

## “CLIVUS”

### THROUGH THE EYES OF THE TRANSORAL SURGEON

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#### SUMMARY :

*The Surgical treatment of lesions of the ventral lesions of the (craniovertebral) Junction is considered challenging, and until a few years ago these lesions were routinely managed by a conventional posterior approach, despite the more rational and technically simpler alternative approach through the pharynx. Technological advances namely, the operating microscope, high-speed drill and extra-long surgical instruments have eliminated difficulties and allowed the transoral approach to become a relatively simple and safe operation.*

*The osseous structures that must be considered in planning such an operation is the subject of this study. The anatomical, embryological and surgical pathological literature is also reviewed.*

#### KEY WORDS :

*Clivus, Transoral Surgery.*

#### GROSS ANATOMY

The term clivus meaning “slope or declivity” (8,31) was used by von Sommerring (1791), Blumenbachii (1807) and Virchow (1857) to describe that of the inner skull base between the foramen magnum and the dorsum sellae (3,28,33) (Fig 1,2).

The boundaries of the clivus are not well defined. The lateral margins are formed by the petrooccipital fissure superiorly and, the synchondrosis between the basiooccipital and exoccipital bones inferiorly. The posterior boundary slopes downward and inferiorly from the base of the dorsum sellae to the margin of the foramen magnum. The anterior margin of the clivus is not well defined, since it blends with the sphenoid sinus. The inferior boundary represents the nasopharyngeal surface of the lower portion of the sphenoid and the basio-occiput. The inferior or exocranial surface is roughened by the attachments of the fibrous raphe of the pharynx. In contrast, the posterior or endocranial surface is usually smooth. The surfaces of the clivus are composed of cortical bone. The central portion is composed of cancellous bone that may be pneumatized to a variable degree by the sinus. The depth of clivus is defined as the maximum distance of the cortex above or below a line that connects the dorsum sellae and the anterior margin of the foramen magnum (5,11,12).

The paired lateral or condylar parts are situated at the sides of the foramen magnum. The occipital condyles, which articulate with the atlas, protrude from the external surface of this part. These cond-

yles are lateral to the anterior half of the foramen magnum. They are oval in shape, convex downward and laterally, and have their long axes directed forward and medially. A tubercle that gives attachment to the alar ligament of the odontoid process is situated on the medial side of each condyle (5,7,22).



Fig.1 : External view of clivus and skull base.



Fig.2 : Diagrammatic internal view of clivus.

The hypoglossal canal which transmits the hypoglossal nerve is situated above and forward the condyle and is directed forward and laterally from the posterior cranial fossa (17).

The carotid canal is situated in the inferior aspect of the petrous portion of the temporal bone and leads from the neck to the middle fossa. Its exocranial opening is just antero-medial to the jugular foramen. The canal first ascends vertically a few millimetres in front of and medial to the tympanic cavity and cochlea, then bends 90° and continues medially, anteriorly and slightly downward, medial to the osseous portion of the eustachian tube. The endocranial opening and termination of the canal are at the petrous apex, adjacent to the posterior border of the foramen lacerum (29).

The jugular foramen is a bird-shaped opening in the base of the skull between the lateral edge of the occipital bone and the inferomedial aspect of the petrous pyramid. It is actually a short canal that is oriented anteriorly, laterally and inferiorly and it connects the posterior fossa with the upper cervical region. From the endocranial aspect it is related to the cerebellum above, the hypoglossal canal medially, the petrooccipital fissure and inferior petrosal sinus anteriorly and the internal auditory meatus superiorly and laterally (11,12,29).

#### DEVELOPMENTAL ANATOMY

The development of the skull is complex, and only those aspects that are important from a clinical standpoint are considered here. The skull consists of a protective case around the brain, the neurocranium and the skeleton of the jaws (23).

The complex developmental pattern is well summarized by Davies and Davies (1961). The calvarial bones develop in the mesenchymal masses that surround the brain. Development can be classified into overlapping stages: The membranous stage, the cartilaginous stage and the ossification stage.

The bones of the mature skull likewise fit into three groups, depending on their origin (Henderson and Sherman, 1964) (14).

1. Cartilaginous origin-ethmoid;
2. Membranous origin-parietal, frontal, nasal, lacrimal and zygomatic; vomer, mandible and maxilla, palate and
3. Mixed cartilaginous membranous origin, occipital, sphenoid and temporal.

#### Membranous stage :

At the beginning of the second month of foetal

life, thick masses of mesenchyme form around the brain. These first appear in the occipital region, where they surround the notochord and extend forward toward the hypophysis to outline the clivus and dorsum sellae. The mesenchymal masses further extend into the regions of the ethmoid, nasal septum and greater sphenoid wing and enclose the optic and auditory centres. Plates of mesenchyme also form the future cranial vault. The mesenchyme surrounds the various cranial nerves forming the primitive cranial foramina.

#### Cartilaginous stage:

Chondrofication of the skull begins during the second foetal month and is limited to the base of the skull. It takes place primarily in three regions:

1. Posteriorly-around the notochord and the auditory centres;
2. Medially-around the hypophysis and;
3. Anteriorly-in the region of the nasal septum.

The bones of the base of the skull are thus formed in cartilage whereas the bones of the vault are ossified in membrane.

The cartilaginous skull base-the chondrocranium-is continuous with the cranial vault. Thus the origin of some of the cranial bones is both cartilaginous and membranous. As ossification proceeds, the chondrocranium diminishes in size. At birth the chondrocranial remnants are still present in the nose, sphenoid and occipital bones, the foramen lacerum and the sphenoccipital and petrooccipital synchondroses (6,14,27).

Occipital bone ossification stage : The occipital bone consists of four segments that surround the foramen magnum. The basal segment (basiooccipital) is anterior, the squamous segment is posterior and inferior, and the lateral segments (exooccipitals) lie on each side of the foramen magnum. These four parts are the result of the ossification pattern of the occipital bone. At birth the basiooccipital, the two exooccipitals, and the squama are separated by strips of cartilage. The squama is formed by the supraoccipital and interparietal ossification centres. The anatomical literature is in agreement that the basal and the two lateral parts are ossified, from the sixth to twelfth week of foetal life. There is also agreement that the inferior portion of the squama (supraoccipital) is formed in cartilage from two ossification centres and the superior portion (interparietal) is formed in membrane.

Disagreement exists, however, as to the number of ossification centres then make up the inferior

portion of the squama (supraoccipital) is formed in cartilage from two ossification centres and the superior portion (interparietal) is formed in membrane.

The importance of this question relates to the diagnosis of midline occipital fractures (Franken 1969) (10).

X-ray examination of the occipital bone at various foetal ages reveals the following:

1. The basiooccipital region is the site of the earliest welldefined ossification centre;
2. Two ossification centres appear to participate in the formation of definitive basioocciput;
3. The interparietal region ossifies earlier than the supraoccipital region.
4. The various segments of the occipital squama unite early, and radial ossification pattern originates at the region of the future occipital protuberance. Ossification of the posterior margin of the foramen magnum varies greatly. Caffey (1953) (4).

Detailed the various accessory centres of ossification that may develop in this region (4,9,15).

#### **Clivus :**

The clivus develops by enchondral bone formation. By the third week of gestation, the notochord in the cephalic region of the foetus has begun to develop (Arey, 1965). As ontogenesis progresses, condensations of mesenchyme presage chondrocranium formation. During the sixth week chondrogenesis of the mesenchymal model appears (Hamilton, et al, 1952) 1,13).

Chondrofication centres begin in the presumptive basioocciput and spread superiorly to unite with cartilaginous centres in the region of the future basiosphenoid (Gray, 1967) (12). Subsequently a parachordal cartilaginous plate migrates medially around the notochord and about the roots of the hypoglossal nerve (Gray, 1967). By the eighth week chondrofication has reached the height of development. The basal portion of the sphenoid bone contains one or two ossification centres by the sixth week of foetal life. At birth the clivus consists of partially ossified components of the basioocciput and sphenoid body, separated by the sphenoccipital synchondroses (Caffey, 1953) (4).

In the lateral view of the skull or in the sagittal tomogram, these components are well seen. The ossified portion of the clivus is separated from the pon-

tine and medullary cisterns by a mantle of cartilage. Ossification of the clivus is generally complete at birth. The synchondroses between the basilar and the lateral parts of the occipital component usually close very early, at between one and four years (Caffey, 1961).

The sphenoccipital synchondrosis, on the other hand closes very much later. According the standard text, the suture closes between 18-25 years. This was investigated carrying out midasagittal laminography in 205 males (8 to 21 years) and 193 females (6 to 18 years). In general, the closing age was between 13 and 16 years for the boys and between 11 and 14 years for the girls (Powell and Brodie, 1963) (24). The time of fusion may vary; however, syncondrosis does not persist beyond 21 years of age (Grant, 1962) (9,11).

#### **Changes of the skull during childhood:**

The human chondrocranium is both phylogenetically and developmentally the most primitive part of the skull (Patten, 1968) (23). Since the chondrocranium forms both the floor of the brain case and the roof of the face, it is a critical region of skull development that coordinates the developing neural and facial skeletons (Moss and Greenberg, 1955) (21).

It also provides, in the occipital condyles, the only junction of the skull with the somatic skeleton.

Multiple enchondral ossification centres appear in the embryonic chondrocranium, and enlarge and coalesce to form seven bones of the adult chondrocranium, Three of which the ethmoid, sphenoid and occipital are unpaired. In the adult skull the chondrocranium extends from the root of the nose to the superior nuchal line. The exact lateral margins are difficult to identify because the original intramembranous and enchondral ossification centres have coalesced into single bones. With minor exceptions, however, the chondrocranium forms the neurocranial floor. Membrane bone forms the face and the neurocranial vault or calvarium (Arey (1865) (1).

The chondrocranium has been proved to be the most stable and predictable portion of the skull. Indeed chondrocranial growth parallels general body growth much more closely than it does brain growth (9).

The growth in length of the vertebrate body (including that of man) proceeds in a cranio-caudal direction, from the head towards the feet. This basic growthlaw, entirely disregarded in human biology and medicine, is dramatically documented by the downward slant of the spinal nerve roots. The seemingly "upwards" gain in height of the growing child

is nothing but an optical illusion. Even the development of the brain follows that law as shown, for instance, by the distal shift of the prospective for ventricle area, by the fronto-occipital spread of the human telencephalon over the deeper parts of the brain and by elongation of the cranial nerves constituting in their entirety what could be called a "cranial cauda equina." Natural and generally accepted neuro-cranial developmental interrelation with the growing brain moulding the shape of its skelotogenic envelope is diametrically reversed, without obvious reason, at the level of the foramen magnum (26).

**PATHOLOGY**

The endocranial surface of the clivus is usually slightly concave, occasionally flat, and rarely convex. The depth of the clivus is defined as the maximum distance of the cortex above or below a line that connects the dorsum sellae and the anterior margin of the foramen magnum. Kruff and Munn (1963) studied the depth of the clivus in 500 normal children whose ages ranged from birth to 15 years. In 488 (97.6%) it was, slightly concave or flat. A concavity with a depth of 2 mm. was seen in eight patients (1.6%), four patients (0.8%) it measured 3 mm. No clivus had a posterior convexity (16). Di Chiro and Anderson (1965) examined ninety-four dry skulls and x-ray of the skull in seventy-two normal adults and thirty-seven normal children. In 77% the clivus was slightly concave; in 19% it was flat; and in 4 it was convex posteriorly. In none was the concavity greater than 3 mm. (7). In 1939, Rossier reported increased concavity of the clivus of more than 3 mm. as suggestive of a spaceoccupying lesion of long duration in the posterior fossa (25).

Stern (1964) reported a concavity greater than 2 mm. In 50% of patients with lesions at the tentorial notch or in the posterior fossa (5).

Di Chiro and Anderson (1965) found a posterior concavity of the clivus of 4 mm. in posterior fossa tumours, obstructive hydrocephalus, pinealomas and supratentorial tumours. They emphasized that increased posterior concavity does not necessarily indicate a mass in the posterior fossa but merely represents long-standing increased intracranial pressure (7). A convex clivus is a common finding associated with platybasia and basilar impression. A hump at the sphenoccipital synchondrosis was associated with a short basiooccipital portion in four patients who had assimilation of the atlas, slight basilar invagination, or platybasia (2,19,20).

The clivus is significantly shortened in achondroplasia because of little or no longitudinal bone growth

at the sphenoccipital synchondrosis (5). Short clivus is always present in achondroplastic dwarfs. In normal patients, short clivus indicates reduced growth or early fusion of sphenoccipital synchondrosis (7,18,32) (Fig 3).

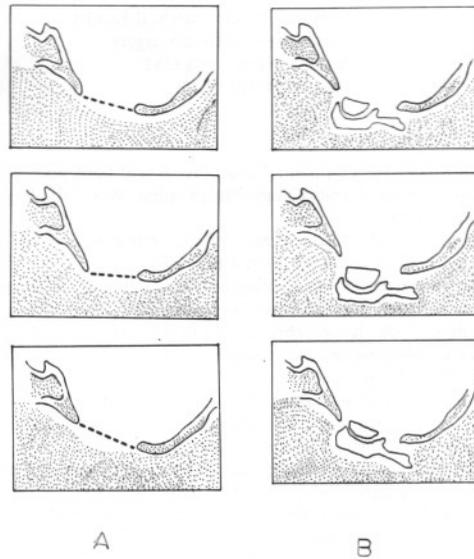


Fig.3 : A. Diagrammatic lateral views of clivus and foramen magnum to show variations in slope and height of foramen magnum when clivus is of different lengths.

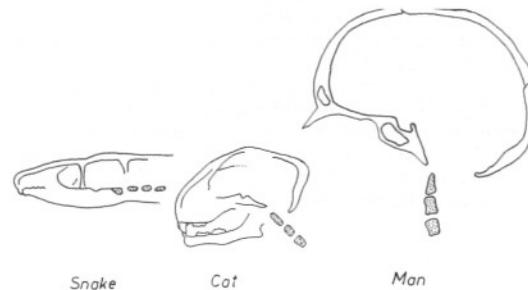


Fig.4 : Diagrammatic sagittal sections of skull and upper cervical spines of reptile, lower mammal (cat), and man to illustrate relationship of planes of anterior fossa floor, clivus and spine. (Redrawn from Mc Rae).

The basal angle is the angle between the plane of the clivus and the plane of the midline portion of the base of the anterior fossa (it is used by anthropologists in the classification of skulls). Anthropologists have used the angles between the spine and the skull and between the clivus and the floor of the anterior fossa as a means of placing man and animals on a hierarchy from high to low. (Fig.4). Man of course, is highest, having will tend to be abnormal and basilar invagination may be diagnosed when not actually present. This is most frequent in patients with a short basioociput. It is difficult to set x-ray criteria for the diagnosis of basilar invagination, especially when it

is of a minor degree. Most, if not all, the lines and angles used will occasionally suggest invagination of the margins of the foramen magnum when such is not present (19,30).

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