The Journal of Laryngology and Otology
June 1992, Vol. **106**, pp. 485–489

Correlation between temporal bone pneumatization, location of lateral sinus and length of the mastoid process

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Abstract

The relationship between temporal bone pneumatization and the location of the lateral sinus and length of the mastoid process was investigated in 60 fresh frozen adult temporal bones, by plain X-rays, computed tomography and surgical dissection including otomicroscopic findings. Temporal bone pneumatization was classified as small, moderate and large. After drilling, the shortest distances between the middle fossa dura and mastoid tip representing the mastoid length and between the sigmoid sinus and posterior border of external auditory canal were measured and compared to the degree of pneumatization. The distances in the specimens with pathological eardrum and adhesions in the middle ear were compared to the ones without gross pathology. The length of mastoid process was significantly shorter in specimens with small pneumatization than those with large (Mann Whitney $P<0.001$).

The specimens with a pathological eardrum and middle ear adhesions had a significantly shorter mastoid length than those without gross pathology. There was no significant difference between degree of pneumatization and the shortest distance between sigmoid sinus and external auditory canal (Mann Whitney $P>0.05$). It is demonstrated that the 'under-developed' mastoid process can be a consequence of hampered pneumatization.

Introduction

The factors influencing the temporal bone pneumatization pattern have been intensely debated for many years. According to the environmental theory (Wittmaack, 1918, Tumarkin, 1957; 1959; Gans and Wlodyka, 1966; Palva and Palva, 1966; Kolihova *et al.*, 1972; Tos, 1982), the extent of mastoid pneumatization is determined by the environmental factors, *i.e.* secretory otitis and middle ear infections. On the other hand the genetic or normal variant theory (Diamant, 1940; Ueda and Eguchi, 1962; Schulter-Ellis, 1979; Sade, 1979) claims that the size of the air cells is genetically determined and that a small cellular system predisposes to acute or chronic otitis. In view of this assertion, the size of mastoid air cell system and its relation with secretory otitis and chronic otitis were investigated by several authors (Diamant, 1952; Diamant *et al.*, 1958; Flisberg and Zsigmond, 1965; Gans and Wlodyka, 1966).

Asymmetry of the size of air cell system has been regarded as support for the environmental theory. (Tumarkin, 1957, 1959; Palva and Palva, 1966; Tos *et al.*, 1985). According to this concept the size of the mastoid air cell system is determined by the degree of pathological involvement of the middle ear during the childhood. Studies on healthy children followed from birth or infancy to school age confirmed this thesis *i.e.* the longer the previous episodes of secretory otitis media, the smaller is the air cell system or *vice versa* (Tos *et al.*, 1985).

Recent interesting animal studies showed histologically that inflammation of the middle ear inhibits the normal process of mastoid pneumatization in pigs and gives rise to hypocelularity of the mastoid process (Aoki *et al.*, 1986; Ikarashi and Nakano, 1987). Most recently, experimental data published by Aoki *et al.* (1990) confirmed this observation. Furthermore they showed that inflammation of the middle ear inhibits the growth of the mastoid process and reduces its length.

The correlation between pneumatization and the position of the lateral sinus was described in previous studies based on X-ray findings, *e.g.* the distance of lateral sinus from the external auditory canal is relatively shorter in poorly pneumatized mastoids and vice versa (Herrmann and Riehm, 1961).

However the measurements of the distance between the lateral sinus and the external auditory canal, and the length of the mastoid process with respect to the degree of pneumatization were not available on human temporal bones. The present study attempts to clarify this subject, based on surgical and radiological evaluations of pneumatization degree and microscopic findings of the eardrum and middle ear of the human fresh frozen temporal bones.

Material and methods

Investigations were carried out on a collection of 60

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Accepted for publication: 24 February 1992.

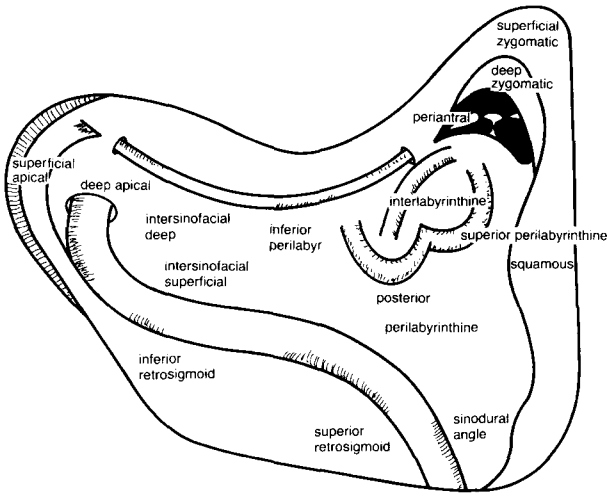

Fig. 1

Superficial groups of the air cells found and classified during the extended mastoidectomy.

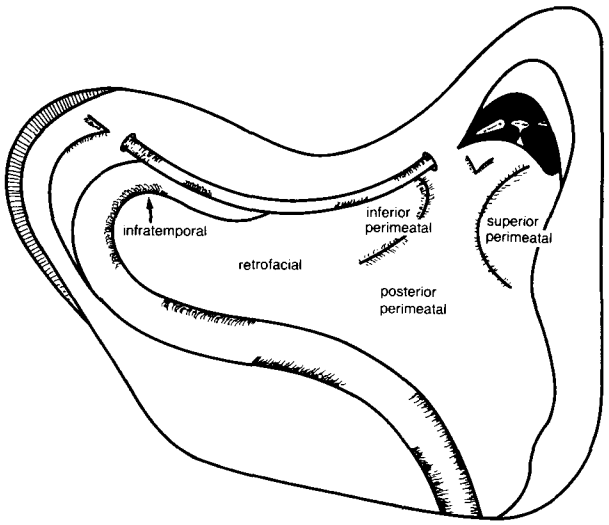

Fig. 2

Deeper groups of the air cells found and classified during the translabyrinthine approach.

unselected fresh frozen adult temporal bones obtained at autopsies. Of these, 48 were from the left and 12 from the right side; sex and age were unknown. In order to determine the mastoid, perilabyrinthine and perimeatal pneumatization deep frozen specimens were examined by conventional radiography in Runström II and Stenver's projections with the same X-ray apparatus and by Computed Tomography in coronal and axial sections. Mastoid air cell areas were measured on X-ray films. The demarcation of the cell system was marked on the radiographs, copied on transparent millimetre paper and the number of square millimetres were counted directly. Tympanic cavity, epitympanum and antrum were not included as in most previous studies (Diamant, 1940; Tos and Stangerup, 1984).

After radiographic examination, the tympanic membrane of each specimen was examined under the operating microscope at different magnifications.

In addition, tympanotomy and atticotomy on each specimen were performed and ossicles, middle ear mucosa and attic were examined and findings were recorded. Thereafter a complete drilling of the temporal bone was performed under the operating microscope simulating the translabyrinthine approach to the internal acoustic meatus. During the drilling 20 different groups of air cells (Figs. 1 & 2) were examined and each group of the air cells were scored from 0 to 5 according to volume and number of the air cells (Hug and Pfaltz, 1981) (Table I). The sum of the scores from the 20 cell groups represented the total score of each temporal bone. Based on the total scores, the degree of pneumatization was classified as small, moderate or large. The total score in each group is shown in Table II.

The posterior wall of the external auditory canal was made as thin as possible as in intact canal wall mastoidectomy. The shortest distance between middle fossa dura and mastoid tip representing the length of the mastoid process were measured using the operating microscope.

Results

The length of the mastoid process. There was a highly significant positive correlation between the length of the mastoid process and the degree of pneumatization ($P<0.05$)(Fig. 3).

Lateral sinus and external auditory canal distance. There was no statistically significant correlation between lateral sinus and external auditory canal distance and the degree of pneumatization ($P>0.05$)(Fig. 5).

Temporal bone pneumatization

1) Planimetry. Median planimetric air cell size was 7.32 cm^2 (range: 1.54 to 17.32 cm^2). The positive correlation between the individual total score of pneumatization and the individual planimetric air cell size is highly significant (Fig. 4). There was also a significant correlation between degree of pneumatization expressed in total score and planimetric size of the mastoid air cells (Table III).

2) CT findings. For technical reasons useful CT pictures

TABLE I

SCORING OF THE AIR CELLS

	Air cells		
Score	No	The biggest diameter	Visualization
0	None	—	—
1	1–2	<1 mm	Can be seen under oper. microscope with 6× magnification
2	1–2	1 mm in diameter	Can be seen without microscope
3	1–2	>1 mm <2 mm	Can be seen easily
4	1–2	>2 mm <3 mm	Can be seen easily
5	1 or more	>3 mm	Large

https://doi.org/10.1017/S0022215100119942 Published online by Cambridge University Press

TABLE II
PLANIMETRIC SIZE OF THE MASTOID AIR CELLS IN VARIOUS DEGREES OF PNEUMATIZATION

Pneumatization degree	Total score range	No. of cases	Planimetric size (mm^2)		Mann-Whitney test
			Median	Range	
Small	31–55	22	4.5	1.5 – 9.22	$P<0.05$
Moderate	57–74	25	7.41	2.54–17.32	$P<0.01$
Large	77–93	13	12.20	5.40–17.32	$P<0.05$

were obtained only in coronal projections in all cases. There was a good positive correlation between CT-findings and total pneumatization score or planimetric air cell size (Table IV).

3) Pneumatization score. Total score range of specimens given during the drilling is shown in Table II.

Tympanic membrane pathology and adhesion. In seven cases of pathology of the drum either atrophy with retraction and myringosclerosis (three cases) or atrophy with retraction (two cases) or severe myringosclerosis (one case) or severe attic retraction (one case) was found at the initial otomicroscopy. In all these cases adhesions around the stapes and in the attic were observed. In three cases adhesions only were found (Table V). The pneumatization score and the length of the mastoid process were significantly smaller in the 10 cases with gross middle ear pathology, than in the 50 cases without gross pathology (Mann Whitney $P<0.05$, Table V).

The length or the mastoid process of the specimens with pathological eardrum and middle ear pathology, was significantly shorter than of those with no pathology (Mann-Whitney test $P<0.001$, Table V).

Discussion

We have been unable to find investigations correlating the length of the mastoid process and the degree of mastoid pneumatization in the literature. Low positioned dura, short mastoid process and narrow space in the attic, often found at surgery for cholesteatoma, have as 'underdeveloped' mastoid process been taken as support for the genetic theory of pneumatization (Cheatle, 1910; Diamant, 1940). Experimental studies on pigs have shown (Aoki *et al.*, 1990) that early post-natal middle ear infection hampers growth of the mastoid process resulting in a shorter mastoid process with hypocellularity. The median length of the mastoid process in infected middle ears was 28.1 mm compared to 36.3 mm on the non-infected, opposite side.

The present study shows that this can also be the case in humans. The mastoid process has been found to be shorter in cases with drum pathology and there was significant correlation with the degree of pneumatization evaluated both planimetrically and directly. In several earlier epidemiological studies of cohorts of otherwise healthy children we have shown that upper airway infections cause secretory otitis and tubal dysfunction in small children (Tos, 1982; Tos *et al.*, 1985). These children may during the following years develop drum pathology, especially atrophy and tympanosclerosis (Tos *et al.*, 1984, 1985). At the same time the pneumatization process will be hampered resulting in hypocellularity. We have documented tympanometrically that children having secretory otitis and tubal occlusion previously, had significantly poorer pneumatization than children without previous middle ear pathology (Tos *et al.*, 1984, 1985).

In this study we were unable to find significantly larger distances between posterior meatal wall and anterior border of the lateral sigmoid sinus, but there were tendencies towards longest median distance in ears with large cell system. The observation of 'a forward lateral sinus is usual and found in diploetic mastoids' was mentioned in earlier publications (Cheatle, 1910; Meltzer, 1934). Herrmann and Riehm (1961) confirmed these observations and

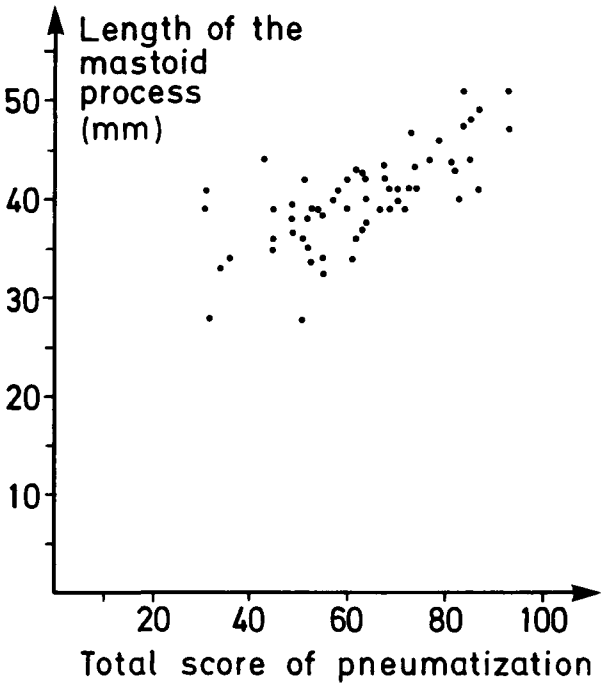

Fig. 3

The individual length of the mastoid process exposed as the shortest distance between middle fossa dura and inferior border of mastoid tip correlated to the individual total score of pneumatization given during the drilling of 60 fresh frozen temporal bones.

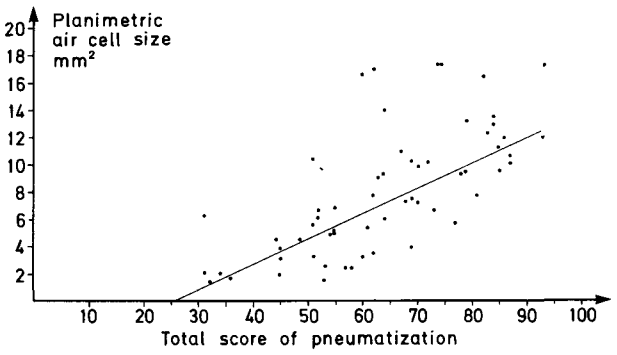

Fig. 4

Individual planimetric air cell size on X-rays correlated to the individual total score of pneumatization given during the drilling of 60 fresh frozen temporal bones as Fig. 3.

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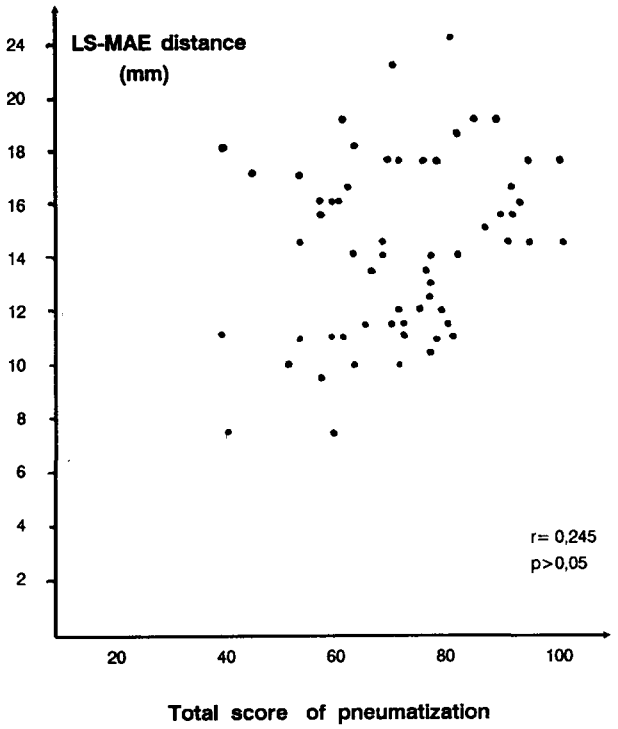

Fig. 5
Individual distribution of LS-MAE distance in various pneumatization.

found on X-rays a larger distance in ears with larger cell system. More recently Shatz and Sade (1990) found similar results. In the studies based on X-ray findings, the shortest radiological distance between the anterior border of lateral sinus and the posterior border of the bony annulus was measured. We measured the shortest surgical distance between the lateral edge of the external auditory canal and the anterior border of lateral sinus. This distance is influenced by the longitudinal axis of the external auditory canal which must be determined genetically and is different from one individual to another.

Temporal bones were collected randomly in the pathology department in patients who died at the hospital and in whom permission to open the cranium was given by the family. For ethical reasons we have not been able to obtain clinical data from the family nor do we have information on sex and age except that all were adults. Diamant (1940) found a larger air cell system in girls 10–15 years than in boys of the same age. No significant difference was found for other age groups. In Diamant's (1940) opinion the sex differences can be attributed to the hormonally induced growth of the cell system which is faster in girls immediately before and during puberty. In our previous study (Tos and Stangerup, 1985) we also found significantly smaller cell systems in seven-year-old boys than girls, but this difference was caused by more pronounced middle ear pathology in boys during early childhood. Since in this study the comparison with pneumatization and length of the mastoid process was done in the same ears, the sex cannot have an influence on the result.

The results were based mainly on blind investigations:

1) X-rays and CT-investigations were carried out and evaluated blind before the anatomical study.
2) Description of eardrum pathology and middle ear conditions were carried out before mastoidectomy without knowledge of the radiological findings.
3) Grading of air cell in 20 locations during the mastoidectomy was done without knowledge of the planimetric data.
4) Measurement of the length of the mastoid process was performed after mastoidectomy and the investigator did have knowledge about the size of the lateral air cells; the measurements were objective and unbiased.

We found a good correlation between the planimetric size of the air-cells which register the area of the lateral borders of the air-cells and the total score of pneumatization which register all cells. Planimetric evaluation of pneumatization on X-ray in Runström II projection is for clinical purposes still sufficient, though CT-evaluation in the coronal position gives excellent information on pneumatization, especially perimeatal and perilabyrinthine.

Conclusion

We have demonstrated in this work good support for Tumarkin's (1957, 1958) environmental theory of pneumatization and showed that the so called 'under-developed' mastoid process which has been taken as a support for a genetic theory, can to a high degree be caused by a hampered pneumatization process a consequence of respiratory tract infection, tubal dysfunction, acute otitis and secretory otitis during early childhood.

Acknowledgements

We are grateful to Reha Alpar from the Subdepartment

TABLE III
CT FINDINGS OF SPECIMENS CORRELATED TO PNEUMATIZATION SCORE AND PLANIMETRIC AIR CELL SIZE

Pneumatization of deeper cells on CT	No. of cases	%	Total pneumatization score Median	Range	Mann-Whitney test	Planimetric air cell size (cm^2) Median	Range	Mann Whitney test
Large superior perimeatal cells	20	33.3	78	69–93	$P<0.01$	10.68	2.60–17.32	$P<0.01$
No or small superior perimeatal cells	40	66.7	55	31–84		5.05	1.54–13.52	
Large inferior perimeatal cells	7	11.7	84	62–93	–	10.20	7.08–17.32	–
No or small inferior perimeatal cells	53	88.3	61	31–87		6.04	1.54–17.32	
Large inferior perilab. cells	26	35	70	60–93	$P<0.01$	9.32	2.04–17.32	$P<0.01$
No or small inferior perilabyrinthine cells	34	65	55	32–85		5.42	1.54–17.32	
Total	60	100	63.5	31.93	–	7.32	1.54–17.32	–

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TABLE IV

EAR DRUM PATHOLOGY AND OR ADHESIONS IN THE ATTIC AND AROUND THE STAPES IN 10 TEMPORAL BONES CORRELATED TO PNEUMATIZATION SCORE AND LENGTH OF MASTOID PROCESS AND COMPARED TO 50 TEMPORAL BONES WITHOUT GROSS PATHOLOGY

Ear drum pathology	Adhesions	No. of cases	Total pneumat. scores	The length of mastoid process	Mann-Whitney test
Atrophy with retraction and myringosclerosis	+	3	31, 69, 68	28, 39, 43.5	
Atrophy with retraction	+	2	34, 70	33, 22	
Myringosclerosis	+	1	51	28	
Attic retraction	+	1	55	38.5	$P<0.001$
Normal ear drum	+	3	36, 49, 69	34, 39.5, 39	
Total pathology	+	10	31–70	28–43.5 (range)*	$P<0.05$
No pathology	–	50	31–93	31–51 (range)*	

of Biostatistics, Hacettepe University, for statistical consulting.

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Key words: Temporal bone