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Discussion and expostulations on postoperative worsening of hearing following middle ear surgeries

Apoorva Kumar Pandey[1], Mudit Gupta[1], Arvind Varma[1], Chetan Bansal[2*], Sahil Deep Singh[1], Aparna Bhardwaj[1] and Sonal Kala[1]

Abstract

Background: Hearing assessment after middle ear surgery has always been of interest to otologists for one of its major unavoidable and unpredictable complication is hearing loss. As the initial indication for operation is to treat precisely this problem, this complication poses a major dilemma for surgeons. We, thus, aimed to detect the proportion of postoperative worsening of hearing, causes, and risk factors in patients undergoing middle ear surgery.

Method: This retrospective descriptive study was conducted in the department of otolaryngology of a tertiary care center and data of medical records were retrieved from January 2016 until December 2020. This study included middle ear surgery patients with pre- and postoperative audiometric results. Those patients whose hearing worsened post-operatively (where bone conduction deteriorated > 10 dB) were noted and assessed accordingly.

Results: The medical records regarding morphological and audiological outcomes of 178 patients were available. We observed auditory degradation after surgery in eight patients (five primary cases and three revision cases), with an overall incidence rate of 4.49%. The mastoidectomy was performed in seven cases, either cortical ($n = 5$) and modified radical ($n = 2$). Modified radical mastoidectomy showed the greatest incidence of hearing loss (40%) among all surgical procedures. Except in one case, where sudden, profound loss occurred following otorrhoea on third day, hearing loss was progressive in rest of cases.

Conclusion: A patient with deteriorating hearing after middle ear surgery must be evaluated properly. There is an increased chance of hearing loss following surgery that involves more ossicular manipulation, drilling, extensive disease clearance, and revision. Utmost care must be taken while operating around ossicles and during disease clearance in key areas. Proper consent should be taken from such patients to avoid future litigations.

Keywords: Sensorineural hearing loss (SNHL), Middle ear surgery, Post-operative, Drilling, Chronic otitis media (COM)

Background

The anatomy of the middle ear is complex, as are the tiny structures and the risk factors that accompany them while manipulating those structures during middle ear surgery. The intricate anatomy of the middle ear makes otologist's work challenging and difficult, as he must balance preservation of functionality with eradication of disease [1]. An inherent risk of surgery for chronic middle ear disease is that it may cause permanent damage of auditory structure resulting in permanent sensorineural hearing loss (SNHL) in 1.2-4.5% [2, 3]. Worsening of hearing resulting into SNHL after middle ear surgery has been described in the medical literature as early as 1960 [4]. However, it is difficult to estimate the true figures due

*Correspondence: drchetanent@yahoo.in
[2] Department of ENT, Satya Pal Wahi ONGC Hospital, Dehradun, Uttarakhand, India
Full list of author information is available at the end of the article
Work was done at Shri Mahant Indiresh Hospital, Dehradun, Uttarakhand, India.

to under-reporting of this surgical misery for fear of litigation, lack of expert and precise audiometric facilities, and to avoid disrepute on the otologist's side.

It is difficult to discern a single cause of postoperative sensorineural hearing loss, as several causes may be involved at once. Round or oval window may be damaged while removing cholesteatoma or granulation tissues; ossicles may dislocate or fracture as a result of its excessive manipulation; lateral semicircular canal may be accidently opened while removing cholesteatoma, resulting in a labyrinthine fistula [5], suctioning during surgery or sometimes rotating burr may unintentionally touch the ossicles. The exposure to excessive sound level along with vibrations due to drill might affect the delicate internal architecture of inner ear resulting into functional as well as morphological damage and temporary or permanent threshold shifts. Ipsilateral cochlea is potentially subjected to higher, damaging acoustic levels of 90 dB and above, whereas contralateral cochlea is exposed to 80-85 dB noise levels during drilling [6].

Aims and objectives of this study were to estimate the prevalence of postoperative worsening of hearing among operated middle ear cases, to find out the probable causes/risk factors, remedial, or rehabilitative measures taken and any incidence of litigation if occurred.

Methods

This observational retrospective study was conducted over a duration of 6 months from January 2021 to June 2021. A retrospective data base extraction from old medical records was done from January 2016 to December 2020. This study was approved from the institutional ethical committee. Data of patients diagnosed with chronic otitis media cases, who underwent middle ear surgery in the Otorhinolaryngology department of this tertiary care center, was retrieved and included in this study. Exclusion criteria for the study were pediatric patients under 12 years of age, profound hearing loss > 90 dB, occupational hearing loss, and history of taking drugs with ototoxic effects. The database of the selected patients was retrieved, compiled, and tabulated. A detailed proforma was used to collect patients' information comprising of patient's name, age, and gender. All patients had undergone proper history taking, thorough ENT examination and necessary preoperative routine, radiological, and audiological investigations. In patients whose hearing status worsened post-operatively, both pre-operative air conduction and bone conduction thresholds as well as post-operative air and bone conduction thresholds were calculated and assessed. The post-operative audiometry testing was done at the end of the 12th week but patients who complained of no improvement after surgery, tinnitus or worsening of hearing were evaluated at 6 weeks and repeated at the end of 3rd and 6th month post-operatively. Worsening of more than 10 dB between pre-operative and post-operative mean BC threshold at 0.5, 1, and 2 kHz was taken as to be significant. The recorded proforma was entered into Microsoft Excel 2016. The categorical data was expressed in number and continuous data in range.

Results

The number of middle ear surgeries performed (by first author) at this institute was 227 during those 5-year duration (Fig. 1). Only 178 of the patients had their postoperative pure tone audiometry findings available as the rest of cases were lost in follow-up. Males accounted for 87 and females for 91. The age range of patients in the study was 11-73 years. A total of 96 patients underwent right ear surgery and 82 patients had their left ear operated on. All surgeries were done under general anesthesia. Eight cases (4.49%) had post-operative worsening of hearing in our series. By far, the most common surgical procedure was a cortical mastoidectomy with tympanoplasty III (37.7%), followed by a cortical mastoidectomy with tympanoplasty I (25.28%) as seen in Fig. 1.

There was a squamous pathology (five out of eight) in majority of patients who suffered from post-operative hearing loss followed by mucosal disease (2 cases) and tympanosclerosis (one case). The majority of patients with postoperative worsening of hearing had an ICW mastoidectomy with a type III tympanoplasty (four out of eight) (Table 1). Out of total 22 revision cases in whole series, postoperative worsening of hearing was seen in 3 cases (13.63%) (Table 1).

The most detrimental effect on air conduction was 33.4 dB in a 44-year-old female (case 8) with COM mucosal who had undergone ICW mastoidectomy with type I tympanoplasty (Table 2). In the same patient, bone conduction was also most severely affected with a 25 dB decline. We also observed a substantial decline in hearing in a 30-year-old male (case no. 7) who had tympanosclerosis with granulations and underwent modified radical mastoidectomy and suffered a 13.4 dB loss in bone conduction threshold. In a female 26 years old (case no. 3) with COM mucosal who underwent CM with type III tympanoplasty, she experienced a decline in bone conduction of 21.7 decibels (Table 2).

Out of total 8 cases, two cases developed profound hearing loss. Except one case (case no. 3), in all cases, hearing loss was reported after 1-2 months postoperatively. Sudden worsening of hearing immediately after surgery was observed in one case (case no. 3), where the patient developed otorrhoea during third day postoperatively and resulted in SNHL despite responding to medical treatment (Table 3). In all cases, it was permanent and

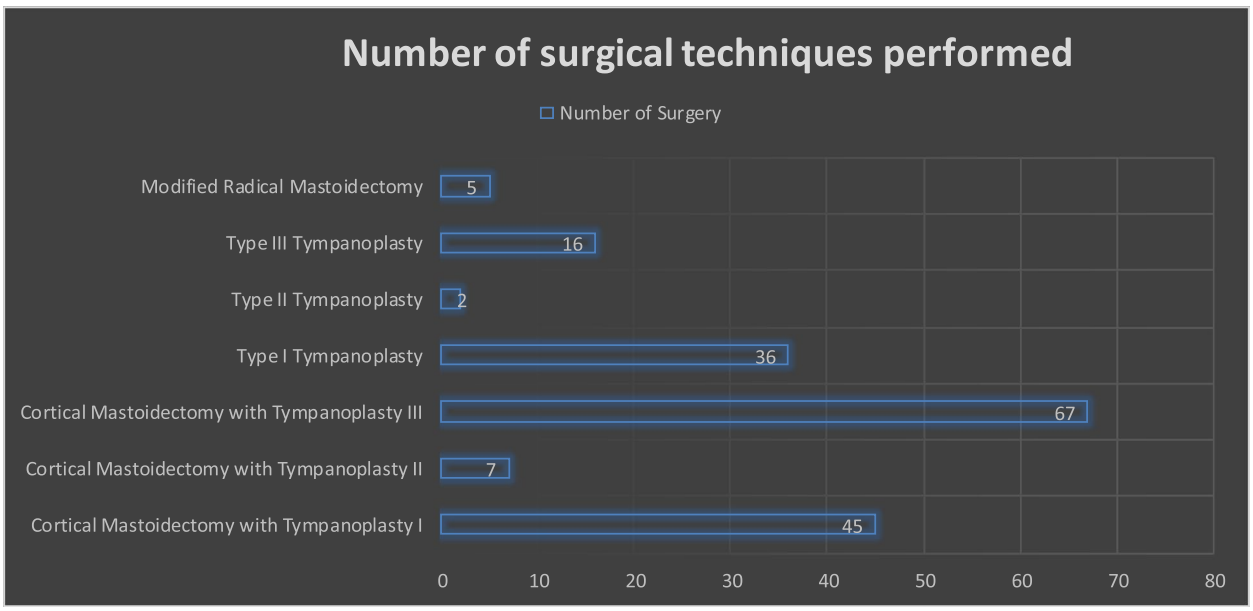

Fig. 1 Number of surgical techniques performed

Table 1 Description of patients who had worsening of post-operative hearing status

Case no.	Age (years)	Sex	Disease	Treatment
1	38	F	COM squamous	ICW mastoidectomy with type III tympanoplasty (revision case, operated elsewhere)
2	21	F	COM squamous	ICW mastoidectomy with type III tympanoplasty
3	26	F	COM Mucosal	ICW with type III tympanoplasty
4	28	F	COM squamous	Modified radical mastoidectomy (revision case, operated elsewhere)
5	30	M	COM granulations with tympanosclerosis	Modified radical mastoidectomy
6	51	M	COM squamous	Type III tympanoplasty with TORP (revision case, twice operated elsewhere)
7	30	M	COM squamous	ICW mastoidectomy with type III tympanoplasty
8	44	F	COM mucosal	ICW mastoidectomy with type I tympanoplasty

Table 2 Hearing status of patients who had worsening after surgery

Case no.	Ear operated	Pre-operative air conduction (dB)	Pre-operative bone conduction (dB)	Post-operative air conduction (dB)	Post–operative bone conduction (dB)
1	Left	63	16	68	31
2	Left	33	11	45	23
3	Left	68.3	26.6	92	48.3
4	Right	55	30	88.3	41.6
5	Right	50	20	65	35
6	Right	53.3	16.6	73.3	33.3
7	Right	78.3	31.6	83.3	45
8	Right	66.6	30	100	55

Table 3 Probable cause of SNHL and pattern of audiogram

Case no.	Disease	Treatment	Probable cause of SNHL	Post-op pattern of audiometry
1	COM squamous	ICW mastoidectomy with type III tympanoplasty	Disease clearance/manipulation/drilling	High frequency loss, right sloping curve
2	COM squamous	ICW mastoidectomy with type III tympanoplasty	Manipulation	High frequency
3	COM Mucosal	CM with type III tympanoplasty	? otorrhoea	All frequencies involved, flat curve
4	COM squamous	Modified radical mastoidectomy	Disease clearance/drilling	All frequencies, tinnitus
5	COM granulations with tympanosclerosis	Modified radical mastoidectomy	Ossicular manipulation	High frequencies
6	COM squamous	Type III tympanoplasty with TORP	Ossicular manipulation	High frequencies, tinnitus
7	COM squamous	ICW mastoidectomy with type III tympanoplasty	Unexplained	High frequency
8	COM mucosal	ICW mastoidectomy with type I tympanoplasty	??? infection	All frequencies

did not respond to intravenous steroids and conservative treatment. Tinnitus was observed in 2 cases (case no. 7 and 8). Vertigo was not complained in any patient. Rehabilitation by hearing aid device was done in 3 cases (case no. 3, 4, and 8). Except in case no. 3 (one case), in all cases, hearing loss was progressive and was noticed by patients after 1-2 months post-operatively despite successful graft take ups in all cases. No litigation was observed in our series. We have been in a practice of explaining all surgical risks and eventually taking proper informed consent regarding probability of worsening of hearing in all ear cases, since long (Table 3).

Discussion

In our study of 178 participants, who underwent middle ear operations for hearing loss, perforation, squamosal disease, and otorrohea over 5 years in otorhinolaryngology department, eight cases were found with postoperative deterioration of hearing. In total, 4.49% of patients reported worsening of hearing. Literature studies show that hearing loss worsened in 0.98-6.67% of cases after middle ear surgery [2, 7, 8]. According to a study, significant hearing loss occurred by more than 10 dB in five ears (3%) after middle ear surgery while a completely deaf ear was seen in one case (0.6%) [5]. A retrospective audit of 611 mastoid operations by 55 surgeons revealed seven dead ears, indicating a 1.1% overall prevalence [9].

In order to restore hearing, middle ear surgeries are routinely done in COM patients. Middle ear surgery aims to improve hearing by removing mechanical complications like obstructions such as cholesteatoma, granulations, adhesions, or pus from the round and oval windows [3]. The surgeon feels stressed about managing middle ear pathology because of anticipated cochlear injury which maybe temporary or permanent. Drilling is needed in the mastoid and near the ossicles when there are granulations, fibrosis, adhesions, retraction pouches, and cholesteatomas in the middle ear. The cause of this untoward complication cannot be pinpointed since various factors are likely to be involved. Among the most common causes of cochlear damage are excessive chain manipulations and acoustic trauma caused by drilling and suction [7]. A drill on the ossicular chain may cause intracochlear pressures similar to high-intensity acoustic stimulation, resulting in SNHL [6]. In our opinion, inadvertent manipulation of ossicles during disease removal, surgeon's experience, mastoidectomy, more extensive disease like tympanosclerosis or cholesteatoma, delayed reporting by patients, delay in starting treatment, cholesteatoma, revision, and post-operative infection might be the potential factors behind post-operative SNHL.

Study participants who suffered from post-operative hearing loss had mastoidectomy in seven out of eight cases. It was observed in our study that cortical mastoidectomy combined with type III tympanoplasty was the most common type of surgery associated with post-operative hearing deterioration. There was a 5.97% prevalence of postoperative hearing deterioration among cortical mastoidectomy with tympanoplasty type III cases done in our whole study. Only one case of post-operative hearing loss had undergone type III tympanoplasty with TORP. Among five patients who underwent modified radical mastoidectomy, two suffered hearing loss afterwards. Accordingly, the more invasive the procedure, the more likely that the hearing levels will deteriorate post-operatively. Hearing deterioration was more prevalent in operations in which the middle ear and the ossicles were excessively manipulated.

According to Seppa et al. [5], in their series, five patients who developed worsening of hearing (> 10 dB), four of them had mastoidectomy. Drilling against an intact ossicular chain or manipulating the ossicles too vigorously were the obvious factors leading to this loss. After undergoing modified radical mastoidectomy, one

patient developed hearing deterioration postoperatively. Also, after removal of cholesteatoma matrix from a large semicircular canal fistula by cortical mastoidectomy procedure resulted complete deafness in one ear. In any chronic ear with a cholesteatoma, above authors emphasized that one should keep in mind that a semicircular canal fistula could easily be formed so that the accidental opening of labyrinth could be prevented during surgical removal of disease pathology. Cholesteatoma cases where ossicular chains were intact were found to be at the greatest risk for sensory loss [5]. When it is imperative that there is a need for epitympanic cleaning, they recommended disarticulating the incus as soon as possible with intact ossicular chain and avoiding accidental drilling around the incus. In none of our five cholesteatoma ears, did we find an intact ossicular chain intra-operatively. It were the manipulations/excursions or propagation of noise/vibration/suction pressure/heat energy to inner ear during disease clearance that probably would have caused the worsening of hearing.

Hartl et al. [6] found a statistically significant negative correlation between drill speed and noise exposure, since they saw an increased magnitude of noise exposure with decreasing drill speed. In a study conducted by Seppa et al. [5], they observed that a surgical procedure using only diamond burrs failed to cause significant hearing loss in either of the ipsilateral or contralateral ear. Hearing deterioration resulted following the use of cutting burrs only. This is probably due to the fact that the cutting burr produces more noise and vibration as compared to diamond burr but these findings were contested by Hartl et al. [6]. Research literature indicates that sound levels over 115 dB can cause sensorineural damage if sustained for more than 15 min [10]. A positive correlation was found between drilling duration and bone conduction threshold at all frequencies during post-operative audiometric analysis by Paulose et al. [2].

Seppa et al. [5] observed that chances of ossicular chain damage were increased when thin squamous epithelium from the handle and neck of the malleus was vigorously removed during a simple myringoplasty procedure. It emphasizes the importance of exercising gentle instrumentation and handling of and/or around an intact ossicular chain because the risk of developing sensorineural hearing loss is maximum in the presence of an intact ossicular chain [5]. We observed that while performing surgery in an inflamed middle ear environment it is easier to remove remnants and its attachments from manubrium than in a dry middle ear mucosa conditions.

Smyth GDL [11], in his series, observed that removal of epithelium from ossicles, removal of tympanosclerosis, inadvertent footplate fracture, wide footplate excursion during placement of a strut, contact between rotating burr and incus, excessive manipulation of isolated stapes while removing disease or while reconstructing ossicular chain, and finally removal of cholesteatoma from lateral canal fistula were the main reasons for post-operative SNHL. He noticed that 1.3% of all myringoplasties were followed by SNHL and the overall incidence of cochlear loss from all causes was 2.5% in complete series. In our series, worsening of hearing was seen in only one tympanoplasty (type III with TORP). In a study, it was noticed that over-underlay tympanoplasty, where significant handling of ossicles is required, resulted into temporary SNHL (23%) post-operatively and protracted noise exposure due to mastoid drilling was followed by permanent SNHL (16%) [12]. In our study, we kept cartilage/fascia as over-underlay graft in all cases.

Prinsley [8] in his "audit of dead ear" reported a prevalence of 1% (approximately) of post-operative dead ear among 617 middle ear operations performed over a duration of 6 years. There were cholesteatomas in five out of six postoperative dead ears, which translates to a 2% prevalence of dead ears among 249 cases of cholesteatoma. There was one chronic otitis media case with a post-operative dead ear, without any peri-operative cholesteatoma. None of the 83 stapedectomy operations resulted in dead ears. In many cases, the author noted, dead ear is inevitable due to the progression of the disease and the length of the disease, but sometimes iatrogenic dead ear presents itself. The author described that factors like manipulation of the ossicular chain, contact between the drill and incus, or dissection of granulation tissue around the eroded labyrinth could have been the probable causes behind the SNHL. In our whole series, we encountered two cases where accidental dislocation of stapes occurred during disease clearance. In those situations, however, there was no perilymph leak and we kept a piece of temporalis fascia over the oval window and repositioned the dislocated stapes over the fascia. Then, we kept very small pieces of cartilage/fibroperiosteal tissue/fat around stapes to prevent the re-dislocation and eventually in no case did we observe any sensorineural hearing loss. In order to inform the patients satisfactorily and avoid future litigation, it is important and advisable to explain all potential surgical complications before the intervention. Even in expert hands, good surgical technique, benign pathology and no obvious and predictable cause of cochlear jeopardy [8], occurrence of post-operative sensorineural hearing loss can occur and which remains a baffling and a subject of debatable speculations.

In another study, it was concluded that [13] routine mastoidectomy in cases with dry ear should be discouraged unless it is deemed inevitably necessary. Toss et al. [14] also concluded the same observation that the

safest method of avoiding noise trauma by drilling and damage incurred by touching an intact ossicular chain is to avoid performing an unnecessary mastoidectomy. In our series, we did mastoidectomy in mucosal disease cases where there was heavily infected mucosa recalcitrant to medical treatment, suspicion of aditus blockage, glue coming out from isthmi on suction, poor tubal function, evident radiological opacification of air cells, and in continuously discharging ears despite treatment.

Tos [14] analyzed 2303 cases of middle ear surgery during 15 years period and noticed worsening of hearing in 1.2% (28 ears) of cases. The incidence of hearing loss was maximum in ears operated for congenital anomalies, granulating otitis, and cholesteatoma, in CWD mastoidectomy and in early period of his study. Similarly, Black and Wormald [15] reported a 4.5% incidence of postoperative SNHL in 211 myringoplasties done over a period of 1 year and observed that surgeon's experience and size of perforation were the most decisive factors affecting post-operative hearing results and SNHL. We are also of the opinion that surgeon's experience plays a vital role in predicting the occurrence of untoward complications during middle ear surgeries.

A study by Anazy et al. [10] included those patients who were eligible for type 1 tympanoplasty for middle ear pathology. Authors found no statistical effects of using a drill, ossicular motion, type of graft, and the surgical approach in the development of sensorineural hearing loss. It remains significantly contributory, however, that the surgeon's experience plays an important role. According to Paulose et al. [2], there was no relationship between type of surgery and post-operative hearing loss. In our opinion, following points must be kept in mind to prevent post-operative worsening of hearing while performing middle ear surgery.

1. Removal of squamous epithelium and fibrous attachments from manubrium should be gentle and to be done in inferior direction. However, in case of difficulty, fibrous elements can be left behind once removal of squamous epithelium is ensured.
2. Drilling around tympanic sulcus should be done in a bloodless field. Area to be drilled must always be in clean and clearly visible state.
3. Fiddling with round window membrane must be avoided.
4. It is advisable to dislocate incudo-stapedial joint prior to removal of tympanosclerotic plaques, adhesions, scars, or fibrous bands.
5. Removal of plaques, bands, or adhesions around stapes or footplate must be gentle and to be done in postero-anterior direction.
6. Too much excursion of ossicular chain, when intact, must be avoided at all costs.
7. Avoid direction suction over round window and oval window.
8. In case of suspected lateral canal fistula, cholesteatoma removal over fistula should be staged manner.
9. In case of accidental opening of lateral canal during disease removal, avoid entry of blood and bone dust into labyrinth. Avoid suctioning over the injured site also. Injured site must be immediately covered with fascia.
10. Reconstructed ossicular assembly should not be done under extreme tensile force/tension.
11. Avoid pulling of granulations/polyps/plaques/bands around footplate or stapes, and round window. Can be staged.
12. Attempts to remove granulations must be exercised cautiously. Avoid vigorous and aggressive removal. Can be staged or they might disappear once aerated tympanum forms after successful grafting.
13. Revision cases always carry an inescapable risk of hearing worsening. Over-zealous attempts of disease clearance and ossicular reconstruction must best be avoided.

In our opinion, the limitations of our study were small sample size, shorter follow-up time, retrospective in nature, and inhomogeneity of surgeries included. As a result, variables regarding clinical presentation, duration of surgery, speed of drill, and other factors affecting postoperative status of hearing were missing from the study. As a future prospect, we recommend evaluating the effects of various variables on post-operative hearing.

Conclusion

If a patient presents with deteriorating hearing following middle ear surgery, a proper evaluation is required. Slow progression of loss, late delay in consultation due to inability to perceive gradual loss and under-reporting can be the causes which obscure its true representation and eventual treatment. To determine postoperative SNHL, audiometry is a simple, reliable, and safe method. As a result of noise trauma and vibration caused by drills, hearing deterioration ensues resulting into temporary or permanent threshold shifts. Due to its unpredictable outcomes, middle ear surgery baffles surgeons; therefore, it is crucial to obtain a thorough and careful informed consent and to provide adequate pre-operative counseling regarding surgical risks.

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Authors' contributions
AKP: concept, design, and outline of manuscript. MG: manuscript preparation. AV: manuscript review and editing. CB: manuscript preparation. SDS: data collection. AB: statistics and analysis. SK: data collection. The authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Taken wide letter no SGRR/IEC/09/21, dated: 17 July 2021 from the Institutional Ethics Committee of Shri Guru Ram Rai Institute of Medical & Health Sciences. Informed written consent to participate was taken.

Consent for publication
Informed written consent for publication was taken.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Department of ENT, SGRRIM&HS, Dehradun, India. [2]Department of ENT, Satya Pal Wahi ONGC Hospital, Dehradun, Uttarakhand, India.

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