Morphology of Developing Human Occipital Squama

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Abstract

Background: To study the limits and ossification of developing human occipital bone.

Methods: In this descriptive study of the development of Occipital squama, 30 foetal skulls were selected. They were grouped as $A_G$ and $A_m$. Gross examination was carried on 15 foetal skulls (Group $A_G$) with a pre-natal age of 8-20 weeks. A strip was cut 1.5 cm above the lambdoid suture and carried along the line of suture till the foramen magnum. After examination of un-stained specimens under dissecting microscope, the specimens were stained with Alizarin Red S and Toluidine blue method for gross staining of calcium. Fifteen foetal skulls of (Group $A_m$) were selected for microscopy and circular strip approximately 3mm was cut in a plate like fashion in radius of 5mm² with external occipital protuberance as a centre of cutting area. It was confirmed that they did not have any congenital or artificial deformity. The specimens were fixed in 10% neutral buffered formalin, decalcified in 2% nitric acid, dehydrated with graded alcohols cleared in inhibisol and embedded in paraffin. The sections were placed vertically in the block with the side facing lambdoid suture anteriorly and the side facing foramen magnum posteriorly. Sections were cut at 500µm interval and stained with haematoxylin and eosin. The process of ossification in occipital squama was studied regarding limits, time and type of ossification centres.

Results: Occipital squama was seen to consist of two parts, supra-occipital and interparietal. Supra-occipital has dual origin. The upper part of cartilaginous supra-occipital between superior and highest nuchal lines known as intermediate segment or Torus Occipitalis, ossified intra-membranously from two nuclei. The interparietal part (also intra-membranous in origin) ossifies above the highest nuchal line from two pairs of nuclei forming medial and lateral plates respectively.

Conclusion: The defect in the fusion of ossifying centres results in variation in developmental process: leading to formation of one or more separate bones known as interparietal bones or Inca bones (Type 1-V).

Introduction

Occipital squama has two parts cartilaginous supra-occipital and membranous interparietal. There is some controversy in literature concerning the limits and ossification of the membranous part of occipital squama, known as interparietal, in man. Most authors have stated that portion above the superior nuchal lines ossifies in membrane. Others have an opinion that area above the highest nuchal line is membranous in origin. Regarding the area between the two nuchal lines, (also known as lamella triangularis or intermediate segment) most of the researchers believe that it is membranous in origin, but it never separates from cartilaginous supra-occipital. Hence supra-occipital part of occipital squama has a dual origin.

There are different views among the anatomists regarding the ossification centres of this region. Some have observed that membranous part of occipital squama ossified from two centres. Some think that three ossification centres are involved. There is also a view that sometimes additional centres appear at the upper part of lambdoid region leading to formation of pre-interparietal bone. These observations were mainly performed on adult skulls. After examining the foetal skulls Srivastava et al (1992) concluded that intra-membranous part of occipital squama ossified from three centres (Figure 1).

The membranous part develop above the superior nuchal lines from three pairs of centres, intermediate segment (that is the part of supra-occipital) is formed from first pair. The interparietal part develops above the highest nuchal line from two pairs of centres. Second pair (having medial and lateral nuclei) forms lateral plate and is separated from intermediate segment by lateral fissure. Above it third pair having upper and lower nuclei forms medial plate of interparietal part of occipital squama. The two parts of medial plate are separated from each other by median fissure: that is later obliterated after 12 weeks.
Figure 1: Diagrammatic representation of centres and their nuclei in the membranous part of the occipital bone above the supra-occipital (SO) bone. Paired centres of the intermediate segment (IS), medial and lateral nuclei of the 2nd pair of centres (II), and upper and lower nuclei of the 3rd pair of centres (III). The intermediate segment is separated from the lateral plate by the lateral fissure (LF).

Srivaslave HC negated the concept of previous researchers regarding pre-interparietal bones, according to whom they are formed by additional fourth pair of nuclei. 13,14, 21 When upper nuclei of third pair join with each other and fail to join with the rest of bone it forms interparietal or Inca bone that is the part of interparietal and is not a separate entity. 1-6 Interparietals should not to be confused with the sutural bones developing from their own ossification centres and found outside the limits of the interparietal part of occipital squama.

Material and Methods

In this descriptive study of the development of Occipital squama, 30 foetal skulls were grouped as A_G and A_m. Gross examination was carried on 15 foetal skulls (Group A_G) with a pre-natal age of 8-20 weeks. A strip was cut 1.5 cm above the lambdoid suture and carried along the line of suture till the foramen magnum. After examination of un-stained specimens under dissecting microscope, the specimens were stained with Alizarin Red -S and Toluidine blue method for gross staining of calcium. 17 Fifteen foetal skulls of (Group A_m) were selected for microscopy and circular strip approximately 3mm was cut in a plate like fashion in radius of 5mm² with external occipital protuberance as a centre of cutting area. The specimens were taken from different hospitals affiliated with Rawalpindi Medical College, Rawalpindi. It was confirmed that they did not have any congenital or artificial deformity. The specimens were fixed in 10% neutral buffered formalin, decalcified in 2% nitric acid, dehydrated with graded alcohols cleared in inhibisol and embedded in parmat. The sections were placed vertically in the block with the side facing lambdoid suture anteriorly and the side facing foramen magnum posteriorly. Sections were cut at 500µm interval and stained with haematoxylin and eosin. The process of ossification in occipital squama was studied regarding limits, time and type of ossification centres 18.

Results

The process of ossification of occipital squama was first studied under dissecting microscope. It was seen that supra-occipital bone under the superior nuchal line was flexible and had smooth appearance and lacked in bony trabeculae pointing to its cartilaginous origin, in contrast, above it, intra-membranous part till highest nuchal line had a rough network of bony trabeculae (Figure 2).

After staining by Alizarin -Red S and microscopy it was further confirmed that the supra-occipital part of occipital squama has dual origin (Figure 3). On each side of midline, these centres were membranous in origin, extended laterally and fused with each other and then with supra-occipital. These centres formed intermediate segment or lamella triangular, which lies between superior and highest nuchal line. A second pair appeared above them, each having two nuclei, forming the lateral plate of interparietal part (Figure 4). Lateral plate was separated from intermediate segment by lateral fissure.

The remaining medial portion of interparietal ossified from third pair, having two centres each, upper and lower. No additional centres were seen anterior to third pair (Figure 5). Microscopic studies showed intra-cartilaginous ossification below the superior nuchal line and intra-membranous origin above it (Fig 6-8).

Figure 2: External aspect of an early 3rd month fetus. Supra-occipital (SO), ossification centres, (I&2), medial fissure (MF), lateral fissure (LF), interparietal (IP), supra-occipital (SO), intermediate segment (IS).
Discussion

There is a disparity in opinions amongst various researchers. It is due to the difference in number, age, race or methodology. The views of Srivastava (1992) are consistent with this study as we belong to the same part of the world and used the same methodology. On the other hand, our views differ from Matsumura because of different ethnic background and methodology. Most of the researchers agreed that interparietal or Inca bones are accessory ossicles formed due to ossification failure. We followed the previous nomenclature and criteria for classification of Inca bones or interparietal bones (1-5).

Regarding the origin of the Inca bone (first observed in Inca tribe of south Chile) it was concluded that the complete division of membranous and cartilaginous part of occipital bone by a transverse suture extending between the two lambdoid sutures at the level of highest nuchal line above the external occipital protuberance, presenting as Os Inca Totum (Type I). On the contrary, there is a difference in opinion regarding pre-interparietal bone. Lot of anatomists took interest in this rare bone and controversial issue as Inca bones can serve as a non-metric cranial variant for separation of populations. We agree with Srivastava that Matsumura and various other researchers were misinterpreting Type V Inca bone as pre-interparietal. In further support of this view, it was seen that various researchers calculated the frequency of pre-interparietal bone more than interparietal (10%) to be more than interparietal (3%). This concept was rejected as it is not possible that a rare centre can give a higher frequency than true interparietal bone. Later Paul himself negated his previous view. He agreed that when upper nuclei of third pair failed to fuse with the rest of bone, it formed separate bone and thus it was wrongly interpreted by researchers as
separate pre-interparietal bone, which is a misnomer.\textsuperscript{11,19,22,23} Due to this misconception of confusing sutural bones as Inca or pre-interparietal bones, it was assumed that any separate bone developing as a separate ossification centre, in the lambdoid suture but outside the limits of interparietal, should be considered as sutural or wormian bones; as they have their own specific shape, size, territories and time of appearance. (after 6 foetal month). Their shape is not regular but oval or round and are surrounded by connective tissue only.\textsuperscript{4,6,14}

Several other researchers used morphometry to clear the confusion between the three types of bones. Their results indicated that actual distance between lambda and external occipital protuberance is in the range of 7-8.3 cm. Any separate bone developing in this region with specific size and location strongly suggest that they are the upper central part of interparietal part of occipital squama and not a separate bone. Sutural bones have a distance of 9-10cm from apex of the bone to external occipital protuberance confirming that they are also separate entities outside the limits of interparietal part of occipital squama.\textsuperscript{5,6,8,22,23} These bones can also act as a pointer of underlying anomalies of CNS and hormonal disturbances.\textsuperscript{24-31}

**Conclusion**

1. Inca bone has a genetic, ethnic and anthropological forbearance. Leaving aside the contradictory views regarding their morphology, these are surely a product of partial or non-union of the ossification centres of occipital squama.

2. The knowledge of Inca bones is an area of great importance for clinicians and anthropologists. Ignorance of these anomalous bones can lead to erroneous diagnosis of fractures leading to unjustifiable surgeries, undue reports in medicolegal cases e.g. child abuses (battered baby syndrome) and extension of fracture line in burr-hole surgeries leading to damage of important structures nearby.

**References**