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Original Article

Anatomical and Functional Outcomes of Canal Wall Down Mastoidectomy with Cavity Obliteration and Posterior Canal Wall Reconstruction

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Abstract

Objectives: We evaluated the anatomical and functional outcomes of canal wall down mastoidectomy (CWDM) with cavity obliteration (CO) by superiorly based musculoperiosteal pedicled flap and posterior canal wall reconstruction (PCR) using free cartilage graft.

Materials and Methods: This hospital-based randomized control trial (RCT) included 60 subjects allocated into two groups (30/group). "Cases" underwent CWDM with CO-PCR and "controls" underwent CWDM. Post-operative anatomical and functional outcomes, including hearing, were assessed at 1st, 3rd, and 6th month and compared.

Results: One (3.33%) subject of the control group found frank cholesteatoma and 1 (3.33%) in the case group had a retraction pocket on examination under microscope (EUM). Three (10%) cases had distorted external auditory canal (EAC) and 100% controls had distorted EAC. Ten (33.3%) controls and 2 (6.7%) cases had complaints of post-operative otorrhoea. One (3.33%) case and all (100%) controls needed water precautions. Four (13.33%) controls experienced caloric induced vertigo, 15 (50%) required timely EUM cleaning, 3 (10%) showed depression in post-aural area, and 1 (3.33%) had a post-aural fistula. No, any case had vertigo, requirement of frequent ear cleaning, and had any other complications except 1 (3.33%) case who had temporary facial paresis. Among cases mean post-operative AC threshold was 40.70 ± 5.26 dB with a gain of 10.73 dB. In controls, AC threshold was 43.67 ± 4.31 dB with a gain of 8.47 dB. Cases had a mean post-operative A-B gap (ABG) of 21.13 ± 7.69 dB with a reduction of 9.30 dB. In controls, mean ABG was 25.30 ± 8.26 dB with a reduction of 8.60 dB.

Conclusion: CWDM with CO-PCR is significantly reduces post-operative morbidity and overall it is found to be a cost-effective procedure.

Keywords: Canal wall down mastoidectomy, Canal wall reconstruction, Cavity obliteration, Neo-external auditory canal

INTRODUCTION

Chronic otitis media (COM) with cholesteatoma is a potentially dangerous disease because it can lead to life-threatening intracranial complications. There are two surgical treatment options for cholesteatoma: The canal-wall-down mastoidectomy (CWDM) and the intact canal-wall mastoidectomy (ICWM). Recurrence of disease is the most evidenced complication associated with ICWM. The CWDM had been found to overcome this problem but with the occurrence of cavity problems along with it as a disadvantage. Mastoid cavity is unnatural and anatomically and physiologically unsatisfactory.[1]

A consensus is emerging among otologists that obliteration of the mastoid cavity that creates after CWDM can be a sound option to prevent cavity related problems such as frequent otorrhoea, recurrent infection, requirement of regular cleaning by surgeon, caloric induced dizziness, tinnitus, unsightly appearance due to presence of wide meatoplasty, and difficulty in using hearing aids. Cavity obliteration (CO) was first introduced by Mosher in

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1911 using superiorly based postauricular soft tissue flap. Subsequently, various methods were introduced using a variety of materials used to fill the cavity such as fat, cartilage, bone, dust, variety of flaps, hydroxyapatite, and bio-active glass.[2-4]

To avoid the presence of an open mastoid cavity, canal wall reconstruction (CWR) has been described. CWR is another technique for the elimination of mastoid cavity problems after CWDM. Various materials have been used for CWR, such as conchal cartilage, costal cartilage, bone pate, bone chip, or silicon block.[5-8]

We performed a surgical procedure that includes CO by superiorly based musculoperiosteal pedicled flap and posterior CWR (PCR) using free conchal cartilage graft [Figure 1]. In this study, we aimed to assess the outcomes of CWDM with and without CO and posterior canal wall reconstruction (CO-PCR).

MATERIALS AND METHODS

After the approval of institutional ethics committee, this hospital-based randomized control trial (RCT) was carried out in the department of otorhinolaryngology and head and neck cancer, SMS Medical College and Hospitals, Jaipur, Rajasthan, India, from June 2018 to July 2019. A total of 60 cases of unsafe (squamous) COM were enrolled in the study and allocated into two groups, including 30 patients in each group. One group included "cases" who underwent CWDM with CO by superiorly based musculoperiosteal pedicled flap and bone pate and PCR using free conchal cartilage graft (CO-PCR) and another group included "controls" who underwent CWDM without CO-PCR. Tympanoplasty and/or ossiculoplasty were done simultaneously in all subjects on the basis of intraoperative findings if required.

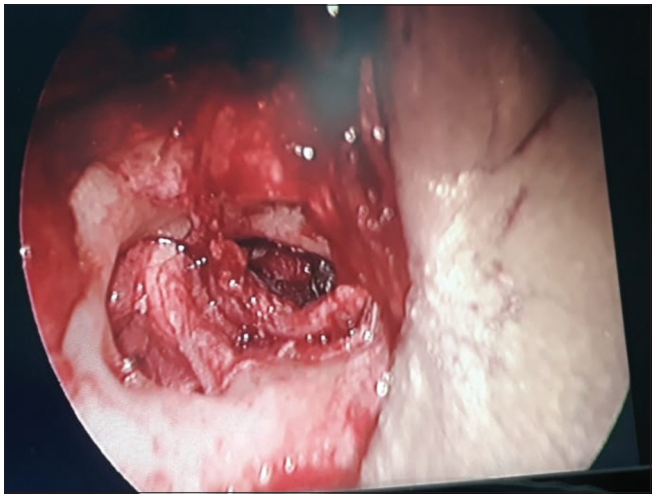

Figure 1: Intraoperative image of CWDM with cavity obliteration with canal wall reconstruction

All subjects presented with COM with active/inactive squamous disease planned for surgery after taking written and informed consent were included in the study. Patients with a mucosal type of COM, COM with complications, previously operated cases, and those who were not willing to participate in the study were excluded from the study.

All eligible patients were approached by the investigator himself. The nature and aim of the study were explained. Detailed history was taken. Thorough general and local examination was done. Routine investigations for surgery along with baseline pure tone audiometry (PTA) to assess hearing status and examination under a microscope (EUM) was done.

Patients were randomized and divided into groups. Surgeon who is a recognized otolaryngologist of ENT department of our institute remained same throughout the study to minimize the inter-surgeon variation.

Patients were discharged and called after a period of 7–10 days for suture removal then at 1st, 3rd, and 6th month post-operatively for follow-up. Follow-up at 1st, 3rd, and 6th month done by EUM. Post-operative PTA was done at the end of 6th month for hearing assessment. Data thus generated was recorded and outcomes were compared in terms of hearing status, post-operative complaints of discharge, recurrent infections, caloric induced dizziness, post-operative external auditory canal (EAC) anatomy, residual/recurrence of disease, and requirement of ear cleaning.

RESULTS

A total of 60 patients fitted with the inclusion criteria were enrolled in the study. Both male and female patients were included with a mean age 23.9 ± 9.53 years. There were 30 male and 30 female subjects, that is, male:female ratio was 1:1. Fifty patients had an active squamous type of COM and rest 10 had an inactive squamous type of disease.

On EUM done 6 months after surgery, of 60 subjects, 2 were presented with signs of recidivism. One subject out of 30 in the control group was found to have frank cholesteatoma. On the other side, in case group 1 subject had a retraction pocket with minimal keratin debris which was cleaned by EUM.

EAC status was examined on post-operative follow-up at the end of 6 months. In the control group, we did

meatoplasty along with CWDM so, in all subjects (100%), both inner and outer anatomy of EAC got distorted (EAC looking widened). On the other hand, in the case group, after CWDM, we reconstructed the posterior wall of EAC along with CO. Hence, anatomy of EAC was well maintained as neo-EAC was reconstructed. Only three cases (10%) in the case group had distorted EAC. Among those three, one had widened EAC (subject with secondary infection of obliterated material), one had non-significant widening and one developed narrowing of neo-EAC. P-value for this between both groups was found to be significant ($P = 0.000$).

Ten (33.3%) subjects in the control group had persistent otorrhoea, which may have been due to secondary infection or persistence of infection. This type of cavity is also called a discharging cavity. However, in the case group, only 2 (6.7%) subjects had complaints of post-operative otorrhoea. Among these two, one recovered by a short course of medical treatment but other had persistence of discharge due to secondary infection of obliteration material. *P* value for this was found to be significant ($P = 0.024$).

During the period of 6 months, follow-up in the case group, only one subject needed water precautions who suffered from secondary infection of obliteration material and was not cured successfully after initial medical treatment, whereas in the control group, all patients needed water precautions. *P* value for this comparison was found to be 0.000, which is significant.

In the case group, no one (0%) experienced vertigo due to caloric stimulation by water or air entry into the canal as semicircular canals were not exposed. On the other hand, in the control group, four subjects (13.33%) complained about this because of the exposed canal ($P = 0.236$).

After the initial period of epithelization (2–3 months), frequent cleaning was usually not required. In the control group, 15 subjects (50%) required timely EUM cleaning for which they depend on the surgeon. Out of 15, 10 (33.33%) were due to discharging cavity and the rest 5 (16.66%) due to the accumulation of wax/epithelial debris. However, in the case group, only one subject (3.33%) was surgeon dependent for regular ear cleaning (subject with secondary infected obliterated material). *P* value for this is 0.000, so it is a significant distribution.

In the control group, three subjects (10%) showed depression in post-aural area and one subject (3.33%) had a post-aural fistula in early post-operative period. In the case group, no subject (0%) showed any abnormality in the post-aural area. However, one subject (3.33%) had facial paresis in an immediate post-operative period which got relieved merely by releasing the dressing and EAC pack pressure with a short course of steroid therapy.

We observed pre- and post-operative PTA of all subjects and AC threshold, BC threshold, and A-B gap (ABG) was compared among both study groups. After CO and CO-PCR, significant improvement was noted in hearing with 10.73 dB in AC threshold ($P < 0.001$) and 9.3 dB in ABG ($P < 0.003$). In control group, improvement in AC threshold was 8.47 dB ($P < 0.001$) and 8.60 dB in ABG ($P < 0.001$).

Among cases mean post-operative AC threshold was 40.70 ± 5.26 dB. Hearing gain was 10.73 dB. On the other hand, in control group post-operative mean AC threshold was 43.67 ± 4.31 dB and gain was 8.47 dB. On the basis of P value, post-operative AC threshold was found to be significant ($P = 0.02$) but hearing gain was non-significant ($P = 0.245$) [Figure 2].

The case group had a mean post-operative ABG of 21.13 ± 7.69 dB. The ABG reduction was 9.30 dB. Whereas, in the control group, post-operative mean ABG was 25.30 ± 8.26 dB. Reduction in ABG was 8.60 dB. On the basis of *P*-value calculation, post-operative ABG was found to be significant ($P = 0.048$), but ABG reduction was non-significant ($P = 0.462$). Pre-operative ABG in most subjects of both study groups was above 20 dB (in case group 80% and in the control group 100%). After surgery in both study groups, a significant number of subjects shifted to below the level of 20 dB (in case group 63.3% and in the control group 43.4 %) [Figure 3].

DISCUSSION

A chronic discharging ear has been a perpetual problem and a challenge to the otologists for centuries. The objectives

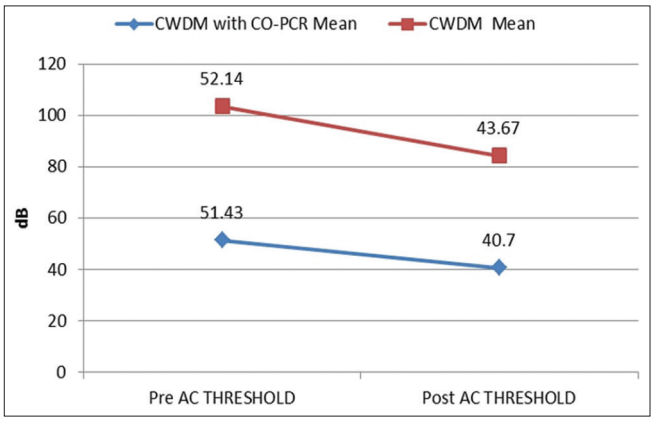

Figure 2: Comparison of audiometric finding (AC threshold) in the two study groups

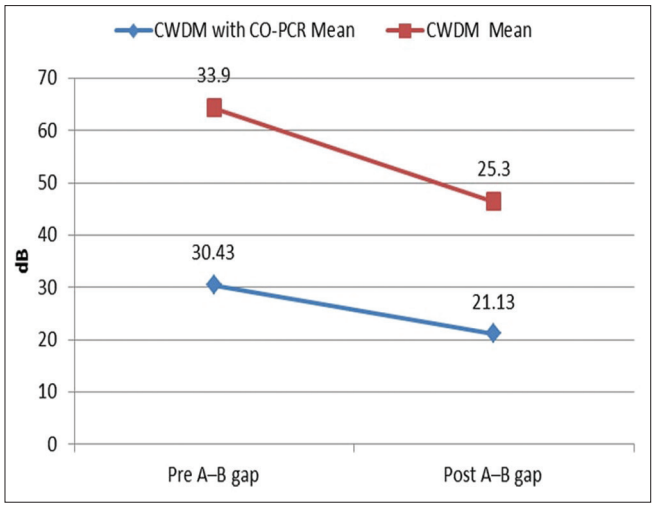

Figure 3: Comparison of audiometric findings (A-B gap) in the two study groups

of mastoidectomy in cholesteatoma are disease-free dry ear (primary), to create anatomic conditions to prevent recurrence and to restore the functional capacity of the ear, that is, the hearing (secondary).

The open mastoidectomy technique has been the mainstay of management of chronic ear disease; however, this type of surgery has its own disadvantages. The major problem is the creation of a large cavity and problems associated with it. To overcome these problems after mastoidectomy, CO and PCR can be done.

A canal wall down mastoidectomy, if not obliterated, can result in persistent otorrhea (discharging cavity) not responding to topical management. Sade, in his landmark article in 1982, proposed the causes of persistent otorrhea as high facial ridge, large cavity, small meatus causing inadequate drainage, tympanic membrane perforation leaving middle ear mucosa and eustachian tube opening open to the discharging cavity, and inadequate clearance of the disease.[9]

Obliteration of mastoid cavity thus leaves a smaller surface requiring epithelization and as a result, healing is fast. The exposed bone is covered with flap which reduces the likelihood of granulation and discharge. The cavity being smaller is also more likely to retain its epithelial migration potential and is self-cleaning. In patients with a successfully obliterated cavity, the smaller surface area and protection of lateral canal by the obliterating material allows most patients to swim free of complications. Hearing aids if required are better tolerated in an obliterated cavity than an open cavity.

In our study, we assessed and compared the outcomes of the two study groups in the form of cavity problems, requirement of frequent otomicroscopic cleaning, rate of secondary infections (discharge), rate of recurrence or residual (recidivism) disease, effect on hearing, and the effect on lifestyle.

Uçar C observed no recurrence in any of subject.[10] Similarly, Kim *et al.* observed in his study that there was no recurrence of disease.[11] Yamamoto *et al.* concluded that no residual cholesteatoma or cystic lesions were detected in the obliterated mastoid cavity. However, residual cholesteatoma in the tympanic cavity was observed in 9 (7.6%) ears.[12] Whereas, Suzuki *et al.* observed that cholesteatoma recidivism was seen in 8 ears (11.0%), residual cholesteatoma in 7 ears (9.6%), and recurrent cholesteatoma in 1 ear (1.4%). Of the 7 residual cholesteatomas, 3 occurred in the attic, and 4 in the mesotympanum. They all were the post-operative case of CWDM with partial CO and soft wall reconstruction.[13]

Liu *et al.* conducted a study on 47 patients who underwent mastoidectomy with obliteration and canal wall reconstruction. They observed that recurrent cholesteatoma was found on post-operative follow-up in two of the revision patients (7.4%) but none in the primary patients.[14] Hence, CWDM with CO-PCR shows better results in terms of recidivism but requires longer follow-up time for more accurate and conclusive results.

In our study, EAC status shows a significant difference between the two study groups and CWDM with CO-PCR results were far better in terms of neo-EAC status. In the control group, we performed meatoplasty along with CWDM so, in all subjects (100%), both inner and outer anatomy of EAC got distorted. Whereas, in "cases," after CWDM, we reconstructed the posterior wall of EAC along with CO. Hence, anatomy of EAC was well-maintained in most as neo-EAC was reconstructed.

Similar to our study, Uçar observed in his study that EACs were smooth and healthy. Epithelization was complete after the 2nd month of the operation.[10] Lee *et al.* observed that in a total of 20 of 22 patients (90.9%), the EAC wall healed well and maintained its cylindrical shape. Of the two remaining patients, in one case, the reconstructed posterior canal wall totally collapsed due to infection and the resultant autogenous bone pate infection. In the other case, the reconstructed posterior wall was exposed and partially reabsorbed, which eventually resulted in posterior wall hollowing. There was no EAC wall stenosis.[15] Kim *et al.* observed that the EAC was well maintained in all patients and no patient experienced a cavity problem; moreover, there was no bone pate infection. The posterior ear canal was well maintained and the retroauricular skin depression was minor, which caused no functional or

cosmetic problems.[11] Yamamoto *et al.* observed that a total of 113 ears (95.8%) achieved the nearly physiologic appearance of the EAC, and these conditions were maintained throughout the follow-up period.[12]

The present study showed that the most significant advantage of CWDM with CO-PCR over CWDM is in terms of relief from post-operative recurrent otorrhea (persistent infection/secondary infection). In the study by Yamamoto *et al.*, post-operative otorrhea was observed in 2.5% cases; however, most patients had good epithelization on the EAC and could cease water restriction 6 months after surgery.[12] Walker *et al.* found that the overall severe post-operative infection rate was 5.6% (16/285) which caused otorrhea. Infection of the bone pate necessitates admission and IV antibiotics.[8] Kim *et al.* and Liu *et al.* also observed no otorrhea in mastoidectomy with CO and canal wall reconstruction.[11,14]

Disease clearance is good after CWDM, but it gives a lot of cavity problems in terms of requirement of post-operative water precautions (restricted water activity, e.g., swimming), calorically induced vertigo by air/water, dependence on doctor for frequent cavity cleaning, and inability to use conventional hearing aids/earphones (problematic mainly for call-center workers). Meatoplasty is an essential part of CWDM. This wide meatoplasty also causes cosmetic/esthetic issues in subjects, mostly in females. Depression of the post-aural area in patients either due to large cavity or post-op infection, also leads to similar concerns. These affect the post-operative lifestyle of the subjects.

Uçar observed that in all patients, epithelization was complete after the 2nd month of the operation. Yamamoto *et al.* observed that most patients had good epithelization on the EAC and could cease water restriction 6 months after surgery. Similarly, Lee *et al.* observed that the average time required for complete epithelialization of the fascial surface and EAC wall was 30.7 days (range 7–84 days). After this period of epithelization, there was no need to take water precautions. In the study of Liu *et al.*, over 86.4% of all cases were water-resistant.

Uçar observed that none of their patients returned with vertigo induced by cold air or swimming. Similarly, in the study of Lee *et al.*, none of patient's complains of dizziness with pressure or temperature changes after CO and canal reconstruction. Liu *et al.* and Kim *et al.* also observed the same.

Kim *et al.* and Liu *et al.* observed that after CO and canal wall reconstruction, there was no need of frequent visits to the surgeon for ear cleaning as was required in CWDM.[11,14]

We observed some other complications in our study. In the "control" group (CWDM), three subjects (10%) developed depression in the post-aural area and one subject (3.33%) had a post-aural fistula in the early post-operative period. In the case group, one subject (3.33%) had facial paresis in the immediate post-operative period which got relieved just by releasing the dressing and EAC pack pressure with a short course of steroid therapy.

Lee *et al.* observed that minor postauricular wound infection (13.6%) was the most common surgical complication. Obliterating material got infected in two patients and consequently mastoid skin fistulas developed.[15] Walker *et al.* in his study observed that four (1.4%) of 285 ears had post-operative facial nerve weakness with two presenting after the CWR procedure and two after ossiculoplasty and CSF leak in 14 (4.9%) cases. These issues resolved either with conservative management or by surgical correction. One (0.4%) had post-operative mild to moderate SNHL.[8] Kim *et al.* and Liu *et al.* observed no any such complications in their studies.[11,14]

Lee *et al.* studied 18 cases that underwent staged operation with follow-up PTA. Thirteen (72.2%) of those showed an improved ABG value of >10 dB hearing level (HL). Stratified hearing results were as follows; seven patients had a post-operative ABG value of <10dB HL and five patients had a post-operative ABG value that fell between 10 and 20 dB HL. A post-operative ABG value>20 dB HL was reported in the remaining six patients. The average ABG value before the staged operation was 35.4 dB HL (range 20–48.8) and after the staged operation, 17.8 dB HL (range 1.5–41.5).[15]

Walker *et al.* observed that pre-operative ABG for the entire cohort (n = 285) was 27.8 dB. 253 (89%) patients underwent a second look with ossiculoplasty. Of those, 148 ears had audiometry performed 1 year or more after the second look surgery. The average ABG for these 148 ears was 23.4 ± 11.7 dB, an improvement of 4.2 dB from pre-operative ABG of 27.6 ± 12.9.[8] Kim *et al.* studied "outcomes of modified canal wall down mastoidectomy and mastoid obliteration using autologous materials;" of the 76 patients that underwent a one-stage operation and PTA at the 12-month follow-up, 11 (14.5%) showed a post-operative ABG value of 0–10 dB hearing level (HL), and 28 (36.8%) showed a post-operative ABG value of 10–20 dB HL. A post-operative ABG value of 20–30 dB HL was observed in 23 patients (30.3%) and a value 30 dB HL was observed in 14 patients (18.4%). The average ABG values were 26.7 ± 10.9 dB HL before the operation and 20.8 ± 10.8 dB HL after the operation (P = 0.001). Post-operative hearing outcomes improved significantly after the operation.[11]

Liu *et al.* revealed a mean gain on PTA of 4.5 and 2 dB, at 1- and 4-year post-operative, respectively. The mean improvement in the ABG at 1- and 4-year post-operative follow-up was 4.4 and 2.2 dB, respectively. ABG improvement at 1-year follow-up was statistically significant ($P < 0.05$), as compared to the pre-operative value. About 70.4% patients experienced excellent (0–10 dB) or a good (11 to 20 dB) gap closure one-year after surgery. About 63.7% had excellent or good gap closure in the operated ear at the 4-year follow-up. Those improvements, both 1 and 4 years after surgery, were statistically significant as compared to that before surgery ($P < 0.05$). In some patients, conductive hearing loss persisted.[14]

CONCLUSION

We conclude that mastoid CO-PCR is a cost-effective surgery which gives better outcomes with respect to cavity problems, recurrent infections, recidivism, surgeon-dependence for frequent otomicroscopic cleaning, hearing improvement, and effect on lifestyle as compared to those in canal wall down mastoidectomy. In addition, it provides a safe, dry, and "self-cleaning" ear.

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