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ORIGINAL RESEARCH–OTOLOGY AND NEUROTOLOGY

VIDEO

Lateral semicircular canal fenestration for congenital conductive hearing loss: Solution for a dilemma

Mohammadtaghi Khorsandi Ashtiani, MD, Nasrin Yazdani, MD, Sasan Dabiri Satri, MD, Zahra Mokhtari, MSc, and **Ali Kouhi, MD,**
Tehran, Iran

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ABSTRACT

OBJECTIVE: To determine functional results after lateral semicircular canal fenestration on congenital conductive hearing loss.
STUDY DESIGN: Case series with chart review.
SETTING: Amir-Alam otolaryngology tertiary referral center.
SUBJECTS AND METHODS: Twenty patients with congenital oval window malformations who were not candidates for ossicular reconstruction underwent lateral semicircular canal fenestration. A skin graft was placed over the perforated fascial graft on the fenestrated area.
RESULTS: The median preoperative mean air conduction (MAC) was 56.9 dB (50.0 dB median air-bone). Postoperative median MAC gain of 34.3 dB ($P < 0.001$) and the median air-bone gap of 18.8 dB were observed. The mean bone conduction (MBC) did not show any significant changes postoperatively ($P = 0.12$). No sensorineural hearing loss, tinnitus, or imbalance was observed.
CONCLUSION: We demonstrated hearing improvement after lateral semicircular canal fenestration. This technique can be considered as an alternative for patients with middle ear anomalies who are not candidates for ossicular reconstruction.

The middle ear's function is to facilitate the conduction of sound signals from air's environment to the fluid environment of the inner ear and so minimize the decay of signal strength. For abnormalities of this system, surgical repair is mainly aimed at simulating the middle ear mechanisms. However, in some special cases, reconstruction cannot be achieved due to technical problems, thus leaving hearing aids as the only available option.

Conductive hearing loss with an intact tympanic membrane has various etiologies varying from congenital (e.g., ossicular anomalies) to acquired (e.g., otosclerosis).[1,2] Among cases with absolutely no option of reconstructing the conducting mechanisms of the middle ear, the most significant examples are patients with an absent oval window or an abnormal facial nerve course over the oval window. In these situations, none of the routine approaches can provide a conducting pathway for sounds traveling through the inner ear. In the following study, lateral semicircular canal (LSCC) fenestration was evaluated as a tool to bypass the oval window and diminish problems in conductivity.

LSCC fenestration was invented over six decades ago and has since been used for otosclerosis. However, due to its high risk of complications and difficult technique in comparison to those of various stapes surgeries, LSCC fenestration has largely been abandoned.

Materials and Methods

In a retrospective study dating from 1998 to 2007, patients with conductive hearing loss and an intact tympanic membrane were consecutively enrolled. Patients with a history of ear trauma, recurrent otitis media, or previous otologic surgery were excluded, along with those with middle or inner ear pathologies (such as vascular anomaly or cholesteatoma). Hearing aids were offered as an alternative to surgery. In those who refused a hearing aid or did not have good hearing with it, after temporal bone imaging was undertaken, patients underwent a middle ear exploration in the ear with the worst hearing. In cases with bilateral conductive hearing loss and abnormalities in the middle ear, such as the absence of the oval window or an abnormal course of the facial nerve that made ossicular reconstruction impossible, a second-stage operation was opted for. Patients were consulted about possible therapeutic options, and informed oral consent regarding possible complications was obtained. Conventional hearing aids and implantable hearing aids were again discussed and offered as an alternative

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to all of the patients, and those who performed well with the hearing aid were excluded. That none of the patients presented here accepted use of an implantable hearing aid may be due to financial costs. All patients were operated on by one surgeon (M.K.A.).

Informed consent was obtained from each patient and the study protocol was reviewed and approved by Tehran University of Medical Sciences Research Ethics Review Board.

Technique

Under general anesthesia, a postauricular incision was made and a fascial graft from the temporalis muscle fascia was harvested. A split-thickness skin graft was also prepared from the postauricular area. The anterior-based tympanomeatal flap was elevated. In-to-out atticotomy was performed until the LSCC was exposed. In addition, posterior canalplasty also provided optimum exposure of the LSCC to the external auditory meatus. Fenestration was achieved with the Lempert technique (i.e., drilling around the dome of the LSCC with a small diamond burr and isolating the dome at about 2 × 6 mm).[3] After the blue line was visible, the dome was removed, as an eggshell would be, with a sickle knife and without injuring the membranous labyrinthine. The fascial graft was designed and perforated to fit the area over the fenestrated LSCC and to be extended under the tympanic membrane. In order to reduce the time of exposure of the membranous labyrinthine, the fascial graft was covered after isolating and before removing the dome. Then, the skin graft was placed to cover the fenestrated area and was then extended over the fascial graft (Video 1, available online at www.otojournal.org). The tympanomeatal flap was put back over the fascial graft and trimmed near the skin graft to prevent the skin graft from lying under the flap (Fig 1). At the end of the operation, to improve the exposure of the fenestration area to the external auditory meatus, meatoplasty was also performed.

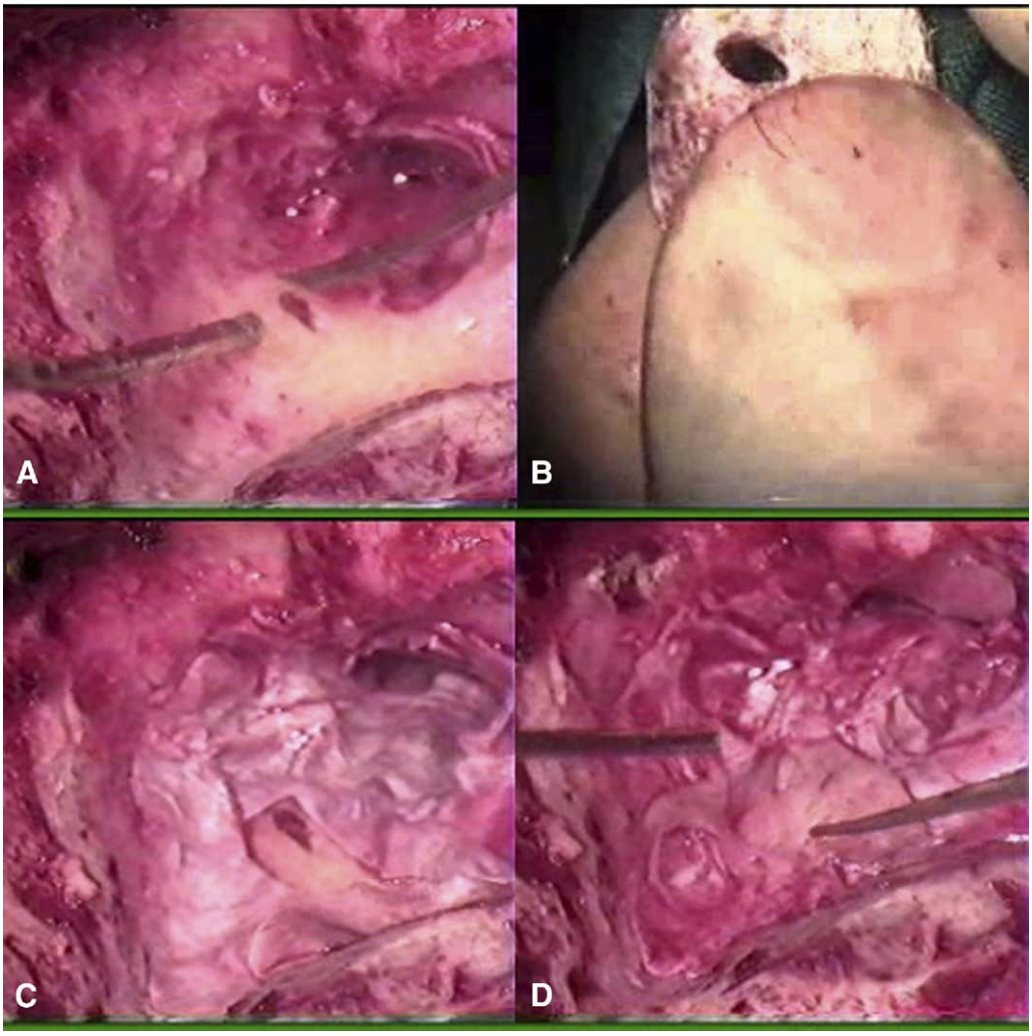

Figure 1 Intraoperative imagine presenting surgical stages of lateral semicircular fenestration. (**A**) Skeletonizing lateral semicircular canal labyrinth and its blue line. (**B**) Temporal fascia graft, which is perforated. Perforation lets the split-thickness skin graft directly contact the labyrinth in order to prevent neo-osteogenesis. (**C**) Fascia graft draped in place. (**D**) Split-thickness skin graft over the fenestrated area.

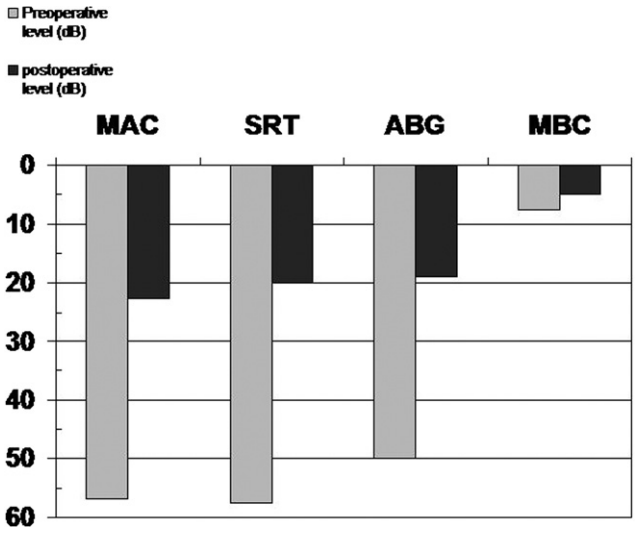

Figure 2 Median of the variables in patients before and after the lateral semicircular canal fenestration. *MAC,* mean air conduction threshold; *SRT,* speech reception threshold; *ABG,* air-bone gap; *MBC,* mean bone conduction threshold.

The patient was kept on dry-ear precautions until the tympanomeatal flap had healed. Postoperative ototopical antibiotics were also prescribed. The wicks were removed at the one-week postoperative visit. The first postoperative audiogram was obtained after three months.

All audiometric assessments were performed by hospital audiologists who were unaware of this study. This study's patients were not isolated from other candidates for audiologic study. Audiometric findings are reported as a four-tone pure-tone average (PTA; 500, 1000, 2000, and 4000 Hz) as recommended by the Committee on Hearing and Equilibrium 1995 Guidelines for the Evaluation of Results of Treatment of Conductive Hearing Loss.[4] Speech reception threshold (SRT) results are also reported. The first postoperative audiometric assessments were done at three months. Postoperative audiometric data that were used for analysis were collected from the most recent audiograms.

Data analysis was done with paired *t* test and χ^2 methods for quantitative and qualitative variables, respectively.

Results

Out of more than 1200 middle ear explorations for conductive hearing loss with an intact tympanic membrane, 20 patients (mean age, 15.4 years; range, 5-29) underwent LSCC fenestration, and two of these underwent bilateral operations (total of 22 LSCC fenestration surgeries). Four patients were siblings from two families. Male-to-female ratio was 13:9; 10 right ear and 12 left ears were operated. Mean follow-up period was 61.6 months (12-125 months).

After a few years, the patients' continued satisfaction with the results of the operation on one side and their interest in this operation, along with positive acceptable audiometric results, led to the contralateral LSCC fenestration of two patients. On the primary side, second-stage fenestration was done after middle ear exploration. However, on the contralateral side, exploration and fenestration were performed at the same time.

The median preoperative mean air conduction (MAC) threshold was 56.9 dB (range, 46.3-71.3 dB) with a 50.0-dB median air-bone gap (range, 35.0-56.3 dB). The median preoperative mean bone conduction (MBC) threshold was 7.5 dB (range, 1.3-22.5 dB), and the preoperative median SRT was 57.5 dB (range, 45.0-70.0 dB). These results are presented in Figure 2.

Postoperatively, MAC, SRT, and the air-bone gap showed statistically significant changes: a median MAC gain of 34.3 dB, a median air-bone gap of 18.8 dB, and a median SRT of 20 dB. The MBC did not report any statistically significant changes postoperatively (median MBC = 5.0 dB; $P = 0.12$). Speech discrimination scores were also not changed ($P = 0.24$).

In Table 1, the means and standard deviations of the variables are presented. No evidence of postoperative tinnitus, persistent vertigo, or subjective hearing loss was reported in patients. Some patients reported transient vertigo that did not last for more than a few hours postoperatively. In one patient, the meatus gradually became stenotic, resulting in hearing loss. A revision meatoplasty resolved the problem.

Discussion

Fenestration operations began after Jenkins performed a fenestration of the LSCC for the first time in 1913. However, Gunner Holmgren elaborated the concept of fenestration by demonstrating that hearing can be improved after establishing a fistula in the LSCC.[3] For covering the fenestration, Sourdille used a pedicled skin flap that attached to the tympanic membrane. One of the greatest studies of this technique was conducted by Lempert.[3]

Bypassing a sound conducting mechanism when its routine system cannot be restored is a known strategy to otologic surgeons. Pau and Just recently described a third

Table 1
Mean of the variables in preoperative and postoperative area and the *P* value of the differences

Variable	Preoperative result ± SD	Postoperative result ± SD	*P* value
MAC	57.2 ± 7.2 dB	24.6 ± 8.9 dB	<0.001
SRT	58.5 ± 6.4 dB	23.5 ± 8.9 dB	<0.001
ABG	48.1 ± 7.0 dB	18.8 ± 6.0 dB	<0.001
MBC	9.1 ± 6.6 dB	5.8 ± 5.4 dB	0.115

MAC, mean air conduction threshold; *SRT,* speech reception threshold; *ABG,* air-bone gap; *MBC,* mean bone conduction threshold.

window technique to bypass obliterative tympanosclerosis.[5] In recent papers few studies have addressed LSCC fenestration for the improvement of hearing. In a study by Farrior et al,[6] 33 patients underwent fenestration of the LSCC. The average preoperative air conduction hearing threshold was 52 dB. In a long-term follow-up ranging from two to 30 years, 69 percent maintained hearing at better than 30 dB (mean, 28 dB), and in 24 percent of the subjects, the average was 35 dB. In two patients (7%), hearing had not improved with fenestration. With a mean postoperative air conduction threshold of 24.6 dB, the hearing improvement attained by our study was also comparable to that of Yi et al;[7] their study of two siblings with congenital absence of the oval window and stapes indicated that fenestration had long-term satisfactory results.

A potential complication of this technique is iatrogenic deafness. The risk is reduced if the procedure is performed carefully with certain precautions during the removal of the LSCC dome so as not to injure the membranous labyrinthine and not suction the fenestrated area. These precautions are similar to those taken during stapes surgery. Also, a thorough familiarity with the anatomy of the in-to-out atticotomy helps to decrease complications. Reducing the exposure time of the membranous labyrinthine by first covering the area with a perforated fascial graft before removing the LSCC dome may also lead to fewer complications. Any remaining bone dust over the membranous labyrinthine could increase the risk of vestibular symptoms. Therefore, frequent washing can reduce this complication.

The pedicled skin flap has the potential for ossification of the fenestration and a later reoccurrence of hearing loss.[7] Trying to overcome this issue by using a fascial graft to cover the fenestration seems to create the same results.[6] Low-speed drilling and creating a smooth margin in the fenestrated area may prevent neo-osteogenesis.[6] Our experience indicates that a skin graft may also have an osteogenesis-inhibitive effect that discourages osteogenesis and occlusion of the fenestration.

In one unpublished study of an otology fellowship thesis during the late 1980s at this hospital under the supervision of one of the authors (M.K.A.), a tympanomeatal flap and fascial grafts were employed. Operations were performed on 10 patients by one surgeon (M.K.A.). Available data from this study are as follows: mean age at surgery, 21 years; female-to-male ratio, 1.8; mean preoperative MAC, 62 dB; mean postoperative MAC at four months, 28 dB; and mean postoperative MAC after the first year and after seven years, 40 dB and 55 dB, respectively. Results of this study also showed that fenestration with a tympanomeatal flap and fascial graft had reversible outcomes in the long term. Due to the lack of systematic documentation and problems such as a lost paper archive after all these years, it is not possible to access to data for more analyses and possible comparisons.

In some of the current study's patients, the air-bone gap in the audiometric results was nearly completely resolved and maintained during the study. There is no specific difference between the operating technique of this and the earlier unpublished study mentioned previously. However, it seems that posterior canalplasty and meatoplasty can give better exposure of the fenestrated area to the external auditory meatus and so may result in more improved hearing. The thinning of the skin graft and close adherence between the epithelium and endosteum may also lead to an optimum postoperative hearing outcome[6] and less air-bone gap.

Bone conduction thresholds seem to be lower when there is a semicircular canal dehiscence. Patients with superior semicircular canal dehiscence show superior bone conduction thresholds as compared to the normal population.[8] Ribaric et al[9,10] demonstrated that fenestration on the LSCC in a small group of profoundly deaf patients led to significant improvement in bone conduction thresholds but none in air conduction. Similarly, Sohmer et al's[11] study on rats came up with the same results. In other words, the semicircular canal fenestration seems to facilitate the excitation of the cochlea with bone stimulation. The decrease in the impedance of the scala vestibuli of the cochlea, the removal of the bony barrier for exciting the vestibular and cochlear receptors, and the elimination of the ossicular chain inertia in bone conduction may serve as explanations for this result.[11] The lack of improvement in air conduction in these referenced studies may be due to the normal oval window and ossicular chain in their subjects and the third window effect with LSCC fenestration (similar to the conductive hearing loss and air conduction thresholds seen in patients with superior semicircular canal dehiscence syndrome). However, this was not the case here in this study, in which MBC was reduced from 9.1 dB to 5.8 dB, even though this difference was not statistically significant.

Concomitant inner ear anomaly is very rare[12] and was not seen among this study's patients. Ossicular malformations must be considered in any patient with nonprogressive congenital moderate conductive hearing loss in a normal eardrum.

Another option for these patients is bone-anchored hearing aid (BAHA) devices that can bypass the middle ear. Tjellstorm and Hakansson showed a significant improvement in ears with BAHA devices compared to unaided ears (29.4 dB with BAHA model HC 200 in all speech frequencies).[13] Although BAHA devices are simple to use, their cost and patient compliance with postoperative care makes LSCC fenestration surgery an attractive option for these patients. This is especially important in Iran, due to the prohibitive price of BAHA devices compared to the cost of undergoing otologic surgery (roughly $10,000 for BAHA devices without insurance coverage opposed to $400 for otologic surgery in a government hospital or $1000 in a private hospital with insurance coverage). In addition, hearing aid processors produce some artificial sound that may differ from the natural sound signals received through the fenestration technique. Future investigation can compare the audiologic benefits of each method.

Audiologic evaluations were not conducted by one person, but by all four audiologists of the audiology ward of the hospital. To reduce interobserver variability, it may have been better if one audiologist had evaluated the patients.

Conclusion

We demonstrated hearing improvement after lateral semicircular canal fenestration without adverse clinical effects on hearing or the vestibular system. According to this study, lateral SCC fenestration may open a new horizon in hearing for patients with oval window anomalies or facial nerve course abnormalities. Also, other conditions, such as a persistent stapedial artery or the recurrent failure of stapes surgery or of ossicular reconstruction techniques, may be treated with this approach.

Author Information

From the Otorhinolaryngology Research Center, Amir-Alam Hospital, Department of Otolaryngology–Head and Neck Surgery, Tehran University of Medical Sciences (TUMS), Tehran, Iran.

Corresponding author: Nasrin Yazdani, Otorhinolaryngology Research Center, Amir-A'lam Hospital, South Sa'adi Ave., Tehran, Iran.

E-mail address: n_yazdani@tums.ac.ir.

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Author Contributions

Mohammadtaghi Khorsandi Ashtiani, main idea of paper, inventing method, performing surgeries, preparation of manuscript (especially methods and discussion); **Nasrin Yazdani,** proofreading paper, patients' visit, data gathering; **Sasan Dabiri Satri,** preparation of manuscript (all parts), data analysis, patients' visit, data gathering; **Zahra Mokhtari,** preparation of manuscript (Discussion), editing revision; **Ali Kouhi,** preparation of manuscript (especially results), data analysis, proofreading.

Disclosures

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