Changes in the foramen magnum axis during human foetal life

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The present findings showed that in early embryonic life the foramen magnum plane has a direction, more like that found in most animals in the sagittal plane due to the cervical flexure found at this early developmental period. Gradually during the foetal period the inclination of the foramen magnum plane changes to a more perpendicular relationship with the trunk preparing for a future erect posture. It was thought that the most important factor in this change of inclination is the rapid growth of the cerebral cortex. The study was carried out in order to see if possible changes in axial inclination of the foramen magnum axis in the sagittal plane can partly explain the changes in the cephalic flexure during foetal life. The material consisted of 38 selected human foetuses and 4 skulls of newborn babies.

Key-words: Foramen magnum; fetus; growth; cephalometry; craniology

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During foetal growth the shape ot the human head changes characteristically. At approximately 10 weeks the forehead is prominent while the occipital region is underdeveloped and there is no clear demarcation between the back of the skull and the neck. During growth the frontal region becomes less prominent and the occipital region develops, becoming gradually more protuberant.

The relationship between the head and the trunk also changes during this period. At the early stages the head is bent forward relative to the trunk whereas with growth this cephalic flexure is gradually reduced so that at birth the anterior cranial base plane is more perpendicular to the body axis.

In the present investigation the possible changes of angulation in the foramen magnum axis in the sagittal plane was studied relative to various craniofacial reference planes to see if possible changes in axial inclination of the foramen magnum axis in the sagittal plane can partly explain the changes in the cephalic flexure during foetal life.

MATERIAL AND METHODS

The material consisted of 38 human foetuses and 4 skulls of newborn babies.

The foetuses were selected according to the following criteria:

1. Only specimens showing very satisfactory fixation (Streeter's grade 1) (*Streeter*, 1948) were accepted. Ac-

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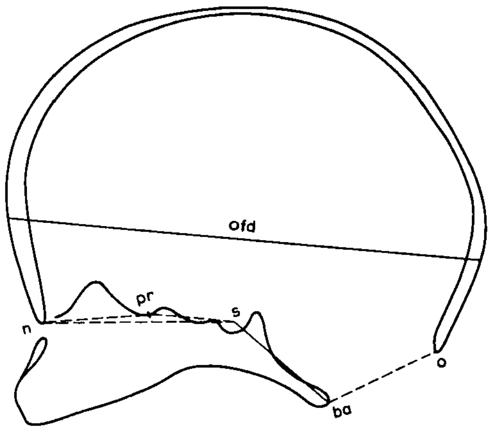

Fig. 1. Reference points and angles used in the investigations: n-nasion: point of intersection between the frontonasal suture and the mid sagittal plane (M.S.P.). In the foetus the most caudal point in the frontal bone is used.
pr-prosphenion: the intersection between the M.S.P. and the junction between the ethmoid and sphenoid elements of the cranial surface of the anterior crania\ fossa.
s-sella: the center of the sella turcica in the M.S.P. ba-basion: point of intersection between the M.S.P. and the anterior border of the foramen magnum.
o-opisthion: point of intersection between the M.S.P. and the posterior border of the foramen magnum.
ofd-occipito frontal diameter: the distance from glabella to the external occipital protuberance.
n-s-ba: the angle between the anterior and posterior cranial base.
n-pr-s: the angular relationship of the spheno-ethmoidal parts of the anterior cranial base.
pr-s-ba: the angular relationship of the spheno-occipital part of the cranial base.
s-ba-o: the angular relationship between the foramen magnum and the posterior cranial base.

cordingly specimens showing any degree of wrinkling, shrinkage or unsatisfactory fixation were discarded.
2. Specimens with any signs of head laceration either due to obstetrical instrumentation or otherwise were discarded.

The foetal heads were sectioned parasagitally immediately lateral to the nasal septum. Angular and linear measurements were made by placing transparent film on the sectioned surface of the sagitally cut head and tracing the points onto the film with a sharp tracing pen under a stereomicroscope.

The newborn skulls were radiographed in a Harvold-Ewald cephalostat and tracings were made of the cephalograms. Angles were measured to the nearest 0.5° (Fig. 1).

This study was performed in order to clarify certain qualitative changes occuring in the cranial areas in the sagittal plane during foetal life. With this in mind the occipito-frontal diameter (ofd) has been used as a measure for evaluating the developmental stages. The relationship between the occipitofrontal diameter (ofd) and the crown rump length (CRL) has been previously investigated (*Scammon & Calkins*, 1929; *Kvinnsland*, 1969) and good association between these body measurements have been found. Chronologically the foetal material represents occipito-frontal diameters from 20.5 mm to 89.5 mm corresponding to crown rump lengths of approximately 43 mm to 263 mm which again corresponds to approximate foetal ages of 10 to 33 weeks (Table I).

Table I. *Distribution of the material*

Occipito frontal diameter (ofd)			
Range (mm)	$\bar{x}$ (mm)/	S.D.$_k$	n
20—29.5	25.0	3.76	6
30—39.5	34.9	2.78	6
40—49.5	44.6	3.71	6
50—59.5	54.3	3.02	6
60—69.5	65.5	2.71	5
70—79.5	73.2	2.75	5
80—89.5	85.3	4.68	4
Newborn 108.5—112.0	110.1	1.84	4

RESULTS

The angle n-s-ba indicating the angular relationship between the anterior and posterior cranial base showed an actual increase in the foetal period (Fig. 2), and allthough this increase was not uniform, (showing a decrease between 50 mm to 75 mm ofd) it increased from 122.3° at 20 mm ofd to 136.7° at 89.5 mm ofd and 145.0° at birth.

The angle n-pr-s indicating the relationship between the sphenoid and ethmoid elements of the anterior cranial base showed a uniform increase from 148.8° at 20 mm ofd to 163.2° at 89.5 mm ofd and 163.5° at birth (Fig. 2).

The spheno-occipital angle pr.-s-ba, however, displayed no significant changes with the developmental stages of the foetus, but stayed relatively stable at about 140°.

The angle s-ba-o indicating the relationship of the foramen magnum to the posterior cranial base showed a considerable increase with age, from 95.5° at 20 mm ofd to 122.6° at 89.5 mm ofd and 127.2° at birth. This indicates that the plane of the foramen magnum (ba-o) gradually becomes more parallell with the anterior cranial base and consequently more perpendicular to the body axis in the sagittal plane during foetal development (Fig. 2).

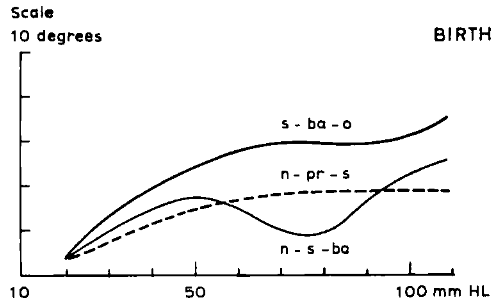

Fig. 2. Curves comparing the angular changes taking place between the anterior and posterior cranial base (n-s-ba), in the spheno-ethmoidal part of the cranial base (n-pr-s) and between the foramen magnum plane and the posterior cranial base (s-ba-o).

DISCUSSION

In man the cranial base shows a higher degree of flexure than in any other animal and it has been stated that the gradual decrease in the size of the angle between the pre-chordal and chordal parts of the cranial base from lower mammals to man gives a good indication of the gradual increase in the development of the frontal lobes of the brain and also to the erect posture characteristic of homo sapiens (*Duckworth*, 1904).

In most animal the foramen magnum plane is having a nearly vertical direction in the sagittal plane due to the fourlegged posture, whereas in the man with his erect posture the foramen magnum plane has a more horizontal direction in the sagittal plane.

The present findings shows that in early embryonic life in the human foetus, the foramen magnum plane has a direction more like that found in most animals due to the cervical flexure in this early developmental period. Gradually during the foetal period the inclination of the foramen magnum plane changes to a more perpendicular relationsip to the trunk, preparing for a future erect posture (Fig. 3).

During the early foetal period of the neck flexure the future tentorium cerebelli and the squamus part of the occipital bone are placed vertically whereas in later stages both these parts migrate backwards and downwards approaching the horizontal position.

It is probably the rapidly expanding cerebral cortex which is the primary factor in displacing the tentorium cerebelli and

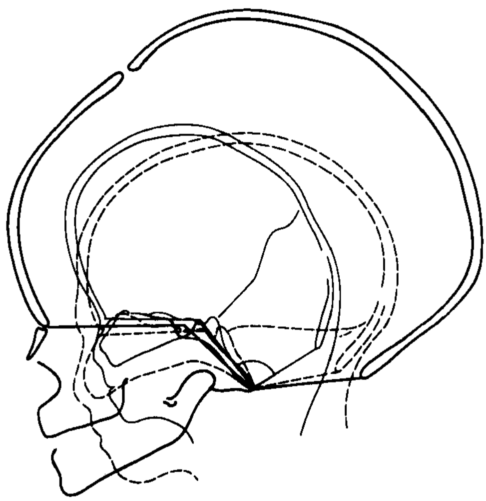

Fig. 3. Superimposition of tracings from foetus with ofd 21.0 mm (thin line) foetus with ofd 77.5 mm (broken line) and newborn ofd 108.5 (thick line). The tracing of the smallest foetus has been enlarged 3.1 times relative to the other two. The tracings are orientated at ba with the n-s lines beeing parallel.

the squamus part of the occipital bone backwards and downwards, changing the axial inclination of the foramen magnum plane from a vertical to a more horizontal direction.

The increase in the angles n-s-ba and n-pr-s is also probably caused by the rapid growth of the brain during the foetal period.

The flattening of the anterior cranial base angle leads to an anterior rotation of the upper face (*Kvinnsland*, 1971) and this in itself will lead to an uplifting of the facial and anterior cranial parts of the head relative to the posterior cranial base and the trunk but probably only to a minor degree.

The orientation of the cerebellum to the medulla is not changed in primate evolution (*Torgersen*, 1954) so it is unlikly that this structure could cause the displacement, allthough it could influence the form of the occipital squama.

The muscles of the neck in the human are orientated for an erect posture with the head orientated such that the anterior cranial base is more or less parallell to the horizontal plane. Since this is also true for the foramen magnum plane the muscules of the neck espesially those involved in posture could possibly also be partly responsible for the gradual displacement of the occipital squama and the foramen magnum plane in a backward and downward direction.

REFERENCES

Duckworth, W. L. H. 1904. Studies from the Anthropological Laboratory. The Anatomy School, Cambridge. Cambridge Univ. Press

Kvinnsland, S. 1969. The Profile of the Foetal Facial Skeleton. Thesis. Univ. of Bergen

Kvinnsland, S. 1971. The sagittal growth of the foetal cranial base. Acta Odont. Scand. 29, 699

Scammon, R. E. & Calkins, L. A. 1929. The development and growth of the external Dimensions of the Human Body in the fetal period. Minneapolis. Univ. of Minnesota Press

Streeter, G. L. 1948. Weght, size and age of human embryos. Contr. Embryol. Carneg. Instr. 11, 143

Torgersen, J. 1954. The occiput, the posterior cranial fossa and the cerebellum. Chapter VII in Aspects of cerebellar anatomy. Johan Grundt Tanum forlag. Oslo