

A COMPARATIVE STUDY OF MYRINGOPLASTY IN DRY AND WET EAR

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ABSTRACT

Myringoplasty is a common otological procedure indicated in mucosal chronic otitis media 4. It aims to close the tympanic membrane perforation to prevent recurrent otorrhea and create a sound-conducting mechanism in a well-aerated, mucosa-lined middle ear cleft, and maintain these achievements over time. The dilemma of the success of ear surgery in wet ear among otologists, encouraged us to compare the results of myringoplasty in both wet and dry ear. In this study the success rate of surgery was calculated by graft uptake and hearing gain. A combined procedure of cortical mastoidectomy with myringoplasty was done in cases with sclerosed mastoid to clear the infection in the mastoid and to make the aditus patent.

Keywords: Myringoplasty, otologists, tympanoplasty, mesotympanum

Introduction

Chronic Otitis Media is the chronic inflammation of the mucoperiosteal lining of the middle ear cleft, characterized by ear discharge, a permanent perforation of the tympanic membrane and impairment in hearing. It is a major public health problem in children and adults ¹. Incidence of Chronic otitis media is higher in developing countries because of poor socioeconomic standards, poor nutrition. In India overall prevalence rate is 46 and 16 persons/1000 in rural and urban population respectively².

Previously, it was thought that the success rate of myringoplasty in actively discharging ear is much lower than that of dry ear. To complicate matters, in India there is a general lack of awareness of the disease per se and also regarding the complications of the disease. Apart from this, people in our country are not aware of the functional benefits of myringoplasty / tympanoplasty and they are generally content to live with discharge and residual hearing loss³.

Spontaneous healing of chronic perforation of the tympanic membrane is uncommon and medical management is not effective in this regard. Hence surgery is necessary for closure of perforation. There are several factors mentioned in literature that may affect surgical results, including age, perforation size and site, the status of the opposite ear, the type of graft and condition of the operated ear (dry or wet). Controversy exists about the condition of the middle ear as a prognostic factor in myringoplasty.

There was a dilemma on success of ear surgery in wet ear and now it is an accepted fact that an actively discharging ear is not a contraindication for ear surgery.

The objective of this study includes: determining the success of graft uptake rates in patients with chronic perforation of the tympanic membrane in dry and wet ear and to analyze hearing gain among the patients included in the study.

Myringoplasty is a surgical procedure to prevent recurrent discharge from the middle ear and to restore hearing mechanism in patients with chronic otitis media, by closing the tympanic membrane perforation using different types of graft. The temporalis fascia graft forms a scaffold for the growing epithelium to close the perforation. Myringoplasty can be combined with cortical mastoidectomy in patients with a sclerosed mastoid, as these patients will lack proper aeration of the middle ear which can lead to failure or recurrence of middle ear disease.

MATERIALS AND METHODS

STUDY DESIGN:

A prospective study was conducted in the Department of ENT at SreeBalaji Medical College and Hospital, Chromepet, Chennai, India during the period of November 2014 to September 2016. The study population included were the patients who attended the outpatient department with active and inactive mucosal type chronic otitis media from the urban population of Chromepet, Chennai, India.

STUDY SAMPLE SIZE:

Total number of 60 patients were included in this prospective study. The daily average outpatient visit in the Department of ENT at SreeBalaji Medical College and Hospital, was around hundred and twenty five patients.

INCLUSION CRITERIA

1. Chronic Otitis Media of active mucosal type- wet ear with active mucoid discharge. Mucoid discharge negative on culture and sensitivity.
2. Chronic Otitis Media of inactive mucosal type- Dry ear for 3 months.
3. Age group from 15 to 50 years, both males and females.
4. Central perforation- small, medium, large in both wet and dry ear.
5. Intact ossicular chain (checked per operatively) in the selected cases.
6. Patients with normal Eustachian tube function.
7. Purely conductive hearing loss less than < 40 dB were included.
8. Cellular and sclerosed mastoid in the X-ray mastoid in both wet and dry ear were selected.
9. Absence of infection in throat, nose and paranasal sinuses.

EXCLUSION CRITERIA

1. Chronic Otitis Media- Squamosal type.
2. Cases with sensorineural hearing loss are excluded.
3. Patients with traumatic perforation.
4. Patients with previous history of surgery for chronic otitis media.
5. Ossicular discontinuity that was checked intra operatively.
6. Age < 15 years of age and > 50 years of age.

7. Evidence of infection of throat, nose and paranasal sinuses.
8. Patients with systemic illness like DM/HTN/ Tuberculosis.
9. Surgically unfit cases.

Methodology

All the sixty patients in the study group were selected according to the inclusion and exclusion criteria.

Patients were divided into two groups:

- Group 1 (Dry ear): when there was no evidence of otorrhoea within three months before surgery.
- Group 2 (Wet ear): presence of mucoid discharge, negative on culture and sensitivity.

All the patients had routine clinical examination, audiological evaluation and assessment. The pre-operative investigations were done in the patients of the study group. The patients with cellular mastoid on X-ray mastoid had

undergone Myringoplasty in both wet and dry ears. A combined procedure of Myringoplasty with Cortical mastoidectomy was done in patients with sclerosed mastoid, in both the groups. Informed and written consent was obtained from all the patients prior to surgery.

- Examination under microscope
- Ear swab culture and sensitivity
- Pure Tone Audiometry
- X ray both Mastoid
- Diagnostic Nasal Endoscopy
- Indirect laryngoscopy
- X ray Paranasal sinuses
- Chest X ray

- Routine Blood Investigations

- ECG

Clinical examination:

Complete ear, nose and throat examination was done for all the 60 patients. Tuning fork test was done before audiometric assessment.

Tuning fork rests:

a) Rinne test-

Positive: Air conduction is louder than bone conduction. It is seen in normal individuals or those having sensorineural hearing loss.

Negative: Bone conduction is louder than air conduction. It is seen in conductive deafness.

b) Weber test-

- Sound is lateralized to the better ear in sensorineural deafness.
- Sound is lateralized to the worse ear in conductive deafness.

c) Absolute bone conduction-

Reduced in sensorineural deafness.

Otoscopic examination and examination under microscope

Examination under microscope and otoscopic examination was done to confirm the diagnosis of mucosal type of chronic suppurative otitis media. The presence of a central perforation, type of middle ear mucosa, discharge from the middle ear, retraction pockets are confirmed. Size of the perforation may be small if it involves one quadrant, medium size if it involves two quadrants and large if it involves more than two quadrants.

Characteristics of dry ear:

- Remnant tympanic membrane is thin, transparent, parchment like, totally avascular or atrophic in appearance.
- Normal tympanic plexus in the middle ear mucosa is seen through the perforation.
- No discharge.



Figure - 5: Picture of dry ear

Characteristics of wet ear:

- Whole of remnant tympanic membrane is congested.
- Middle ear mucosa may be congested and edematous.
- Margins of perforation may be edematous and granular.
- Discharge may be seen in middle ear through perforation- mucoid in nature.

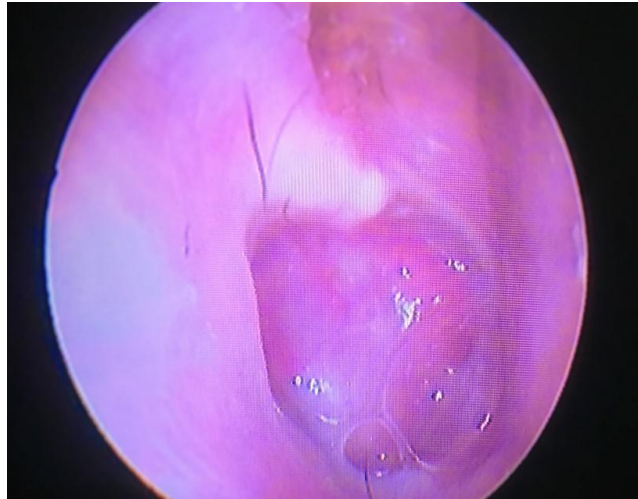


Figure-6: Picture of wet ear

Ear swab culture and sensitivity was done for all cases of wet ear with mucoid discharge to rule out the presence of active infection. Pure tone audiogram was done to establish the pre- operative, post-operative air-bone gap. Hearing gain was assessed by gain in the air-bone gap.

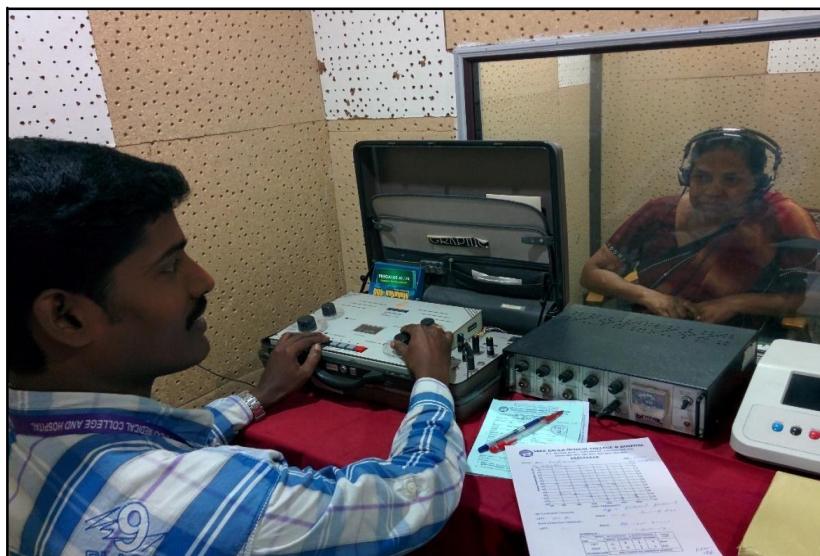


Figure - 7: Pure tone Audiometry

Diagnostic nasal endoscopy and indirect laryngoscopy was done in all cases to rule out any focus of sepsis. X ray of the paranasal sinuses was done to rule out coexistent sinusitis. Chest X ray, routine blood investigations and ECG were carried out in all patients for anaesthetic assessment. All patients underwent surgery under general anaesthesia. Patients were nil per oral from midnight. The ear was prepared by shaving 2cm above and behind the ear.

Positioning and preparation

After intubation, patients were put in reversed Trendelenberg position with a head ring. The head of the patient is turned to the opposite side, so that the ear to be operated is facing up. A sand bag is placed below the face on the opposite side for support. The ear, pre-auricular and post-auricular region is painted with betadine and draped.

Incision

All patients underwent surgery by the post aural approach (Wilde's incision) using Ziess operating microscope.

Procedure

After infiltrating the post auricular and supra auricular region with 2% xylocaine and 1:1,00,000 adrenaline, temporalis fascia is obtained through a separate incision in the supra auricular region. The areolar tissue over the temporalis fascia is stretched by blunt dissection to identify the plane of temporalis fascia. The fascia is elevated from underlying temporalis muscle by injecting saline underneath the fascia, to easily remove the fascia. The temporalis fascia is harvested by sharp dissection using 15 blade and dissecting scissors. The incision is sutured using 4-0 ethilon suture.

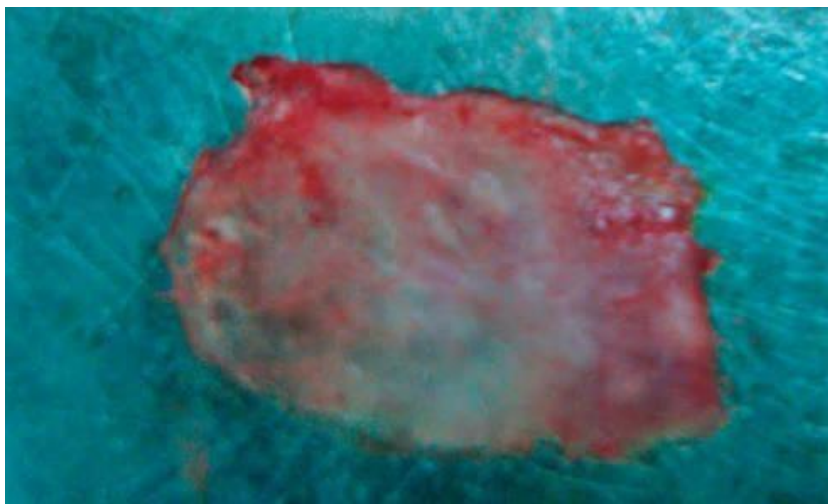


Figure - 8: Temporalis fascia graft

The ear canal is irrigated to remove debris. After infiltrating the canal wall skin with 2% xylocaine and 1:1,00,000 adrenaline in all four quadrants. The perforation margin is freshened using a sickle knife in the right hand and a 20 gauge suction needle on the left hand. Using a round knife the edges of the under surface of the perforation are scraped. This is to remove the squamous epithelium migrated to the medial surface of the perforation. Initial vertical incisions

are made at 6'o'clock and 12'o'clock positions. The incisions are joined horizontally. The tympanomeatal flap is elevated upto the fibrous annulus and secured.

A curvilinear incision is made in the post-aural region (Wilde's incision) along the posterior bony canal wall close to the conchal cartilage separating the posterior meatal skin from the rest of the subcutaneous tissue over the mastoid cortex starting superiorly from the linea temporalis up to the tympanomastoid suture inferiorly. A horizontal incision is made above the spine of Henle along the linea temporalis. The cartilaginous canal along the posteriormeatal skin flap is separated from its attachment at the spine of Henle by Lempert's periosteal elevator. The posterior meatal skin flap is also separated from its attachments along the tympanosquamous and tympanomastoid sutures. The posterior meatal skin and subcutaneous tissue are retracted using retractor. Mac Ewen's triangle is identified and the mastoid bone is drilled with large circular cutting burr, demarcating the tegmen plate superiorly, posterior bony canal laterally and the lateral sinus posteriorly. These structures are identified by change in colour of bone (bluish for lateral sinus and pinkish for tegmen), change in sound (from low pitched to high pitched) and presence of sentinel bleeding.

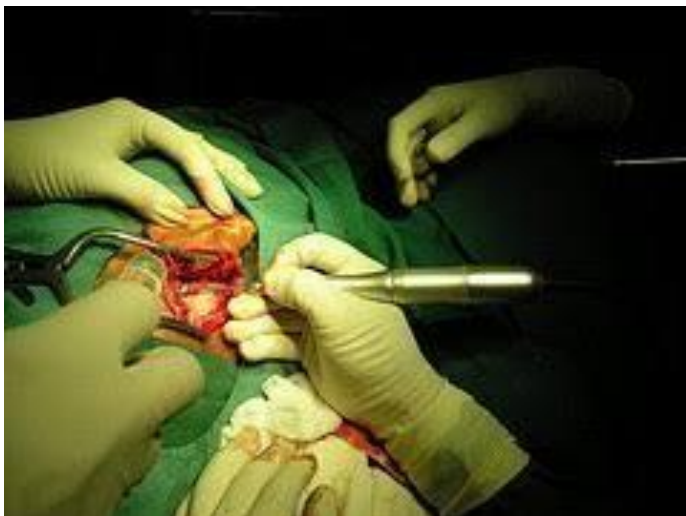


Figure - 9: Post aural approach

The depth of the fibrous annulus and the middle ear should always be kept in sight in external canal and compared with the depth of mastoid drilled while removing the peri-antral cells. Occasionally a korner's septum, which represents an embryonic petro-squamous junction, may be present. By comparing the depth of the middle ear, this plate of bone is penetrated to enter the antrum. Presence of any polypoidal mucosa blocking the mastoid antrum are removed. Once the antrum is identified, other landmarks like the dome of the lateral semicircular canal and fossa incudis with the short process of incus is identified. The posterior canal wall is thinned out adequately. All the possible mastoid air cells are exenterated. The patency of the aditus is checked and cleared from any polypoidal mucosa if present. The tympanomeatal flap is elevated along with the fibrous annulus. The patient's head is adjusted accordingly and the middle ear is clearly visualized. Malleus is identified and skeletonized. The

incudo-stapedial joint is identified and the ossicular integrity is checked. Hemostasis is achieved and checked before placing the graft. After trimming the margins of the temporalis fascia graft, it is placed by underlay technique. In the superior aspect a slit is made to accommodate the manubrium of the malleus. A drum elevator is used to tuck in the graft in all directions and to the lateral attic wall. The tympanomeatal flap is repositioned. The perforation edges are checked and graft repositioned accordingly. Gel foams are placed in the middle ear space and beneath the flap. Adequate gel foams should be placed at the region of the Eustachian tube orifice, to avoid medial displacement of graft.

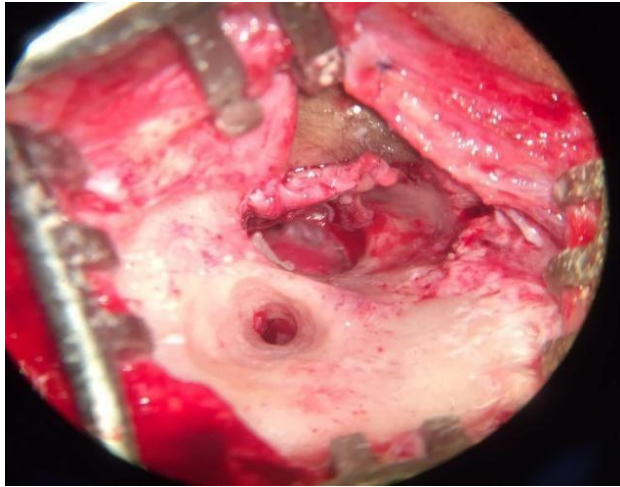


Figure- 10: Myringoplasty with cortical mastoidectomy

Gel foams soaked in antibiotic drops are placed in the external auditory canal. The retractors are removed and the post auricular incision is sutured with 3 -0 ethilon suture material. No drain is used. An antibiotic wick was placed in the ear canal. Betadine ointment is applied over the supra auricular and post auricular incisions and closed with a mastoid dressing.



Figure - 11: Post aural wound closure

Postoperative Care

All patients were kept nil per oral for 6 hours post operatively. Patients were on IV fluids, IV Antibiotics, IV Analgesics for 2 days.

The following post-operative complications were looked for:

- Facial nerve weakness/palsy
- Soakage of mastoid dressing
- Wound infection of post aural incision
- Giddiness

On the first postoperative day, the mastoid dressing was changed. Patients were usually discharged on the second postoperative day and were prescribed oral antibiotics for 10 days. The same post-operative drugs were followed for all the 60 patients.

1. 3rd generation Cephalosporin
2. Analgesic
3. Proton pump inhibitor
4. Antihistamine
5. Multivitamin

At the time of discharge, the patients were instructed to keep the ear dry. Head bath was restricted for 3 weeks after surgery. A cotton ball impregnated with petroleum ointment was advised to be kept in the outer ear canal. All patients were instructed not to air travel or swim for 1 month. Post-aural sutures and the antibiotic wick were removed on the seventh day.

Follow up

All the patients were followed at a period of regular intervals at the end of 1 month, 3 months and 6 months after surgical procedure. By 3 months, the grafted drum had thinned considerably and takes on the appearance of a normal tympanic membrane.

Success of surgery

The graft uptake and hearing gain was considered as success of surgery. The graft uptake was determined by the transparency of the graft and vascularity by oto-endoscopic examination in both wet and dry ear. The graft uptake was considered as failure in case of residual perforation. The hearing gain was calculated, by reduction in the air -bone gap in the pure tone audiometry after the surgery in both groups.

Statistical analysis

To calculate the rate of graft take-up, a statistical analysis was done using chi-square test. To calculate the gain in the AB gap between the two groups, the student t - test was applied.

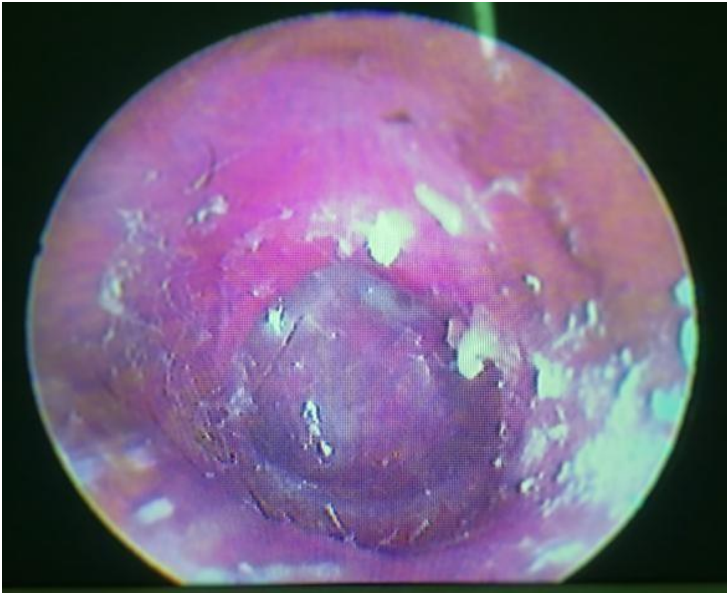


Figure - 12: Graft uptake after surgery in dry ear

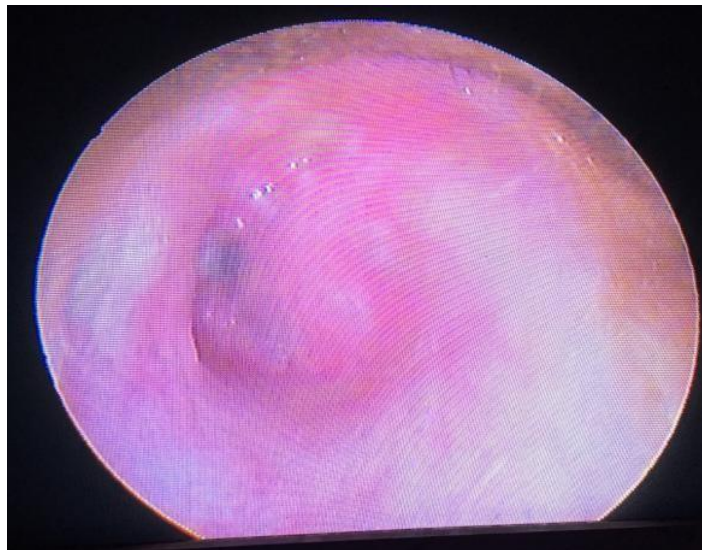


Figure - 13: Graft uptake after surgery in wet ear

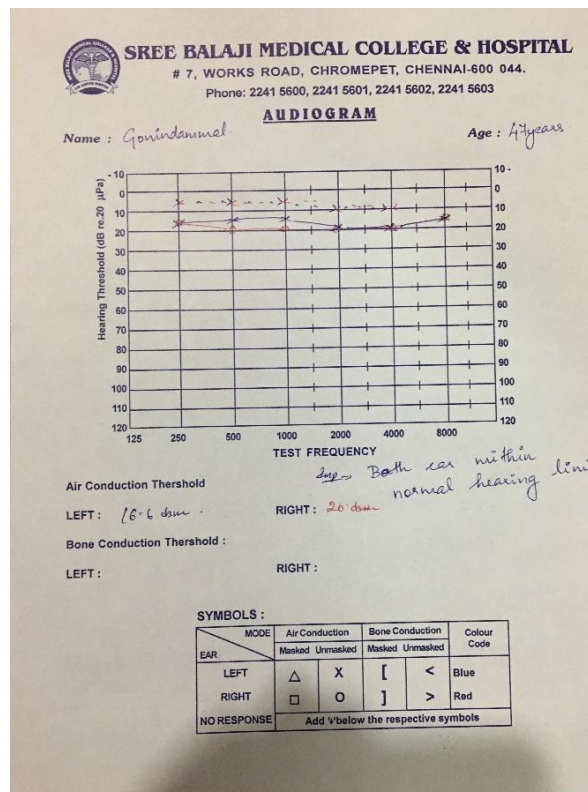
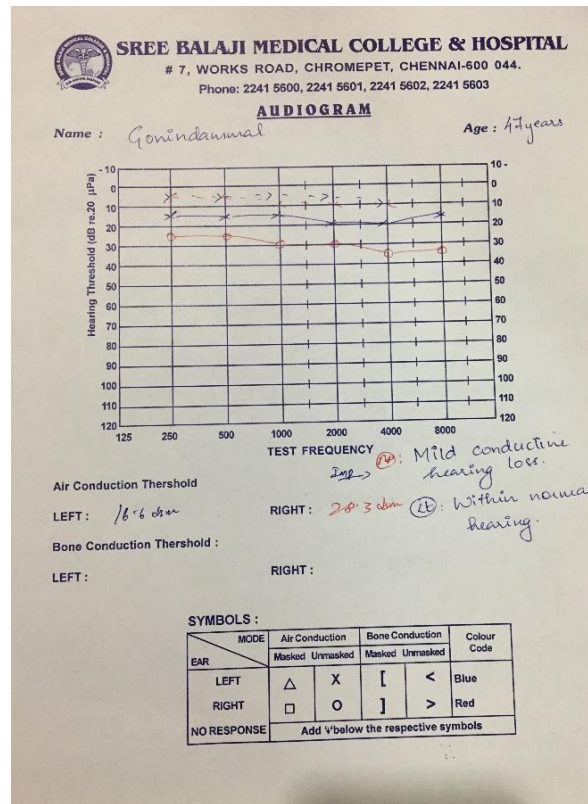


Figure - 14: Pre-operative and post-operative pure tone audiogram

1. RESULTS

The primary aim of this study was to compare the rate of success of the graft uptake and hearing improvement. To meet these goals, 60 cases with tubotympanic type of chronic otitis media were taken. They underwent myringoplasty with or without cortical mastoidectomy, depending on the cellularity of the mastoid. We observed the rate of graft uptake and hearing gain, 1 month, 3 months and 6 months following surgery.

Age and sex distribution Table- 1:

Age Group	No. of males	No. of females	Total no. of patients
15-20	3	2	5
21-30	13	18	31
31-40	9	12	21
41-50	2	1	3
Total no. of patients	27	33	60

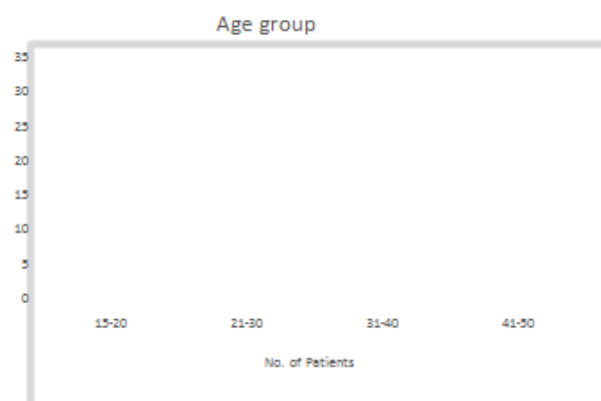


Figure - 15: Age distribution



Figure - 16: Sex distribution

Of the 60 patients, 27 patients were males and 33 patients were females. The age of the patients in the study varied from 15 years to 50 years. 31 patients were in the age group of 21-30 years, 21 patients were in the age group of 31-40 years, 5 patients were in the age group of 15-20 years and 3 patients in the age group of 40 -50 years.

Distribution depending on the size of perforation

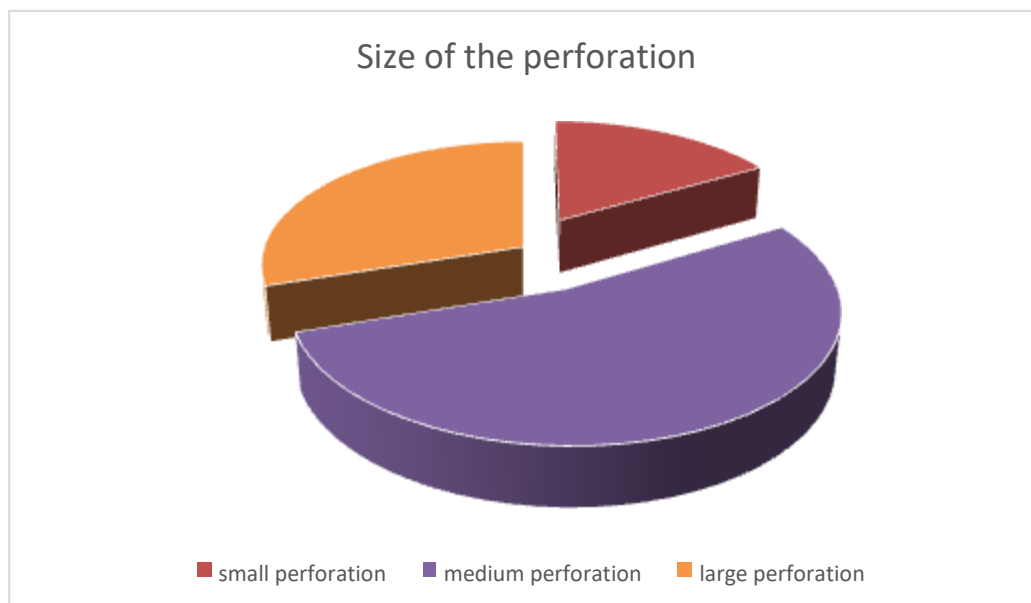


Figure - 17: Distribution depending on the size of perforation

The size of the perforations that were included in this study were small, medium and large. Out of the 60 patients included in the study, 10 patients had small perforations, 32

patients had medium perforations and 18 patients had large perforations. All the perforations were only central perforations.

Pre-operative investigations were done for all patients with wet ear and dry ear.

DISCUSSION

A prospective analysis of the rate of success of graft uptake and hearing improvement in a total of 60 patients, suffering from active and inactive chronic suppurative otitis media who underwent myringoplasty with or without cortical mastoidectomy, were included in the present study. The study group was divided into two; 30 patients with dry ear and 30 patients with wet ear. We also discuss the age and sex distribution, the size of the perforation, the cellularity of the mastoid and incidence of graft uptake in the 60 patients who presented to our institution. It is a common belief that myringoplasty should be done in a totally dry ear to obtain a successful surgery. The uncertainty about the effect of wetness of the middle ear on the outcome of surgery, in addition to the high number of patients who present with wet ear on the day of surgery and postpone it, encouraged us to investigate the results of myringoplasty in wet ear. Cortical mastoidectomy is done along with myringoplasty in order to clear the disease in the mastoid antrum.

Age Distribution

In the present study all sixty patients between the age group of 15 to 50 years were included. We observed that majority of the cases were within the age group of 21 -30 years (31 patients), followed by 21 patients in the age group of 31-40 years. 5 patients were in the age group of 15 - 20 years and 3 patients were in the age group of 40 -50 years. The mean age was 25.25 years.

Sex Distribution

According to the review of literature there is no statistical significant relationship between the sex and graft uptake. Our series showed a female preponderance with 55% females (33 females) and 45% males (27 males), which is similar to a study done by MasoudNaderpour et al which showed that, out of 60 patients, 33 (55%) patients were females and 27 (45%) patients were males³⁸. Hence showing a female preponderance.

Distribution according to the size of the perforation

The size of the perforation generally will not influence graft uptake and hearing gain. We have considered small, medium and large perforation depending upon involvement of number of quadrants of pars tensa of the tympanic membrane in both wet and dry ear. In the present study, among the 60 patients, 32 patients had medium sized perforation, 18 patients had large perforation and 10 patients had small perforation.

Distribution according to mastoid pneumatization

In this study, X-ray mastoid was done in all patients.

Among the 30 patients with wet ear, 16 patients had sclerosed mastoid and 14 patients had celluarmastoid.
Among the 30 patients with dry ear, 10 patients had

sclerosed mastoid and 20 patients had cellular mastoid.

Success rate of surgery

The successful closure of tympanic membrane was seen in 26 patients with wet ear and 29 patients with dry ear in each group respectively. Overall success rate in patients with wet ear was 89.65% and in patients with dry ear was 96.67%. Applying chi-square test, the graft take up shows a statistical insignificance in between both the groups ($p = 0.931$). Hence both the groups showed a similar success rate.

A combined procedure of myringoplasty and cortical mastoidectomy was done in patients with sclerosed mastoid in both the groups. However in patients with wet ear, graft uptake was better

for patients who underwent a combined myringoplasty with cortical mastoidectomy, when comparing with patients who underwent myringoplasty alone.

Hearing gain after surgery

Hearing gain was calculated by comparing the AB gap before and after surgery in the present study. The statistical significance was calculated using the student t - test. The observation showed that the mean pre-operative A-B gap for dry ear was 29.45 dB and wet ear was 28.85 dB. The mean post-operative A-B gap for dry ear was 20.11 dB and wet ear was 21.24 dB. In patients with dry ear, the average reduction in A-B gap was 9.38 dB. In patients with wet ear, the average reduction in A-B gap was 7.61 dB. To see whether there was any statistical significance between both the groups, the student t – test for independent samples was applied.

CONCLUSION

Myringoplasty is the most effective method in the management of tubotympanic type of chronic suppurative otitis media, in the aspect of closure of perforation and hearing improvement. Patient selection and proper work up for identification of risk factors, before a well-planned surgery are very important in order to obtain a good result. In the present study various factors like age, sex, size of the perforation, cellularity of the mastoid did not affect the outcome of surgery. The graft uptake in dry ear is much higher (96.67%), in wet ears the success rate is (89.65%) which is compatible to the other. The hearing gain in dry ear was 9.38 dB and in wet ear was 7.61 dB. Based on our data, the presence of mucoid ear discharge, negative on culture and sensitivity, does not interfere with the outcome of surgery with regard to graft uptake and hearing gain. Hence an actively draining central perforation is not a contraindication for ear surgery. According to our study, success rate of myringoplasty in wet ears is not inferior to that of dry ears.

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Ethical approval: The study was approved by the Institutional Ethics Committee

CONFLICT OF INTEREST

The authors declare no conflict of interest

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REFERENCES

- [1] O.BenGamra, I.Nacef, N. Romdhane, A.Kaabi, Abid W, Hriga I, Mbarek Ch. Tympanoplasty Outcomes in Dry and Wet Ears. *Otolaryngol Open J.* 2016; 2(2): 51 -57.
- [2] Chadha S K, Gulati K, Garg S, Agarwal AK. Comparative prevalence of otitis media in children living in urban slums, non-slum urban and rural areas of Delhi. *Int J Pediatric Otorhinolaryngol* 2014;78:2271 -4.
- [3] DebabrataPanigrahi, S. R. Das, S. K. Pani. "Role of Cortical Mastoidectomy in Outcome of Myringoplasty in Active and Quiescent Stage of Tubotympanic Type of Chronic

- Suppurative Otitis Media". *Journal of Evolution of Medical and Dental Sciences* 2015; Vol. 4, Issue 69, August 27; Page: 11931 -11935.
- [4] Rourke T, Snelling J D, Aldren C. Cartilage graft butterfly myringoplasty: how we do it. *ClinOtolaryngol* 2010; 35:135-8.
- [5] Silviu A, Gregorio B, Franco T. Prognostic factors in tympanoplasty. *Am J Otol* 1998; 19: 136 -40.
- [6] Austin DF. Reporting results in tympanoplasty. *Am J Otol* 1985; 6: 85 -8.
- [7] Becvarovski Z, Kartush JM. Smoking and tympanoplasty: implications for prognosis and the middle ear risk index (MERI). *Laryngoscope* 2001; 111:1806-11.
- [8] Sergi B, Galli J, De Corso E, Parrilla C, Paludetti G. Overlay versus under lay myringoplasty: report of outcomes considering closure of perforation and hearing function. *ActaOtorhinolaryngol Ital.* 2011; 31: 366 -71.
- [9] Berthold E. Uebermyringoplastik. *WierMed Bull* 1878; 1: 627.
- [10] Wullstein H. Theory and practice of myringoplasty. *Laryngoscope* 1956; 66: 1076 -93.
- [11] Zollner F. The principles of plastic surgery of the sound-conducting apparatus. *J LaryngolOtol* 1955; 69: 637-52.
- [12] Tarasov DI. Disease of the middle ear. *M Medicine* 1988; 66: 1076-1095.
- [13] Frenckner P. Pedicle graft from ear canal skin for myringoplasty. *ActaOtolaryng* 1955; 45: 19.
- [14] Shea JJ. Vein graft closure of ear drums perforations. *J. Laryng.* 1960; 74: 358.
- [15] Jansen C. Use of free tissue transplants of autogenous nasal septal perichondrium. *Laryngoscope.*1963; 73:78: 394.
- [16] Goodhill V. Tragal perichondrium and cartilage for myringoplasty. *Arch Otolaryn.*1967; 71:480 -491.
- [17] Banzer M. *Disputatio de AuditioneLaesa. Wittenbergae: JohannisRohrerei; 1651.*
- [18] Toynbee J. On the use of an artificial membrane in cases of deafness dependent upon perforations or destruction of the natural organ. London: J Churchill & Sons; 1853.
- [19] Wilde W (1853) *Aural surgery.* Dublin.
- [20] Blake CJ. *Transactions of the first congress of the international otological society.* New York: D. Appleton& Company; 1887.
- [21] Sooy FA. A method of repairing a large marginal perforation. *Ann Oto E.* 1956;65:911.
- [22] Heermann H. Tympanoplasty with fascial tissue taken from the temporal muscle after straightening the anterior wall of the auditory meatus. *HNO* 1961; 9:136 -7.
- [23] Storrs L A. Temporalis muscle fascia and denatured fat graft in middle-ear surgery. *Laryngoscope* 1963; 73: 699-701.

- [24] B. J. Singh, A. Sengupta, S. K. Das, D. Ghosh, B. Basak “A Comparative study of different graft materials used in myringoplasty”. *Indian J Otolaryngology Head Neck Surgery* (April- June 2009) 61:131-134.
- [25] Martin MS. *Mastoid Surgery*, in *Myers Otolaryngology Head and Neck Surgery*, Ch 115. 2nd ed. Elsevier, ISBN-13: 9781416024453. 2008: 7 –30.
- [26] Scott – Brown’s *Otorhinolaryngology Head and Neck Surgery*. Seventh edition.
- [27] Scott – Brown’s *Otorhinolaryngology Head and Neck Surgery*. Sixth edition.
- [28] Vishnu Prasad, Kishore Chandra Prasad. A study of middle ear reconstruction, the degree of functional restoration and causes of graft failure following chronic ear disease. *Egyptian Journal of Ear, Nose, Throat and Allied Sciences* (2014) 15, 103 -108.
- [29] Glasscock - Shambaugh *Surgery of the ear*. Sixth edition.
- [30] Wever EG, Lawrence M. *Physiological acoustics*.
- [31] Princeton (NJ): Princeton University Press; 1954.
- [32] Kirikae I. *The structure and function of the middle ear*.
- [33] Tokyo: University of Tokyp Press; 1960.
- [34] Puria S, Peake W T, Rosowki J J. Sound pressure measurements in cochlear vestibule of human cadaver ears. *J AcoustSoc Am* 1997; 101:2754 -70.
- [35] Tonndorf J, Khanna SM. Tympanic membrane vibrations in human cadaver ears studied by time- average holography. *J AcoustSoc Am* 1972; 52:1221-33.
- [36] Decraemer WF, Khanna SM, Funnell WRJ. Interferometric measurement of the amplitude and phase of tympanic membrane vibrations in cat. *Hear Res* 1989; 38:1-18.
- [37] Goode RL, Killion M, Nakamura K, Nishihara S. New Knowledge about the function of the human middle ear: Development of an improved analog model. *Am J Otol* 1994; 15:145-54.
- [38] Guinan J J, Peake W T. Middle ear characteristics of anesthetized cats. *J AcoustSoc Am* 1967; 41:1237 -61.
- [39] Willi UB, Ferrazzini MA, Huber AM. The incudo- malleolar joint and sound transmission loss. *Hear Res* 2002; 174:32-44.
- [40] Terkildsen K. Pathologies and their effect on middle ear function. In: Feldman A, Wilber L, editors. *Acoustic impedance and admittance: The measurement of middle- ear function*. Baltimore: Williams & Wilkins; 1976. p. 78-102.