Basicranial Changes in Shunt-treated Hydrocephalic Children—A Two-year Report

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Basicranial changes were studied in a sample of 29 shunt-treated hydrocephalics, aged 7 to 18 years, by analyzing differences in angular relationships between structures seen on roentgenologic cephalograms taken at intervals of about 2 years following initial examination. In addition, the natural head position was recorded in 24 subjects at a follow-up examination. The cranial base among the boys showed increased flexure during the follow-up period. This finding was reflected in a decrease in the angle between the sphenoidal and clival planes and that of the nasion-sella-basion. Head posture, calculated in terms of the craniovertical and cervicohorizontal angles, was more forwardly flexed in the shunt-treated subjects than in the corresponding controls.

KEY WORDS: *hydrocephalus, cranial base, craniofacial development, head posture.*

As an intermediate structure, the cranial base divides the human skull into its neural and facial components. From a developmental point of view, the shape of the cranial base is regarded as one of the factors determining dentofacial form (Enlow, 1975). The inclination of the clivus for example appears to be related to the position of the glenoid fossa and hence to the spatial relations of the mandible (Björk, 1955; Houston, 1967; Hopkin et al, 1968; Anderson and Popovich, 1983; Kerr and Hirst, 1987).

A recent cross-sectional study suggests that the craniofacial structures of shunt-treated hydrocephalics differ in both size and proportion from those of normal subjects (Huggare et al, 1986). The roentgenologic anatomy of the cranial base, as evaluated in lateral projection, was found to deviate markedly, and pronounced basilar kyphosis was observed—especially in subjects with prolonged shunting times.

To detect a change in cranial base flexure and deviation in head posture, a study was undertaken in which the original shunt-treated patients were reexamined about 2 years after the initial evaluation.

Subjects and Methods

Cephalometric radiograms were obtained at intervals of about 2 years on 29 actively shunt-treated hydrocephalics, 10 girls and 19 boys, aged 7 to 18 years at the time of first examination. The radiograms were analyzed as to head posture (Solow and Tallgren, 1971) and to some basicranial planes that, according to the cross-sectional data of Aantaa and Koski (1962) and Huggare (1987), seem to remain stable throughout normal skull development (Fig. 1, Table 1).

The radiograms were taken in a cephalostat

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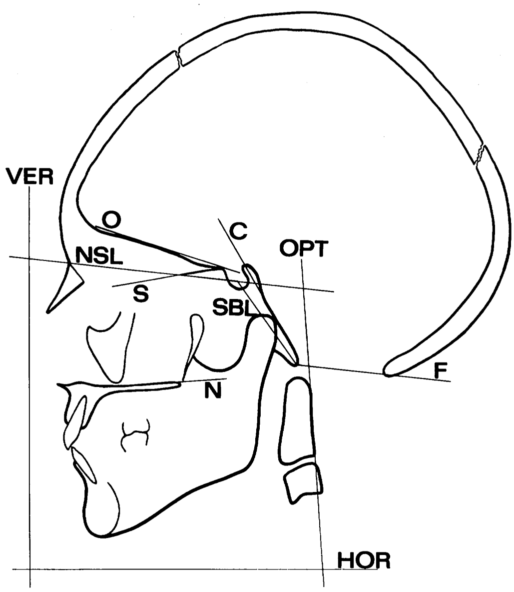

FIGURE 1 Angular measurements for the analysis of head posture and basicranial relationships. Abbreviations are defined in Table 1.

(Lumex, Tagarno, A/S) with a 190-cm film focus distance. In the first series, the subject's head was positioned according to the Frankfort horizontal plane, whereas in the second series the natural head position of 24 subjects was recorded as described by Showfety et al (1983) and Huggare (1985). Since only angular measurements were used, no correction was made for the 5.5% enlargement.

To evaluate cranial base changes during the follow-up period, the differences in the angular variables between the first and second cephalograms were calculated, and their statistical significance was evaluated by a paired *t* test. The head position was compared with that of normal subjects from the north of Finland (Huggare, 1987), and the significance of the differences between the shunt-treated patients and normal individuals was calculated, using the Student's *t* test.

RESULTS

The only significant change among the girls during the follow-up period was a decrease in the angle between the clival and sphenoidal planes (C/S) and an increase in the angle between the clival and nasal planes (C/N; Table 2). The boys, on the other hand, displayed greater changes, particularly in the angles of the clival and sphenoidal planes (Table 3). The angles between the foraminal and clival (F/C) planes and the C/S planes were reduced during the follow-up period, whereas those between the C/N planes and the sphenoidal and orbital (S/O) planes were enlarged. There was also a small change in the relation of the foraminal plane to the orbital and nasal (F/O; F/N) planes. The cranial base angulation, determined as the angle between the nasion-sella and sella-basion lines (NSL/SBL), was reduced (Table 3).

The head was more downwardly flexed among the boys because the craniovertical and cervicohorizontal angles (NSL/VER; OPT/HOR) were significantly smaller in the shunt-treated group than in normal subjects (Tables 4 and 5).

DISCUSSION

This sample consisted of actively shunt-treated children with a primary diagnosis of hydrocephalus, caused by congenital aqueductal stenosis in nine cases, perinatal periventricular/intraventricular hemorrhage in 11 cases, meningitis in three cases, encephalocele in two cases, arachnoidal cysts in two cases, a Dandy-Walker cyst in one case, and meningomyelocele in one case. In general, the primary shunt was inserted early, 20 patients having received shunt treatment during the first year of life

TABLE 1 Anatomic Planes and Cephalometric Lines Used for Calculation of Head Posture and Basicranial Changes in Shunt-Treated Subjects*

Code	*Nomenclature*	*Definition*
C	Clivus plane	Dorsal tangent to the clivus, excluding dorsum sellae
F	Foraminal plane	Line through basion and opisthion
N	Nasal floor plane	Main direction of nasal floor
O	Orbital roof plane	Tangent to orbital roof
S	Sphenoidal plane	Tangent to planum sphenoidale
NSL	Nasion-sella line	Line through extreme anterior point of frontonasal suture and center of sella turcica
OPT	Odontoid process tangent line	Posterior tangent to odontoid process
VER	True vertical line	Vertical line projected onto film
HOR	True horizontal line	Line perpendicular to VER

* Aantaa and Koski, 1962; Solow and Tallgren, 1971.

TABLE 2 Means, Standard Deviation (in Degrees), and *t*-Values for Changes in Basicranial Variables During a 2-Year Period in 10 Shunt-Treated Girls, 7 to 18 Years of Age

Variable	$\bar{x}$	*SD*	t *Value*
F/C	−1.1	2.84	1.22
F/S	2.0	4.04	1.31
F/O	−0.3	2.83	0.34
F/N	0.3	1.89	0.50
C/S	−2.9	2.34	3.23*
C/O	−1.8	2.35	2.43
C/N	2.6	2.67	3.10*
S/O	1.1	2.79	1.08
S/N	−0.9	3.53	0.67
O/N	1.8	4.54	1.25
NSL/SBL	−0.9	1.79	1.58

* $p \leq 0.05$ (paired *t* test).

(minimum, 1 day; maximum; 6 years). The mean age at primary shunting was 1.5 years ± 1.9 years.

The difference in results obtained in the boys and the girls seem to confirm the findings of a previous cross-sectional study (Huggare et al, 1986), according to which shunt-treated boys displayed much stronger craniofacial aberrations than girls.

It seems evident from the present results that in shunt-treated boys, the sphenoidal and clival planes in particular are affected. The sphenoidal plane showed a steeper inclination, especially with regard to the orbital plane, and the clival plane became more vertical, causing increased basilar kyphosis. In the boys, the progression of the kyphosis showed an almost significant correlation with age, ($r = 0.42$) whereas in the girls, there was a slight negative correlation ($r = -0.22$).

TABLE 3 Means, Standard Deviations (in Degrees) and *t* Values for Changes in Basicranial Variables During a 2-Year Period in 19 Shunt-Treated Boys 7 to 18 Years of Age

Variable	$\bar{x}$	*SD*	t *Value*
F/C	−3.0	3.00	4.35*
F/S	1.1	2.85	1.69
F/O	1.5	2.65	2.41‡
F/N	−1.5	3.06	2.14‡
C/S	−3.6	3.61	4.32*
C/O	−0.8	3.17	1.08
C/N	1.6	3.17	2.23‡
S/O	4.2	4.50	7.39*
S/N	2.2	4.66	2.07
O/N	0.3	3.96	0.33
NSL/SBL	−1.5	2.48	2.58‡

* $p \leq 0.001$.
† $p \leq 0.01$.
‡ $p \leq 0.05$.
(paired *t* test).

The cranial base in untreated hydrocephalics is extremely obtuse, and the sphenoidal bone, including the hypophyseal fossa, seems to be depressed (Kantomaa et al, 1987), the opposite being true in shunt-treated subjects (Huggare et al, 1986). The physiologic basis for this change may be fluctuations in dural stress caused by the intracranial pressure changes associated with shunt treatment. Since the dura mater functions as the periosteum of the intracranial bone surfaces and adheres to the base of the skull at the clinoid processes (Warwick and Williams, 1973), the bones in these regions can be expected to respond to increased dural stretch with bone apposition, radiologically detected as a steepening of the angle between the S/C planes.

The slight decrease in the angle between the NSL/SBL lines noted during the observation period, however, cannot be explained merely as a reflexion of bone surface remodelling, but to some extent must result from changes in the position of the landmarks determining the actual angle. Although it was not mentioned in the results section, no pronounced retardation in the length growth of either the anterior or the posterior cranial base, measured in nasion-sella and sella-basion distances, was observed during the 2-year period. This finding indicates that the explanation for the decreased nasion-sella-basion angle must lie in an upward displacement of the hypophyseal fossa. This is in keeping with the hypothesis proposed by Kantomaa et al (1986).

One interesting finding related to the head position of the shunt-treated subjects: their craniovertical and cervicohorizontal relations were found to be significantly smaller than these of normal Finnish subjects (Huggare, 1987). The natural head position of five shunt-treated subjects could not be calculated, however, because of their severely defective faculty of motion, rendering them unable to cope with the recording procedure. Although the shunt-treated subjects had a lowered head position, their craniocervical relationship did not differ significantly from normal. The change in the inclination of the foramen magnum plane to the orbital and nasal planes must be an expression of the fairly static craniocervical relationship.

A probable explanation for the more flexed head position is mechanical interference from the shunt running subcutaneously along the patient's neck. However, head position is intimately related to visual perception (Wesson, 1964), and both untreated and shunt-treated hydrocephalics have visual weakness, a tendency for strabismus, and minor visual field defects (Plotkin et al, 1972; Humphrey et al,

TABLE 4 Means and Standard Deviation (in Degrees) and *t* Values for Head Posture Variables in Shunt-Treated Girls, 7 to 18 Years of Age, and a Sample of Normal Finnish 14-Year-Old Girls*

	Shunt-treated (N = 9)		*Normal (n = 18)*		
Variable	$\bar{x}$	*SD*	$\bar{x}$	*SD*	t *Value*
NSL/VER	94.8	5.31	94.7	5.93	0.05
NSL/OPT	95.3	8.92	92.2	8.02	0.92
OPT/HOR	89.0	7.84	92.7	6.94	1.26

* Huggare, 1987.
(Student's *t* test).

TABLE 5 Means and Standard Deviation (in Degrees) and *t* Values for Head Posture Variables in Shunt-Treated Boys, 7 to 18 Years of Age, and a Sample of Normal Finnish 14-Year-Old Boys*

	Shunt-treated (N = 15)		*Normal (N = 30)*		
Variable	$\bar{x}$	*SD*	$\bar{x}$	*SD*	t *Values*
NSL/VER	86.5	5.19	94.2	5.52	4.49†
NSL/OPT	85.1	10.46	89.1	8.50	1.26
OPT/HOR	90.7	10.92	96.1	6.82	2.14‡

* Huggare, 1987.
† $p \leq 0.001$.
‡ $p \leq 0.05$.
(Student's *t* test).

1982;Mankinen-Heikkinen and Mustonen, 1987); consequently, the present findings may reflect visual disorders. These findings of a lowered head position correspond well with those made on head posture in blind subjects (Fjellvang and Solow, 1986).

An association has been found between head posture and craniofacial morphology, in that subjects with a forwardly flexed head, e.g., generally present a steeper cranial base angle (Björk, 1955; Solow and Tallgren, 1976). Although the present findings seem to be in agreement in this respect, it is not feasible to expect these associations to be expressions of the same biologic event in cases of pathologic cranial development and in normal growth.

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