Paul K. Kleinman, M.D.
Joseph L. Zito, M.D.
Robin I. Davidson, M.D.
Vassilios Raptopoulos, M.D.

# The Subarachnoid Spaces in Children: Normal Variations in Size[1]

**Intra- and extraventricular subarachnoid spaces in children were studied by high-resolution computed tomography. Scans were reviewed of 34 patients who were selected as highly likely to have normal scans. Sizes of the ventricular system and the seven extraventricular subarachnoid compartments were analyzed and graded on a subjective scale from 0 (not visible) to 4 (markedly enlarged). Data were also analyzed by age group (greater or less than 2 years of age). The subarachnoid spaces were found to be both larger and more variable in size before the age of 2 years and to be quite uniform thereafter. Based on these findings, it is inadvisable to base specific diagnoses during the first 2 years of life solely upon modest enlargement of the subarachnoid spaces.**

**Index terms:** Children, central nervous system • Subarachnoid space, computed tomography

**Radiology 147:** 455-457, May 1983

HIGH-RESOLUTION cranial computed tomography (CT) provides highly accurate assessment of cerebrospinal fluid (CSF)-containing spaces. Considerable variability in the size of the ventricular and subarachnoid spaces has been detected when employing pneumoencephalography, and these observations have been applied to the interpretation of CT images (1, 2). Though the variability in ventricular size with age has been studied (3), no systematic examination has been carried out of the total intra- and extraventricular subarachnoid spaces in children as detected by high-resolution CT. It is essential to define the normal variations in size of the CSF-containing spaces; these must be differentiated from pathologic processes manifested by an increase in CSF volume.

## METHODS

CT scans were obtained using a GE 8800 unit. In small infants, 5-mm contiguous sections were obtained from the foramen magnum to the vertex; in older children, 10-mm contiguous sections were obtained.

The CT scans and clinical records were reviewed on 304 patients under 6 years of age seen at the University of Massachusetts Medical Center during a 24-month period. In an attempt to select only normal scans, all patients with neurological conditions that might be expected to produce an alteration in CSF space size were excluded (*i.e.*, no patients were included who had abnormal head circumference, delayed growth and development, evidence of increased intracranial pressure, central nervous system infection or neoplasia, persistent altered state of consciousness, or progressive or uncontrolled seizures). All CT scans that demonstrated focal parenchymal abnormalities were excluded. Lastly, no newborns were included in this study because of the great difficulty in determining the extent of neurological disease based on clinical findings.

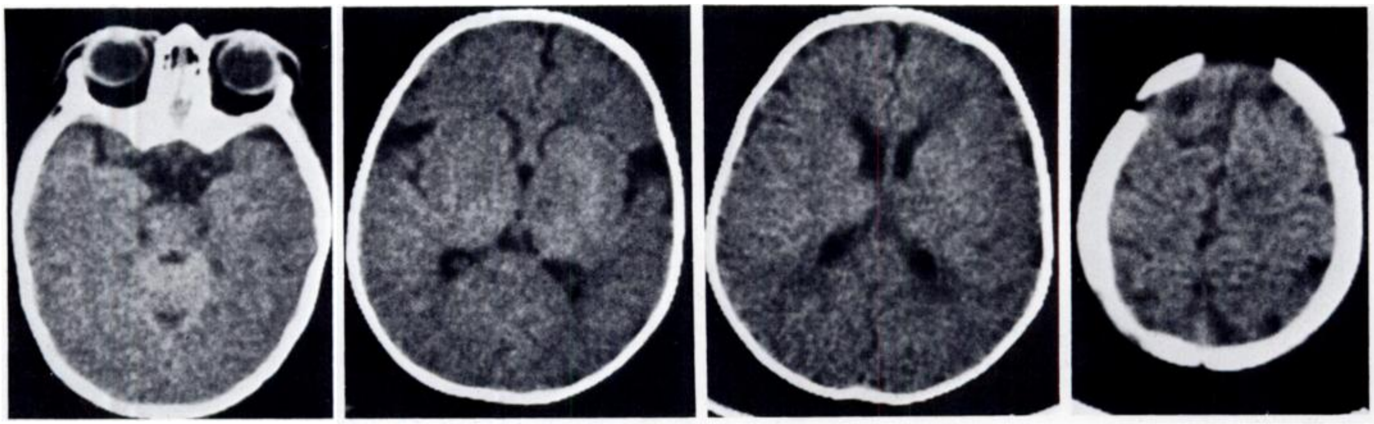
Employing these stringent criteria, a total of 34 scans of 34 patients was selected and reviewed. The sizes of the ventricular system and the seven extraventricular subarachnoid compartments were analyzed (TABLE I). Each space was graded on a scale of 0 to 4, with 0 being "not visible" and 4 representing "marked enlargement." Representative examples are depicted in Figure 1. This subjective, rather than quantitative, method was selected because it seemed to resemble most closely the manner in which scans are assessed clinically. The statistical analysis was performed employing the Student t test.

## RESULTS

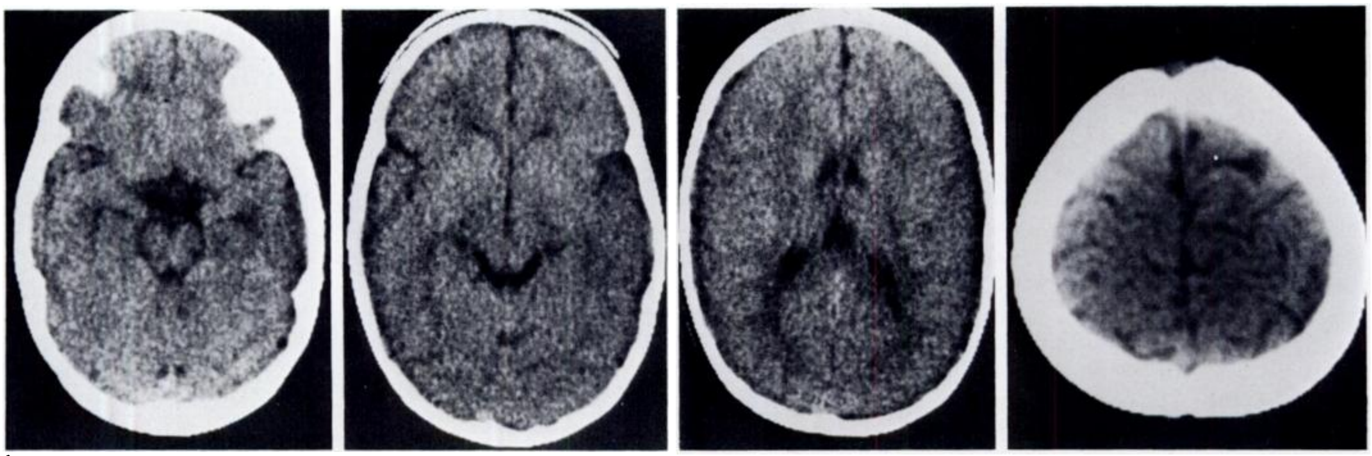
The patient population was divided into two groups: Group 1—less than 2 years of age; Group 2—greater than 2 years of age. For both groups, the average number of spaces graded 0, 1, 2, and 3 per child was determined (no patient received a grade of 4). These averages were calculated for the total CSF spaces (13 spaces), as well as for the ventricles (6 spaces), the extraventricular spaces (7 spaces), and the cortical sulci (2 spaces). The data were then tabulated and appear in TABLE II.

[1] From the Departments of Radiology (P.K.K., J.L.Z., V.R.) and Neurosurgery (R.I.D.), University of Massachusetts Medical Center, Worcester, MA. Presented at the Sixty-seventh Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL, Nov. 15-20, 1981. Received June 29, 1982; accepted and revision requested Sep. 9, 1982; revision received Oct. 29, 1982. ht

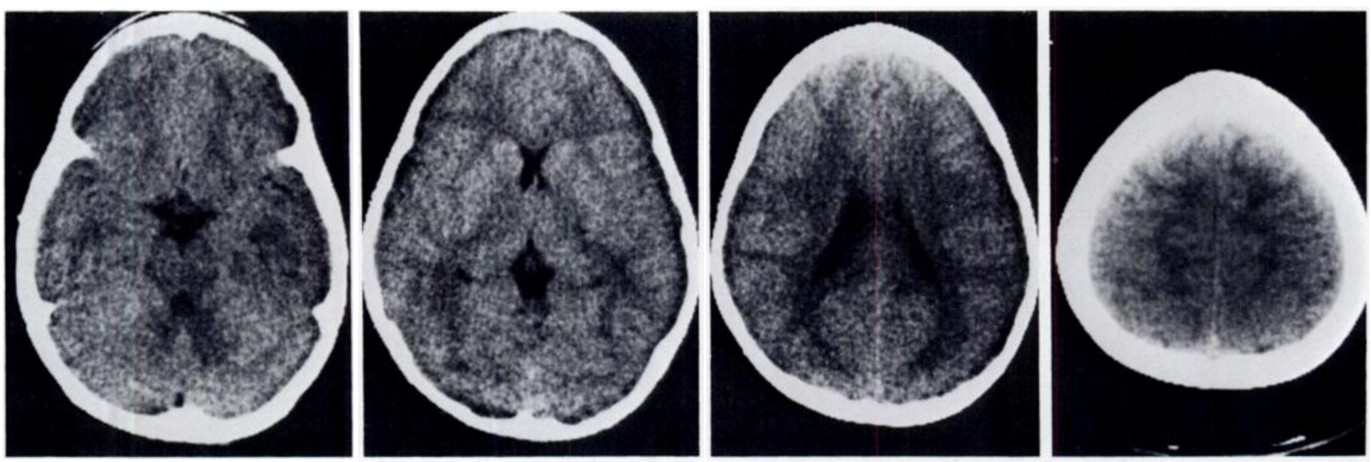
Figure 1



a.



b.



c.

Representative scans and assigned grades at four comparable levels in three children.

a. 2 months. Body, lateral ventricles (BLV)—2, frontal horns (FH)—1, occipital horns (OH)—2, temporal horns (TH)—0, third ventricle (III)—1, fourth ventricle (IV)—1, cisterna pontis (CP)—2, suprasellar cistern (SC)—2, sylvian fissure (SF)—2, cortical sulci (CS)—2, interhemispheric fissure (IHF)—2.

b. 13 months. BLV—1, FH—1, OH—1, TH—1, III—1, IV—1, CP—1, SC—2, SF—1, CS—1, IHF—1.

c. 42 months. BLV—1, FH—1, OH—1, TH—0, III—1, IV—1, CP—1, SC—1, SF—0, CS—0, IHF—0. Sections through cisterna magna and CP angle cisterns not illustrated.

TABLE II shows that the total intracranial CSF volume is greater before 2 years of age than after. Statistically, the average patient in Group 1 had significantly fewer spaces graded 0 than did patients in Group 2 ($p < .001$) and more spaces graded 2 than patients in Group 2 ($p < .002$). Though the number of spaces graded 3 was small, their frequency was greater in Group 1 than in Group 2 ($p < 0.58$). In a separate analysis of the extraventricular spaces, again there were significantly fewer spaces graded 0 in Group 1 ($p < .001$) and more spaces graded 2 for Group 1 ($p < .02$). Sulci graded 0 were rare under age 2, and no sulci were graded above 1 in patients over age 2. The ventricular size appeared to be somewhat greater during the first 2 years of life, approaching that seen in young children after age 2.

## DISCUSSION

In the preCT era, Harwood-Nash and Fitz described enlargement of the subarachnoid spaces during infancy, indicating that enlargement of the basilar cisterns and cortical sulci is frequently a normal finding during the first 6 months of life (1). More recently Fitz has used CT to observe enlargement of the cortical sulci, concluding that the enlargement is definitely normal until 6 months of age and perhaps up to a year (2). Fukuyama *et al.* attempted to measure both ventricles and extraventricular subarachnoid spaces in a group of patients from birth to 40 years of age (4). Their assessment of these spaces was somewhat limited because of the resolution of their scanner, but their conclusions indicate normal prominence of the subarachnoid spaces through 1 year of age and probably to age 2.

Using a high-resolution scanner, the present study confirms the variability in the size of the subarachnoid spaces during the first 2 years of life. These spaces were found to be largest during infancy, and by age 3 approached the appearance noted in older children and young adults. Beyond age 2, a monotonous uniformity in the appearance of the subarachnoid spaces was evident.

The pattern of subarachnoid space enlargement seen in some of the younger children in this study is similar to that described in patients who have macrocephaly with head growth parallel to a normal growth pattern. Of 15 patients described by Pettit *et al.*, eight demonstrated normal neurological development and normal follow-up (5). This pattern was identical to that seen in the seven patients who demonstrated neurological abnormalities. Thus, the authors concluded that this enlargement of the extraventricular subarachnoid spaces with normal or slightly enlarged ventricular size was a benign condition that did not require surgery. Their findings are in agreement with those of others and suggest that, at least in some patients, the subarachnoid space enlargement is a benign condition, if not a normal phenomenon (6–8). The observation of a wide range in CSF space size in children under 2 years of age in our series would tend to support that conclusion. Though it is uncertain why this expansion of the subarachnoid spaces seems to be present only during infancy and early childhood, it is possible to speculate based upon some known facts of brain development.

The development of the cerebral gyri begins in the latter part of gestation, and maximal gyral growth occurs between 0 and 2 years of age (9). The enlargement of the sulci noted in our patients was most evident during the first 24 months of life; thus enlargement of the brain and development of the gyral pattern is accompanied by an increase in the size of the subarachnoid spaces surrounding these structures. This expansion of the CSF spaces may be a response to the growing brain, and when maximum growth is achieved at approximately 2 years of age, a gradual decrease in sulcal size would be expected. Beyond this age, the sulci would be barely evident, an observation made in the present study.

With an understanding of these normal size variations during the first 2 years of life, it is inadvisable to base specific diagnoses solely upon modest enlargement of the subarachnoid spaces. Diffuse enlargement of the subarachnoid spaces may raise the consideration of a generalized alteration in CSF dynamics, and a regional enlargement of a subarachnoid space may suggest a variety of localized anatomic alterations. Beyond the age of 2, the spaces are predictably small and, thus, more reliable conclusions can be drawn. In infants and young children, a series of head circumference measurements and a thorough understanding of the clinical findings, including growth, development, and neurological abnormalities, are essential if meaningful CT interpretations are to be made.

**Acknowledgments:** We wish to thank Marilyn Shapleigh for her assistance with the statistics and Liz Shultis and Kathy Delongchamp for their aid in preparation of the manuscript.

Department of Radiology
University of Massachusetts Medical Center
55 Lake Avenue North
Worcester, MA 01605

**TABLE I:** Cerebrospinal Fluid Spaces Graded

| Spaces |
|---|
| Ventricles |
| Lateral ventricles |
| Bodies |
| Frontal horns |
| Occipital horns |
| Temporal horns |
| Third ventricle |
| Fourth ventricle |
| Extraventricular spaces |
| Cisterna magna |
| Prepontine cistern |
| Cerebellopontine angle cistern |
| Superior cerebellar cistern |
| Sylvian fissure |
| Cortical sulci |
| Interhemispheric fissure |

## References

1. Harwood-Nash DC, Fitz CR. Pneumoencephalography. In: Harwood-Nash DC, Fitz CR, eds. Neuroradiology in infants and children. Vol. 1. Saint Louis: Mosby, 1976: 225–296.
2. Fitz CR. Computed tomography in the newborn. In: Krobkin R, Guilleminault C, eds. Progress in perinatal neurology. Vol. 1. Baltimore: Williams and Wilkins, 1981:85–120.
3. Naheedy MH, Strand RD, Gilles FH. Evaluation of cerebral ventricles by computed tomography in the first year of life. J Comput Assist Tomogr 1982; 6:51–53.
4. Fukuyama Y, Miyao M, Ishizu T, Maruyama H. Developmental changes in normal cranial measurements by computed tomography. Dev Med Child Neurol 1979; 21:425–432.
5. Pettit RE, Kilroy AW, Allen JH. Macrocephaly with head growth parallel to normal growth pattern: Neurological, developmental, and computerized tomography findings in full-term infants. Arch Neurol 1980; 37: 518–521.
6. Kendall B, Holland I. Benign communicating hydrocephalus in children. Neuroradiology 1981; 21:93–96.
7. Ment LR, Duncan CC, Geehr R. Benign enlargement of the subarachnoid spaces in the infant. J Neurosurg 1981; 54:504–508.
8. Modic MT, Kaufman B, Bonstelle CT, Tomsick TA, Weinstein MA. Megalocephaly and hypodense extracerebral fluid collections. Radiology 1981; 141:93–100.
9. Ford FR. Forebrain cortex. In: Ford FR, ed. Diseases of the nervous system in infancy, childhood and adolescence. 6th ed. Springfield: Charles C Thomas, 1966:231–259.

**TABLE II:** Comparison of Cerebrospinal Fluid Space Sizes Above and Below Age 2

| Spaces | Grade | Group 1 | | Group 2 | | $p$ Value |
|---|---|---|---|---|---|---|
| | | m | sd | m | sd | |
| Total spaces | 0 | 0.80 | 0.68 | 3.31 | 2.01 | .000 |
| | 1 | 9.07 | 2.46 | 9.37 | 2.09 | .702 |
| | 2 | 2.87 | 2.50 | 0.32 | 0.58 | .002 |
| | 3 | 0.27 | 0.59 | 0.00 | 0.00 | .058 |
| Ventricular | 0 | 0.20 | 0.41 | 0.42 | 0.61 | .237 |
| | 1 | 4.67 | 1.05 | 5.42 | 0.69 | .017 |
| | 2 | 1.07 | 0.96 | 0.16 | 0.50 | .003 |
| | 3 | 0.07 | 0.26 | 0.00 | 0.00 | .267 |
| Extraventricular | 0 | 0.60 | 0.74 | 2.89 | 1.73 | .000 |
| | 1 | 4.40 | 1.96 | 3.95 | 1.84 | .494 |
| | 2 | 1.80 | 1.90 | 0.16 | 0.38 | .005 |
| | 3 | 0.20 | 0.56 | 0.00 | 0.00 | .128 |
| Sulcal | 0 | 0.07 | 0.26 | 1.37 | 0.83 | .000 |
| | 1 | 1.40 | 0.91 | 0.63 | 0.83 | .015 |
| | 2 | 0.47 | 0.83 | 0.00 | 0.00 | .020 |
| | 3 | 0.07 | 0.26 | 0.00 | 0.00 | .267 |

*m* = mean number of cerebrospinal fluid spaces in this grade per child; *sd* = standard deviation.