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Association of various factors related to mastoid buffer and middle ear ventilation in etiopathogenesis of squamous chronic otitis media—a cross-sectional study

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Abstract

Background Active squamous chronic otitis media (COM) is an entity with a deep retraction pocket of the pars tensa or flaccida that has retained debris of squamous epithelial where the fundus cannot be visualized involving the pars flaccida or pars tensa, associated with cholesteatoma. Eustachian tube dysfunction (ETD) is a known etiological factor for squamous COM, based on Wittmack's theory; however, there are very few recent studies in this regard. Contracted mastoid pneumatization (diploic or primary sclerosis) and presence of Korner's septum have also been implicated to be associated with middle ear pathology, with conflicting results.

Hence, the present study was undertaken to find out the association of three important factors, namely eustachian tube dysfunction, type of mastoid pneumatization, and Korner's septum related to mastoid buffer and middle ear ventilation in etiopathogenesis of active squamous chronic otitis media. The study also attempted to identify various conditions of nose and nasopharynx associated with ETD. This would enable us in appropriate surgical decision making with long term benefits in term of hearing and disease outcomes.

Results Out of the total 37 patients, with active squamous chronic otitis media, it was observed that Eustachian tube dysfunction was found to be associated with 23 (62.16%). The majority of patients had a diploic/primary sclerosed mastoid pneumatization pattern which is 32 (86.48%) of patients. Korner's septum was found to be associated with 13 (35.13%) patients of the total 37 patients with active squamous chronic otitis media. All these findings were found to be statistically significant.

Conclusion In this study, we found that there was a statistically significant positive association of all etiological factors namely Eustachian tube dysfunction, contracted mastoid (diploic/primary sclerotic mastoid), and the presence of Korner's septum with causation of active squamous otitis media. Out of these factors, occurrence of diploic mastoid seemed to be the most constant association. Eustachian tube dysfunction of mechanical type, associated with various nasal pathologies, most common was, deviated nasal septum.

Keywords Chronic otitis media, Retraction pocket, Cholesteatoma, Eustachian tube dysfunction, Mastoid pneumatization, Korner's septum

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Background

Chronic otitis media (COM) is a long-term inflammation of the middle ear that results in permanent tympanic membrane changes such as perforation, dimer formation, tympanosclerosis, atelectasis, retraction pockets, or cholesteatoma [1]. The term “chronic suppurative” otitis media (CSOM) is no longer recommended, as the disease often encompasses inactive perforations and retractions without pus formation [2]. Squamous chronic otitis media and mucosal chronic otitis media are two main sub-classifications of COM. Chronic otitis media (squamous type), according to Browning’s classification, can present in an inactive form (retraction pocket) or an active form (frank cholesteatoma formation). Inactive (squamous) COM retraction of the pars flaccida or pars tensa (usually posterosuperior), where the fundus is seen and self-cleaning, with the potential to become active with retained debris. Active squamous COM, which is typically connected to frank cholesteatoma, is an entity with a deep retraction pocket of the pars tensa or flaccida that has retained debris of squamous epithelial where the fundus cannot be visualized. It could involve Pars flaccida or Pars tensa (posterosuperior retraction pocket, marginal perforation). Both Pars flaccida and Pars tensa cholesteatoma can begin with the development of retraction pockets [3, 4]. As inactive squamous otitis was not included in atticointral diseases, the terminology changed from atticointral disease to squamous chronic otitis media [5]. There is still a difference between active and inactive COM, even if there is a chance that the ear could eventually turn active. Active COM is defined as having inflammation and pus production.

Chronic otitis media (COM), which is often caused by acute otitis media, negative pressure in the middle ear, or otitis media with effusion, is linked to a permanent change in the pars tensa or flaccida [5]. The most common pathophysiology advocated for the squamous type of COM is Wittmack’s theory, which results in primary acquired cholesteatoma. Tubal dysfunction is thought to be the primary cause of the development of a retraction pocket, which then results in negative middle ear pressure and a frank cholesteatoma [5]. “Eustachian tube (ET) dysfunction and poor mastoid pneumatization have been found to have a causal relationship with middle ear pathology [6, 7]. One of the early sequelae seen is tympanic membrane retraction. The aetiology of middle ear disease is multifactorial, but an abnormal function of the ET appears to be the most important factor in the pathogenesis of the disease. ET dysfunction is defined as an inadequate dilatory function causing secondary ear pathology, which can result from mechanical obstruction. Compared to adults, in children with otitis media

with effusion and healthy children, the active tubal function is poor. ET opening dysfunction or muscular opening hypofunction in children is considered a primary endogenous etiologic factor for chronic otitis media.” The following events lead to acquired cholesteatoma: mechanical or functional ET blockage, elevated negative middle ear pressure, tympanic membrane atelectasis, and a retraction pocket in either the posterosuperior or attic section of the tympanic membrane middle ear [8]. Another factor associated with the etiopathogenesis of squamous chronic otitis media is temporal bone pneumatization [7]. “Temporal bone pneumatization plays an important role in COM’s aetiology, course, and outcome. Recently, the mastoid air cell system has been recognized as an important contributor to the pathophysiology of middle ear inflammatory diseases. Various studies have been designed to investigate the correlation between middle ear disease and the mastoid air cell system. It is debatable whether the hypo cellularity results from previous middle ear disease (environmental pneumatization theory) or whether the size of the cell system is genetically determined” [9]. Pars flaccida retraction pockets and cholesteatoma have been linked in a significant way to poorly pneumatized mastoids, and it has been demonstrated that the severity of retraction is directly related to the degree of pneumatization [10]. But research has also revealed the presence of cholesteatoma in ears with well-pneumatized mastoids [8]. It is still unclear if cholesteatoma is related to either primary sclerosis or secondary sclerosis [11]. Most otitis media cases develop secondary sclerosis because of new bone growth [8]. Other factors like Körner’s septum (KS), the persistence of the petrosquamosal suture, and a developmental remnant are associated with squamous chronic otitis media [12]. “During mastoid surgery, it could be taken as a false medial wall of the antrum so that the deeper cells might not be explored. In general, it is very uncommon to find the persistence of KS in the adult temporal bone as compared to the paediatric temporal bone” [12].

There is a huge research gap in the knowledge of the etiopathogenesis of squamous-type otitis media, and the existing studies have conflicting results [6, 9, 10]. We undertook this study to find out the individual contribution of various factors likely to be associated with mastoid buffer and middle ear ventilation in etiopathogenesis of squamous chronic otitis media so that we could target appropriate management to achieve long-term clinical benefits in terms of prevention of recurrence of cholesteatoma and a better hearing outcome. In the present study, we attempt to analyze the role of Eustachian tube dysfunction, mastoid pneumatization, and the contributory role of Körner’s septum in the causation of

squamous chronic otitis media of the active type as they can affect the mastoid buffer and middle ear ventilation. This is probably the first prospective study conducted to find out the individual contribution of various factors like Eustachian tube dysfunction, type of mastoid pneumatization, and presence of Korner's septum that can affect the mastoid buffer and middle ear ventilation in etiopathogenesis of squamous chronic otitis media.

Methods

This was a prospective observational study cross-sectional study, carried out between November 2020 and December 2023 in the Department of Otolaryngology, a tertiary care teaching hospital situated in the rural area, on 50 patients of COM (squamosal active type), between the age group of 16–75 years, attending in out-patient department, casualty of the hospital or brought from rural peripheral areas in camps, diagnosed based on history and general physical examination and detailed otorhinolaryngological examination. “A predesigned proforma was used to record the relevant information (patient data, clinical findings, and investigation reports). All the patients who met the inclusion/exclusion criteria and after obtaining written and informed consent from them, a total of 37 patients were enrolled for the study. Inclusion criteria included COM (Squamosal active type), between the age group of 16–75 years and who has given consent to undergo a CT scan and DNE. Exclusion criteria included patients with chronic otitis media mucosal type and inactive squamosal type disease, the patients above 75 years of age and below 16 years of age, with totally adhesive tympanic membranes, marginal perforation, and total perforation, suspicion that ear pathology is malignant, congenitally diseased ear, congenital cholesteatoma, old operated cases, and tuberculous otitis media.

The study was conducted after prior institutional ethics committee approval. All patients were included based on history regarding ear discharge, reduced hearing, tinnitus, earache, vertigo, and facial nerve palsy. The otoscopic examination was performed, to find the tympanic membrane status like pars tensa retractions, posterior superior retraction pocket (PSRP), attic retractions, and perforations which suggested a squamous type of chronic otitis media and status of the middle ear.

Relevant investigations were done and included “Pure Tone Audiometry as a baseline investigation for assessing the type and degree of hearing loss. High-resolution CT of the temporal bone for all the patients to look for mastoid pneumatization, cholesteatoma, or disease extent and presence of any anatomical variations like Korner's septum, contracted mastoid due to low-lying dura or anteposed sigmoid sinus.

Dynamic slow motion video endoscopy (DSVE) for assessment of Eustachian function and nasal/paranasal sinus/nasopharyngeal pathology was done for all the patients. “DSVE was done by a 30° nasal endoscope of 4-mm diameter under local anesthesia. Grading of ET opening was done. All the subjects with DSVE grades 0 and 1 were assumed to have normal ET function, whereas grades 2 and 3 and patulous tubes were assumed to be dysfunctional. Patients were also assessed for deviated nasal septum and classified as per Jain Bhalerao classification [13], for adenoid hypertrophy, huge concha bullosa, turbinate hypertrophy, and cleft lip/palate.

Statistical analysis was done by using descriptive and inferential statistics using the chi-square test, and the software used in the analysis were SPSS 17.0 version, GraphPad 6.0 version, and EPI-INFO 6.0 version, and $p < 0.05$ is considered as the level of significance ($p < 0.05$). Statistical results were appropriately tabulated, and the graphs were made. It was then compared with the available literature on similar studies and the inferences were recorded” (Figs. 1, 2, 3, 4, and 5).

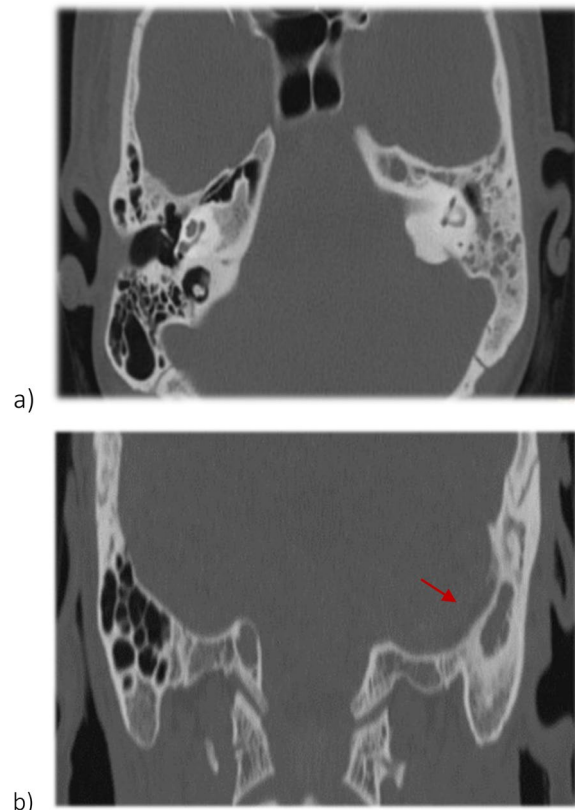


Fig. 1 Axial scan and coronal scan showing well pneumatized mastoid on right side (a) and left mastoid showing secondary sclerosis with soft tissue density lesion (red arrow)

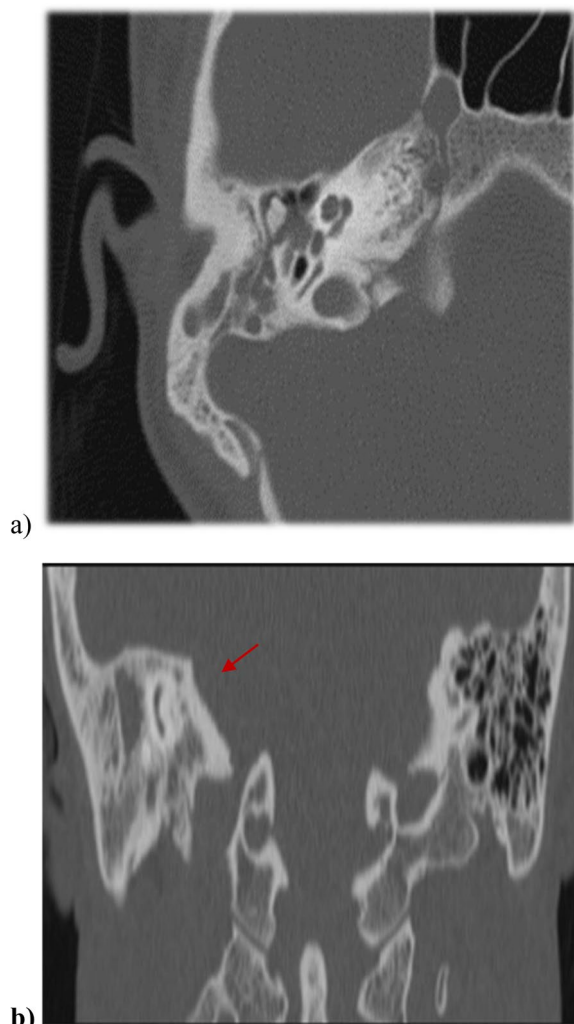


Fig. 2 Axial scan and coronal scan showing diploic mastoid on left side (a) and right mastoid showing secondary sclerosis with soft tissue density lesion (red arrow) (b)

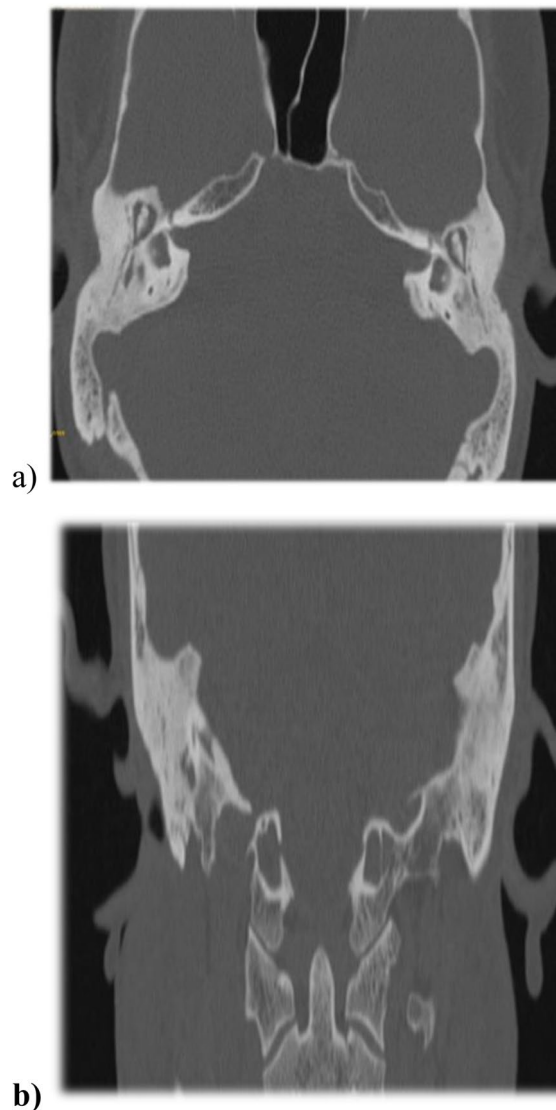


Fig. 3 a, b Axial scan and coronal scan showing primary sclerosis mastoid on both sides

Results

Of the total of 37 patients, the youngest patient in our study was 16 years old while the eldest was 72 years. The most common age group affected, with squamous chronic otitis media was 16 to 35 years (54.05%), with male to female ratio being 1.2:1 as depicted in Table 1. The number of ear surgeries performed was more on the left side than on the right side. In 21 (56.80%), the patients' left ear was operated and in 16 (43.20%) patients, and the right ear was operated as depicted in Table 1. Also in our study, 97.3% of patients had foul smelling discharge followed by 91.89% with reduced hearing, 62.16% had earache, tinnitus was present in 54.05% of patients, and other symptoms comprised of vertigo and facial weakness which 13.51% (Table 1).

None of the patients presented with blood-stained discharge or allergy. Also, 32.40% of patients had history of ear discharge since childhood and 48.64% of patients more than 10 years, 18.90% with duration of less than 10 years (Table 1).

In our study, the Eustachian tube dysfunction was found to be associated with 23 (62.16%) patients of the total 37 patients with active squamous chronic otitis media. This was found to be statistically significant ($P=0.0001$) as depicted in Table 2. We also found that out of 36 patients with deviated nasal septum, 23 cases (63.88%) had Eustachian tube dysfunction. Out of 7 patients with concha bullosa, 6 cases (85.71%) had

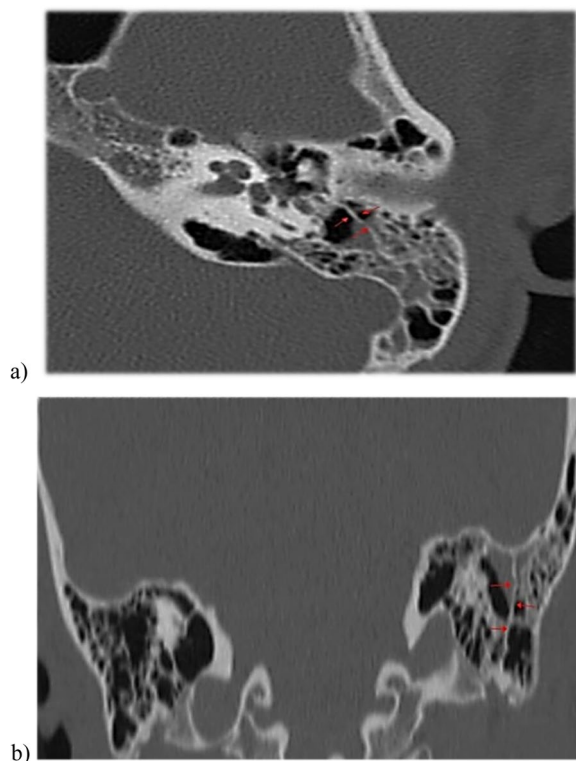


Fig. 4 Korner's Septum, **a** axial section (red arrows) and **b** coronal section (red arrows)



Fig. 5 **a** Axial scan showing deviated nasal septum to right with bilateral Concha bullosa

Eustachian tube dysfunction. Among 4 patient with adenoids and 3 patient with cleft palate, both were found to have Eustachian tube dysfunction, as shown in Table 3. Diploic/primary sclerotic mastoid was found to be associated with 32 (86.48%) patients of the total 37 patients with active squamous chronic otitis media. This was found to be statistically significant ($P=0.0001$) (Table 2). Korner's septum was found to be associated with 13

Table 1 Baseline characteristics of patients

Parameters	Number of patients <i>n</i> = 37	Percentage
Age		
16–35	20	54.05
36–55	15	40.54
> 56	2	5.4
Gender		
Male	21	56.8
Female	16	43.2
Laterality of ear operated		
Right	16	43.2
Left	21	56.8
Presenting symptoms		
Foul smelling otorrhea	36	97.30
Reduced hearing	34	91.89
Tinnitus	20	54.05
Earache	23	62.16
Others	5	13.51
Duration of discharge		
Since childhood	12	32.4
> 10 years	7	18.9
< 10 years	18	48.64

(35.13%) patients of the total 37 patients with active squamous chronic otitis media. This was found to be statistically significant ($P=0.0001$) (Table 2).

Discussion

The present study was conducted on 37 subjects of active squamous otitis media, in order to determine the relationship between various factors associated with the etiology of squamous chronic otitis media, namely eustachian tube dysfunction, contracted mastoid (diploic or primary sclerosis), and the presence of Korner's septum, and we found a positive correlation of occurrence of these factors with squamous COM.

The contributory role of each etiological factor in causation of type of active squamous chronic otitis media was also studied to better understand the pathophysiology of Squamous COM, and also in order to enable targeting appropriate management to achieve long-term clinical benefits in preventing disease recurrence and a better hearing outcome.

Classically, acquired cholesteatomas are divided into the attic by the pars flaccida and sinus, as well as by the posterosuperior retraction (PSRP) of the pars tensa [3]. Because the Pars tensa is closely associated with the Eustachian tube, Eustachian tube dysfunction can result in Pars tensa retractions due to middle ear negative pressure. Also, when the middle ear mucosa irritates the

Table 2 Association of various factors with active squamous chronic otitis media

Type of disease	Number of patients	ET dysfunction on DSVE	Normal ET function	P value
Active squamous otitis media	37 (100%)	23 (62.16%)	14 (37.83%)	46.91 P=0.0001, S
	Number of patients	Well pneumatized	Diploic/primary sclerosis	
Active squamous otitis media	37 (100%)	5 (13.5%)	32 (86.48%)	191.6 P=0.0001, S
	Number of patients	Korner's septum present	Korner's septum absent	
Active squamous otitis media	37 (100%)	13 (35.13%)	24 (64.86%)	96.30 P=0.0001, S

Table 3 Distribution of patients according to Eustachian tube dysfunction and other factors associated with it

Other associated factors	Number of patients	ETD
Deviated nasal septum	36 (97.29%)	23 (63.88%)
Concha bullosa	11 (29.7%)	6 (85.71%)
Adenoids	4 (10.81%)	4 (100%)
Cleft palate	3 (2.70%)	3 (100%)

tympanic membrane, the double layer of collagen fibers and elastic fibers breaks down, making the tympanic membrane weaker and causing retraction pockets, especially in the pars tensa [2]. The pars flaccida is more likely to pull back because it is more fragile. The progression of the cholesteatoma seems to depend on changes in the attic ventilation routes and a longer time for the disease to develop [3].

Eustachian tube dysfunction was found to be associated with 23 (62.16%) of the total 37 patients with active squamous chronic otitis media, which was found to be statistically significant. Our results were similar to Gue et al. who found in their study that eustachian tube dysfunction is a major pathogenic factor in chronic otitis media [13]. Kaushik et al. found that 33.33% of patients with squamous chronic otitis media had Eustachian tube dysfunction [14]. In this study, maximum Eustachian tube dysfunction (mechanical) was seen in 23 cases of the deviated nasal septum, followed by concha bullosa in 6 cases, and the presence of adenoids in 4 cases and functional dysfunction in cleft palate in 3 cases. Jain et al. investigated the various types of deviated nasal septum and their relationship with Eustachian tube dysfunction, discovering that 80% of cases with deviated nasal septum had Eustachian tube dysfunction as well as the presence of concha bullosa, resulting in pressure drop and torus edema [15]. Goldman et al., in their study, found the incidence of ETD to be as high as 79% in patients with cleft palate and lip

[16]. Gudziol et al. found that in adults with cleft lip or palate, there is persistent ETD [17].

In this study, contracted mastoid (diploic or primary sclerotic mastoid) lesions were found to be associated with 32 (86.48%) of the total 37 patients with active squamous chronic otitis media and were found to be statistically significant. Sade et al. found in their study that poorly pneumatized mastoids tend to develop retraction pockets and cholesteatoma, while well-pneumatized mastoids are rarely at risk of cholesteatoma [18]. Sade et al. found that ears with poorly pneumatized mastoids lack the buffering action on middle ear pressure and hence have a tendency to develop a negative gas balance with persistently high negative pressure and resultant COM [19]. Our result was similar to study by Jain et al. found that contracted mastoid cells with primary sclerosis have a tendency to cause squamous chronic otitis media by affecting the mastoid buffer system [6]. But contradicting most of the studies and our present study, Isma et al. found that the incidence of cellular mastoid was much higher in chronic otitis media [20].

In this study, Korner's septum was found to be associated with 13 (35.13%) of the total 37 patients with active squamous chronic otitis media. This was found to be statistically significant. Our results were similar to those of Goksu et al. who found the incidence of Körner's septum (KS) to be 21% in temporal bones, 30.4% in ears with chronic otitis media, and 6.58% in normal ears. In their study, they also found that in 33% KS was incomplete [21]. Hence, the association was found between presence of KS and COM, by its higher occurrence in diseased ears. Cigdem et al. found that out of 356 ears that underwent tympanoplasty, the incidence of Körner's septum was 28% [22]. The occurrence of this entity may be underreported by studies, as there are very few studies related to this.

Contracted mastoid (primary sclerosis and diploic) is found to be the major factor in the causation of squamous chronic otitis media, but since ETD also has an etiological relationship with squamous chronic

otitis media, if ETD is not addressed in patients, this might lead to an inadequate hearing outcome and a likely recurrence of the disease. Negative pressure being the culprit for structural weakening of tympanic membrane which results in retraction pocket and cholesteatoma formation. This fact also emphasizes the importance of mastoid air volume in the development of squamous COM, which is low in diploic or primary sclerotic mastoid patients. Other studies have also validated this [4, 9, 10]. Korner's septum is an important anatomical variation, can likely be genetical, the presence of which can reduced the mastoid air volume, if found to have a synergistic role with other factors in causing squamous COM.

Mastoid obliteration techniques might decrease the air volume. Also, limited surgical approaches like inside-out, which aim at only exteriorizing the cholesteatoma sac, may not provide the adequate mastoid volume needed to prevent the recurrence of the retraction pocket or cholesteatoma. But it is also crucial to keep good hearing and avoid recurrences; therefore, we need to address the nasal pathologies especially deviated nasal septum for correction of Eustachian tube dysfunction, which is often neglected in squamous chronic otitis media and contracted mastoid (diploic/primary sclerotic mastoid) is the major contributory factor related to the etiopathogenesis of active squamous COM, the focus of surgery should not be only on disease clearance, but also on purpose of ventilation. Early identification of the causes is not always possible as Eustachian tube dysfunction in many occasions is not associated with nasal symptoms. However, we propose that in any case of squamous otitis media from stage of inactive retraction pocket itself should be investigated for all the three proposed etiological factors in order to prevent the progression of inactive squamous into active squamous chronic otitis media.

Conclusion

In the present study, we concluded that there was a positive statistically significant association of all etiological factors namely Eustachian tube dysfunction, contracted mastoid (diploic/primary sclerotic mastoid), and the presence of Korner's septum with causation of active squamous otitis media, an entity associated with cholesteatoma. This pilot study is probably the first one done in order to elucidate the contributory role of different etiopathogenetic factors related to buffering action of the mastoid and middle ear, with implications in disease occurrence. Among them, contracted (diploic/primary sclerotic) mastoid was the most significant and constant etiological factor, in causation of active squamous otitis media (primary cholesteatoma).

The likelihood of the development of active squamous otitis media increases with ETD. Eustachian tube dysfunction (ETD) of the mechanical type, was associated with various nasal pathologies, most common being, deviated nasal septum, followed by concha bullosa therefore needs to address nasal pathologies especially deviated nasal septum for correction of Eustachian tube dysfunction, even in cases of squamous COM, for better treatment outcomes and prevention of recurrence. There appears to be the contributory role of Korner's septum however mostly in the presence of other etiological factors like ETD and/or contracted mastoid.

Abbreviations

OM	Otitis media
COM	Chronic Otitis Media
CSOM	Chronic suppurative otitis media
CT	Computed tomography
HRCT	High resolution computed tomography
MRI	Magnetic resonance imaging (MRI)
ET	Eustachian tube
ETD	Eustachian tube dysfunction
KS	Korner's septum
PTA	Pure tone audiometry
TM	Tympanic membrane
PT	Pars tensa
PF	Pars flaccida
TS	Tympano-sclerotic
PSRP	Posterior superior retraction pocket

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Authors' contributions

MM and SJ prepared the manuscript, contributed to data acquisition, and edited the manuscript. SJ contributed to the conceptualization, and preparation of the manuscript and revised it critically for important intellectual content. VH contributed to data acquisition and approved the final draft of the manuscript. CVS contributed towards data acquisition and approved the final draft of the manuscript. PTD and SG contributed towards data acquisition and approved the final draft of the manuscript. SVM and NP contributed towards data acquisition and approved the final draft of the manuscript.

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Availability of data and materials

All data sets collected during this study are available upon reasonable request from the corresponding author.

Declarations

Ethics approval and consent to participate

Ethics committee's name: Institutional Ethics Committee(Jawaharlal Nehru Medical college and Acharya Vinoba Bhawe Rural Hospital Sawangi (Meghe),Wardha), This approval has been granted on assumption that the proposed research work will be carried out in accordance with ethical guidelines prescribed by Central Ethics Committee on Human Research (C.E.C.H.R) Date of approval: 22/12/2020 Reference number: DMIMS(DU)/IEC/2020-21/9330. All the patients who met the inclusion/exclusion criteria and after obtaining written and informed consent from them.

Consent for publication

Written informed consent was taken from the patients.

Competing interests

The authors declare that they have no competing interests.

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References

- Glasscock ME, Julianna Gulya A, Lloyd B, Minor/Dennis S. Poe (2006). Shambaugh surgery of the ear 6th edn. Peoples medical publishing house USA Shelton, Connecticut: p 502–503.
- Browning GG, Saumil N Merchant, Gerard Kelly, Iain RC Swan, Richard Canter, William S Mckerrow (2008) Chronic otitis media. In: Gleeson M, Browning GG, Burton MJ, Clarke R, Hibbert J, Jones NS, et al, editors. Scott-Brown's Otorhinolaryngology, Head and Neck surgery. 8th edn Great Britain. Edward Arnold (Publishers) Ltd: vol 2; p 997–998
- Sudhoff H, Tos M (2000) Pathogenesis of attic cholesteatoma: clinical and immunohistochemical support for combination of retraction theory and proliferation theory. *Am J Otol* 21(6):786–792
- Sudhoff H, Tos M (2007) Pathogenesis of sinus cholesteatoma. *Eur Arch Otorhinolaryngol* 264(10):1137–1143
- Dr. Mithula Murali, Dr. Shraddha Jain. (2021). A study on various factors associated with the etiopathogenesis of squamous chronic otitis media: a cross-sectional study. *Annals of the Romanian Society for Cell Biology*, 4077–4084. Retrieved from <https://www.annalsofscb.ro/index.php/journal/article/view/524>
- Jain S, Singh P, Methwani D, Kalambe S (2019) Role of Eustachian Dysfunction and primary sclerotic mastoid pneumatization pattern in aetiology of squamous chronic otitis media: a correlative study. *Indian J Otolaryngol Head Neck Surg* 71(Suppl 2):1190–1196. <https://doi.org/10.1007/s12070-018-1259-x>
- Sethi, Ashwani & Singh, Ishwar & Agarwal, A. & Sareen, Deepika. (2006). Pneumatization of mastoid air cells: role of acquired factors. *Int J Morphol*. 24. <https://doi.org/10.4067/S0717-95022006000100007>.
- Homquist J, Bergström B (1977) Eustachian tube function and size of the mastoid air cell system in middle ear surgery. *Scand Audiol* 6(2):87–89. <https://doi.org/10.3109/01050397709045003>
- Sadé J, Fuchs C (1996) Secretory otitis media in adults: I. The role of mastoid pneumatization as a risk factor. *Anna Otol Rhinol Laryngol* 105(8):643–647. <https://doi.org/10.1177/000348949610500810>
- Iqbal IZ, Watson C (2016) A study of mastoid pneumatization and the presence of cholesteatoma in 393 patients. *J Laryngol Otol* 130(1):66–68. <https://doi.org/10.1017/S0022215115003047>
- Lee DH, Jung MK, Yoo YH, Seo JH (2008) Analysis of unilateral sclerotic temporal bone: how does the sclerosis change the mastoid pneumatization morphologically in the temporal bone? *Surg Radiol Anat* 30(3):221–227. <https://doi.org/10.1007/s00276-008-0310-0>
- Wojciechowski T, Skadorwa T, Drożdż A, Ciszek B, Szopiński K (2019) The radioanatomical assessment of the Körner's septum. *Surg Radiol Anat* 41(6):669–673. <https://doi.org/10.1007/s00276-018-2149-3>
- Han WG, Yoo J, Rah YC, Chang J, Im GJ, Song JJ, Chae SW, Jung HH, Choi J (2017) Analysis of eustachian tube dysfunction by dynamic slow motion video endoscopy and eustachian tube dysfunction questionnaire in chronic otitis media. *Clin Exp Otorhinolaryngol* 10(4):315–320. <https://doi.org/10.21053/ceo.2016.01683>
- Kaushik MR, Shukla A, Dehadaray AY, Mishra P, Johnson J (2018) The elusive eustachian tube and its role in chronic otitis media. *Indian J Otol* 24:53–55
- Jain S, Bhalerao P, Singh C (2020) ARTICLE A new endoscopic and anatomical classification of deviated nasal septum with clinical relevance *Medical Science. Med Sci* 24:2544–2554
- Goldman JL, Martinez SA, Ganzel TM (1993) Eustachian tube dysfunction and its sequelae in patients with cleft palate. *South Med J* 86(11):1236–1237. <https://doi.org/10.1097/00007611-199311000-00010>. PMID: 8235774
- Gudziol V, Mann WJ (2006) Chronische Tubendysfunktion und ihre Folgeerkrankungen bei Erwachsenen mit einseitiger Lippen-Kiefer-Gaumen-Spalte [Chronic eustachian tube dysfunction and its sequelae in adult patients with cleft lip and palate]. *HNO* 54(9):684–688. <https://doi.org/10.1007/s00106-005-1362-7>
- Sadé J, Fuchs C, Luntz M (1997) Shrapnell membrane and mastoid pneumatization. *Arch Otolaryngol Head Neck Surg* 123(6):584–588. <https://doi.org/10.1001/archotol.1997.01900060026004>. PMID: 9193217
- Sadé J, Fuchs C, Luntz M (1996) The pars flaccida middle ear pressure and mastoid pneumatization index. *Acta Otolaryngol* 116(2):284–287. <https://doi.org/10.3109/00016489609137842>
- Iqbal IZ, Watson C (2012) A study of cholesteatoma and mastoid pneumatization; otolaryngology. *Head Neck Surg* 147(2):P79
- Goksu N, Kemaloglu YK, Koybasioglu A, Ileri F, Ozbilen S, Akyildiz N (1997) Clinical importance of the Körner's septum. *Am J Otol* 18(3):304–306
- Cigdem TK, Sema ZT, Hulya KN (2012) Analysis of anatomic variations in temporal bone by radiology. *Int Adv Otol* 8:239–243

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