ventricle is not usually seen on coronal scan if it is normal, and it must be dilated to be seen clearly. The fourth ventricle is difficult to measure because of its complicated shape and poor delineation on ultrasonography.¹¹ We chose to evaluate ventricular size on coronal scans quantitatively through the bodies of the lateral ventricles because of the reproducibility of these views. Such measurements are now possible using the echo analyser of most portable real time units.

We found no significant variation of initial ventricular area in relation to gestational age. One explanation is that during the first few days of life the lateral ventricles are small and slit like, and may be difficult to image. Their entire outline is often not seen on ultrasonography, rendering direct measurements unreliable. Sauerbrei *et al* reported that the lateral ventricles averaged 8.6 mm (range 9 to 11) in width between 25 and 35 weeks' gestation in normal preterm infants, with no variation as a function of gestational age.¹² By the end of the first week of life a rapid increase in ventricular size occurs, probably in association with the increase in the volume of cerebrospinal fluid. Changes from

the fetal low pressure to the neonatal high pressure circulatory state that occur during this transitional period may possibly be accompanied by changes in the secretion or reabsorption, or both, of cerebrospinal fluid.

During infancy, increase in occipitofrontal circumference correlates well with increase in intracranial volume¹³ and cellular brain growth.¹⁴ The close relationship between the size of the lateral ventricles and the occipitofrontal circumference suggests that both variables change at a similar speed during extrauterine growth. By using a combination of measurements of occipitofrontal circumference and ventricular area it is possible to monitor changes in ventricle size in high risk preterm infants.

The most useful reference points for postnatal ventricle growth in preterm infants are established with knowledge of the subsequent developmental outcome of these infants. In our study, 94% of the infants had good outcomes at 2 years of age. The five infants with developmental delay (defined by a developmental quotient of less than 80) were not excluded from the study because neurologically they were no different from the rest of the sample. On the other hand, the relatively low developmental quotient (0.77) observed during this stage of the mental development of premature infants may be transitory and may not reflect definitive developmental retardation.¹⁵

These postnatal reference ranges developed for preterm infants who have good outcomes at 2 years should be used as the appropriate standards for growth of lateral ventricles.

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