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Review Article

A comparative study of pneumatization of Temporal bone

Vishram Singh[a,*], D. Krishna Chaitanya[a,*], B.K.S. Chauhan[b], I. David Victor Kumar[c]

[a] Department of Anatomy, Santosh Medical College, Santosh University, India
[b] Department of Radiology, Santosh Medical College, Santosh University, India
[c] Department of ENT & Otorhinolaryngyology, AIIMS, New Delhi, India

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ABSTRACT

Introduction: The present review is based on the study of various classifications of pneumatization of temporal bone and their comparison. The air cells are classified based on their location in the temporal bone in a radiograph or based on their interpretation by a radiologist or otolaryngologist with the help of different reference structures.
Methods: The analysis of pneumatization in temporal bone is done by reviewing research articles related to pneumatization of temporal bone in pig, sheep, macaque and humans published in Pubmed, Sciencedirect, Scopus, and Medline, Indexed journals.
Results and discussion: According to classical classification the temporal bone is divided into five regions viz., middle ear, squamomastoid(mastoid), perilabyrinthine, petrous apex and accessory. The cells are named accordingly and they are further classified into various grades by the degree of pneumatization and density of cells present in the respective regionsMost recent work which has been cited in various articles, is done by Han et al. [19] In this pneumatization is classified based on the visualization of various reference structures such as, sigmoid sinus, labyrinth, and internal carotid artery. The lack of consensus among surgeons and otolaryngologists regarding the classification of the pneumatization of temporal bone may be a cause of failure in a few otologic surgeries such as 1^0 mastoidectomies etc and postoperative care of skull base surgeries.

1. Introduction

The temporal bone on either side of skull consists of four components: the squamous, petromastoid and tympanic parts and the styloid process. The squamous part has a shallow mandibular fossa associated with the temporomandibular joint. The petromastoid part is relatively large. Its petrous portion houses the auditory apparatus and is formed of compact bone. In contrast, the mastoid process is trabecular and variably pneumatized.

The squamous part belongs to the cranial vault. It undergoes membranous ossification. The petrous or petromastoid part, in contrast, belongs to the cranial base and undergoes endochondral ossification.

Embryologically, the mastoid air cell system begins with the formation posteriorly of a lumen from the attic during embryonic development at around week 22 of pregnancy. It is virtually completed with the formation of the lumen of the mastoid cavity at week 34[4,6]. The lumen formation and membrane epithelialization of the mastoid air cells continue until birth[11]. There are various air cell formations, which are affected by differences in the pattern of bone metabolism at each air cell region that occurs after birth[4].

2. Material & methods:

The analysis of pneumatization in temporal bone is done by reviewing research articles related to pneumatization of temporal bone in pig, sheep, macaque and humans published in Pubmed, Sciencedirect, Scopus, and Medline, Indexed journals.

3. Results and discussion

Pneumatization can be defined as the process where the epithelium infiltrates the developing bone and forms epithelium lined air cell cavities[20]. This process starts between 22–24th weeks of intrauterine life and mastoid cells begins at the 33rd week and continues till the age of 8–9. The pattern of pneumatization is usually completed by the age of 10 in females and 15 in males.

* Corresponding author.
E-mail address: chetandandala@gmail.com (D. Krishna Chaitanya).

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Function of these air cells being air reservoir, insulation, sound resonance, acoustic dissipation, protection, and lightening of the weight of the skull.

Major factors contributing or affecting this process of pneumatization seem to 'environmental' factors' stated by wittimack[10] and 'genetic' factors stated by Diamant[12,13]. Holmquist stated that the success of the middle ear surgery depends on the degree of the mastoid pneumatization.

The earliest work on temporal bone pneumatization was completed by Zuckerkandl (1879) but much of the present knowledge on temporal bone pneumatization is derived from extensive clinical research during the last century (such as Tremble, 1934; Bast and Anson; 1949; Allam [8]; Shapiro, 1971; Hug and Pfaltz [14]; Robinson et al., 1993; Sade and Fuchs, 1997; Sade et al., 2006). Much of the early knowledge is based upon either gross anatomical observations (e.g., Diamant, [12,13]. Followed by studies of internal structure using serially sectioned specimens (e.g., Diamant, 1954; Fukuzaki, 1967; Lozupone and Favia, 1990) or radiographs (Schulter-Ellis, 1979; Gregg and Steele, 1982).

Though there is a lack of consensus on the development and classification of the pneumatised air cells among the academicians, researchers and clinicians, however they mostly seem to agree on the classification of Allam[8], hence followed in the present article as well. According to this classification the pneumatised areas of temporal bone can be divided into middle ear, squamomastoid, perilabyrinthine, petrous apex and accessory regions. In this classification these regions can be further classified based on degree of pneumatization and density of air cells as under

1. Middle ear:
   a Epitympanum
   b Mesotympanum
   c Hypotympanum
2. Squamomastoid
   a Antrum
   b Central mastoid tract
   c Peripheral cells
3. Perilabyrinthine
   a Supralabyrinthine
   b Infralabyrinthine
4. Petrous apex
   a Petrosal cells
   b Apical cells
5. Accessory cells
   a Zygomatic cells
   b Occipital cells
   c Squamous cells
   d Styloid cells.

According to classification by Jadhav et al. [15] where reference structures used are based on the work of Han et.al. [19] These reference structures(the labyrinthine and petrous segments of the internal carotid canal) divided the air cells into 3 groups using.

- Labyrinthine segment of internal carotid canal is used as a reference structure to classify the pneumatization of the temporal bone around the inner ear structures using the following grouping:

Group 1: No evidence of pneumatization in the region of the inner ear (Fig. 1A).

Group 2: Pneumatization present either medial or lateral to the superior semicircular canal on axial section (Fig. 1B).

Group 3: Perilabyrinthine pneumatization (Fig. 1C).

- Petrous segment of the internal carotid canal is used for assessing the pneumatization of the petrous apex.

Group 1: No pneumatization of the petrous apex (Fig. 2A).

Group 2: Mild pneumatization of the petrous apex there are irregularly evident small numbers of air cells on either side (medial or lateral) of the carotid canal (Fig. 2B).

Group 3: Complete pneumatization of the petrous apex; pneumatization is present surrounding the carotid canal (Fig. 2C).

According to Ahmet Koc et al. [8]

The degree of pneumatization(pneumatic, diploic and sclerotic) is variable and the pneumatized air cells develop along. Five main tracts are recognized

i) Posterosuperior cell tract
ii) Posteromedial cell tract
iii) Subarcuate tract
iv) Perilabyrinthine tract
v) Peritubal tract

3.1. Significance of pneumatization

There is no unanimity among various workers regarding the significance of pneumatization and disease process and vice-versa, etc., following text deals with different views.

Although it is not known whether the degree of pneumatization of the temporal bone is the cause or the result of otitis media, it is clear that the degree of pneumatization influences the development of otitis media and formation of cholesteatoma,[5] and is also

Fig. 1. [15]. A, No evidence of pneumatization in the region of the inner ear. B, Pneumatization present either medial or lateral to the superior semicircular canal on axial section (yellow arrows). C, Perilabyrinthine pneumatization (yellow circle).

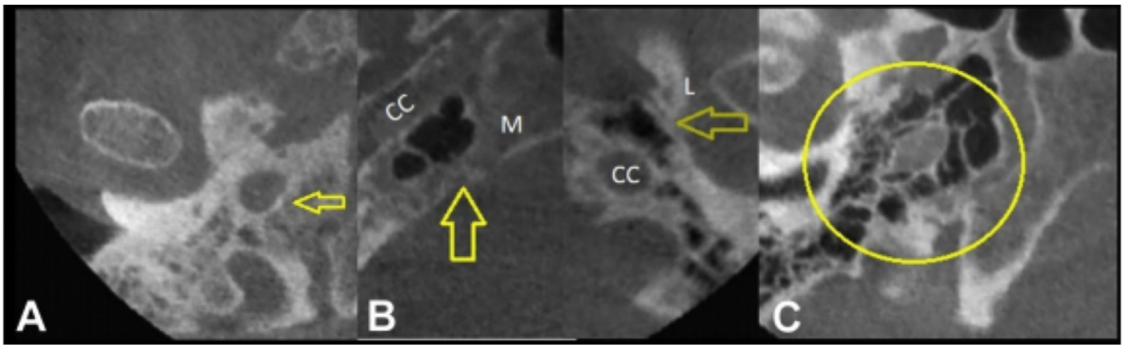

Fig. 2. [15] A, No pneumatization of petrous apex. B, Mild pneumatization of petrous apex; there are irregularly evident small numbers of air cells on either side (medial or lateral) of the carotid canal (yellow arrows). C, Complete pneumatization of petrous apex; pneumatization is present surrounding the carotid canal (yellow circle).

considered as an important prognostic factor in middle-ear surgery.[8]

The temporal bone has also been used to differentiate taxonomic features anatomically between modern Homo sapiens from neandertals and asian homo erectus. Significant features being external surface and semicircular canals.[18] As noted by Sherwood (1995), pneumatization in modern humans is highly variable ranging from complete acellularity to extensive pneumatization with frequent bilateral asymmetry.

Pneumatization is usually confined to mastoid, perilabyrinthine and petrous regions occasionally or rarely extending into squamous part of the temporal bone.

There seemed to be a definite variation in the overall extent of pneumatization but the volume and total area overlap. Air cells seem to be particularly concentrated in well developed mastoid process and follow the orientation of petrous apex[9,14].

The degree of pneumatization determined by virapongse et al. [7] was according to a scoring system where a subjective evaluation of the approximate area of pneumatization and number of air cells were considered, where group 1 contained 0–10 cells, group 2 contained 11-30 cells, group 3–31 to 50 cells and group 4 – 50 or more cells. They found air cells were confined to periantral triangle in cases of poorly pneumatised ears and the air cells extended beyond the triangle in a well pneumatised ear.

Bronoosh et al. [17] studied the pneumatization in relation to the pneumatised articular tubercle, where radiological landmarks considered were sigmoid sinus, labyrinth and internal carotid artery. The presence of pneumatised articular tubercle seemed to be positively correlated to a well pneumatised bone.

In a study where CBCT(cone beamCT) was used rather than the conventional CT in which the pneumatization classified was into three groups using labyrinthine and petrous segment of internal carotid canal. There was no statistical difference between the two groups, this may be attributed to the fact that they eliminated mastoid air cell system[15].

Ontogenic changes: These changes are observed in the mastoid portion of the temporal bone rather than the petrous portion since the former develops postnatal especially after the age of 4 and depend on several factors such as biomechanical forces, epithelial changes and so on[20].

3.2. Comparative anatomy

Since procuring human temporal bones is becoming very difficult, cumbersome a few animal models are being considered for practicing various procedures and also understanding the basic anatomical structures and topography.

The animal models reviewed in this study are a miniature pig, sheep, and macaque.

3.2.1. Sheep

The anatomical structures of sheep such as external auditory meatus and the plane of the mastoid process seem to be morphologically similar. These bones can be utilized for practicing procedures such as cochlear implants and an active middle ear implant could be successfully done[1,5] in middle ear and inner ear respectively. The main disadvantages of this animal model are the absence of pneumatization, a sigmoid sinus and lack of a relationship of mastoid to middle cranial fossa, which make the bone not suitable for practicing mastoidectomy and study the pneumatization The temporal bone of the young sheep is smaller than the human one. The hypotympanum is pronounced in a bullous manner. Tympanic membrane and middle ear are very similar to the human one. The outer ear canal is smaller and shorter[3].

3.2.2. Pig

Similarities with the anatomy of a pig's model are tympanic membrane, ossicular chain, relationship of facial nerve to semicircular canals. Disadvantages seem to presence of excessive amount of soft tissue, pneumatization of the bone inferiorly rather than posteriorly as in humans. This model can be useful for practicing procedures on ossicular chain abnormalities. This is not suitable for inner ear and middle ear implants. The pig has a long and narrow external ear canal but a very similar middle ear anatomy compared to humans. The mastoid in both animals is not pneumatized[3].

Middle ear and tympanic membrane of both animals are morphologically equal to the structures found in human ears. The lamb's middle ear can be used for teaching anatomy although some structures are smaller than in human ears. The pig's ear is not useful for training mastoidectomy but can be used for surgical exercises on the ossicular chain[3].

3.2.3. Guinea pig

This can be used only for experimental purposes, otherwise it does not resemble topography of human bone[16].

Several authors have described and studied animal models in detail for experimental purposes, among them Lavinsky and Goycoolea [2] were the first to describe sheep as a possible animal model for otologic surgery because of these significant similarities in ear anatomy. Gurr et al. [3] proposed lamb and pig temporal bones as alternatives in ENT education.

4. Conclusion

In conclusion, present review emphasizes the need to study temporal bone pneumatization in further detail to establish a new classification of the air cells, for better understanding of the

pneumatization. This can further be used by anatomists, surgeons, and anthropologists for an improved perspective.

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