Growth of the cranial vault: Influence of intracranial and extracranial pressures

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The cranial vault is composed of several flat membranous bones whose growth is mainly a result of the activity in the interposing sutures. The reactions of the calvarium and cranial base to provoked stimuli of the sutures differ depending on their developmental stage. In this report the effects of pressure, exerted extracranially by means of mechanical forces or intracranially by means of hydrodynamic fluctuations, are described. ☐ *Cranial base; craniofacial growth; hydrocephalus; shunt treatment*

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The bony calvarium start out as five osseous islands, being displaced outwards on the expanding neurocranial content (1). At birth the thin, membranous bones of the future brain case are lined internally and externally by the fibrous tissue of the cerebral capsule, whereas the spaces between them are gradually filled through growth at the bone edges, which leads to formation of sutures and eventually their obliteration (2).

The activity in the periosteum-lined interbone contact zones, the sutures, is important for the cranial vault growth, and any factor affecting the sutural growth is

Fig. 1. Skull representing a Mayan child from the lower social class (from the Museo de Antropología, Yucatan, Mexico, by permission of Dr. Caron).

Fig. 2. Extreme macrocephalia in a newborn hydrocephalic child.

expected to be associated with a profound and widespread effect on the size and shape of the vault.

Here the effect of extracranially exerted mechanical forces and intracranial pressure fluctuations will be dealt with.

Extracranial pressure

Artificially induced reshaping of the cranial vault has been practiced in many cultures. The baby's skull is moulded by wrapping it in bandages or by using a cradle board (3). According to the mythology of the Maya culture, the skull shape symbolized the social class. The skulls of the lower classes were shaped to make it easier to carry heavy loads (Caron, personal communication) (Fig. 1).

Collections of reshaped skulls are important resources for studying the effect of external force on the craniofacial skeleton. Björk & Björk (4) observed that symmetrically deformed skulls have significantly shorter cranial bases and maxillae than undeformed control skulls, whereas asymmetrically deformed cranial vaults are associated with asymmetry of the cranial base. When skull deformations are categorized on the basis of the visual impression of the vault, vertically elongated American Indian skulls display basal kyphosis, whereas platybasia and dorsal shifting of the foraminal plane are observed in flattened skulls (5). Examinations of artificially deformed American Indian crania (6) and Peruvian crania (7) nevertheless showed that both types of deformation are associated with a flattened cranial base. In a collection of prehistoric Cypriot skulls the cranial base angulation did not differ between partially flattened and well-shaped specimens (8).

Intracranial pressure

Hydrocephaly and its treatment with a valve-regulated shunt device create conditions with fluctuations in the subdural pressure (9). The frequency of infantile hydrocephalus in Sweden is estimated to be 0.53/1000 live births (10).

The signs and symptoms related to increased intracranial pressure depend on the age of the patient at onset. During infancy rapid ventricular dilatation and increased cranial circumference occur (Fig. 2). The sutural reactions are characterized by diastasis, and if the raised pressure is longstanding, the sutural margins

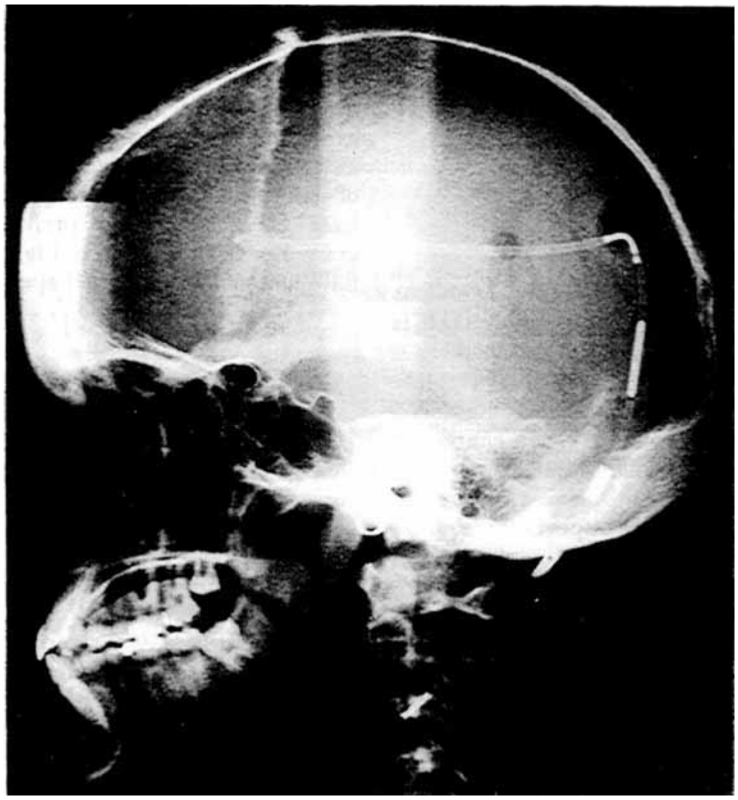

Fig. 3. Lateral roentgenocephalogram of an 8-year-old boy, taken 2 weeks after a shunt operation for hydrocephaly. Note the thin calvarium and coronal suture diastasis.

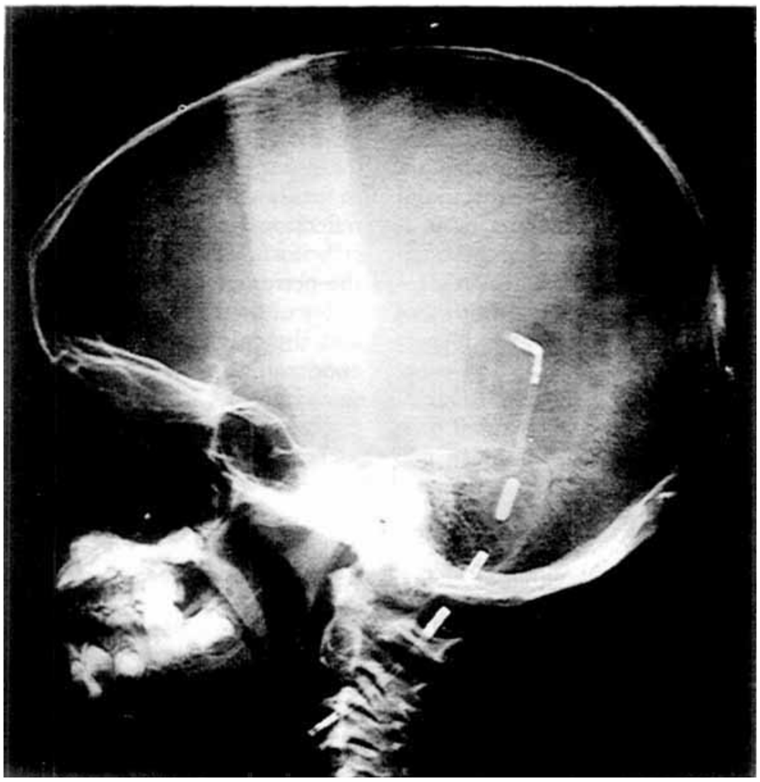

Fig. 4. Lateral roentgenocephalogram depicting the calvarial and cranial base reactions to prolonged shunt treatment.

develop deep interdigitations with spiky appearance (11–13) (Fig. 3). Later, when the cranial sutures are closed, the volumetric expansion in the neurocranial content causes extensive resorption of the inner table of the cranial vault and the cranial surface of the basicranium. This is particularly evident when hydrocephaly manifests in conjunction with conditions of pathologic sutural obliteration, as in Crouzon and Apert syndromes, for instance (14).

A sudden relief of intracranial hypertension is associated with particular cranial vault and cranial base changes. Overdrainage of cerebrospinal fluid, which frequently occurs in association with shunt treatment, may cause calvarial bone overlapping and sutural synostosis (15, 16).

With prolonged shunt treatment the inner surface of the calvarium becomes heavily depository (17–21). In lateral projection, the thickening of the calvarial bone is most obvious in the frontal and parietal regions, where laminated layers of new bone are sometimes visible. The flattened cranial base in untreated hydrocephalics turns progressively acute in shunt-treated patients, and the anterior part of the base becomes superiorly repositioned (19, 22–25) (Fig. 4).

In interpreting these morphogenetic reactions, the function of the dural system is an important factor. The inner periosteal lining of the calvarium, the dura mater, is firmly attached by fold-like appendages, known as reflections to the cranial base at the crista galli, the cribriform plate, the lesser wings of the sphenoid, and the petrous temporal crests. These fiber tracts are capable of mediating mechanical forces between the base and the calvarium (26). Since the dura serves as the endocranial periosteum, its release from pathologic stretching, as in shunt treatment for hydrocephaly, is expected to initiate bone apposition, leading to increased cranial vault thickness and superior repositioning of the anterior cranial base. In an analogous situation, experimental elevation of the alveolar periosteum, increased bone formation has been observed (27).

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