1. 圧電型骨伝導スピーカの開発

圧電バイモルフは薄い圧電セラミック二枚の間に薄い金属板のような弾性材料を挟んでサンドイッチ状に貼り合わせたシンプルな圧電振動子で屈曲振動をおこなう。

1-1　筐体振動型

圧電バイモルフの音響振動力を人体に伝搬させる目的のデバイスとして最初に試作したものは図２に示す筐体振動型の構造である。バイモルフの寸法は 40×8.0×0.6 [mm]である。

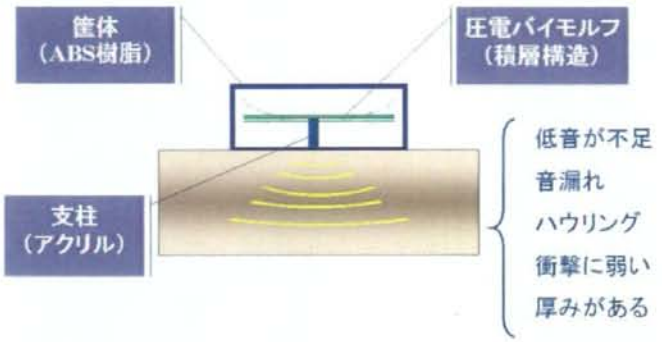


図２　筐体振動型の構成図

この構成では圧電バイモルフが発生する振動の慣性力はこれを支持する支柱に伝搬し支柱が固定されている筐体の底板を敲くものである。この筐体の底板の反対側が音響放射面となり、この面を人体頭部に接触させることで音響振動の人体への伝搬が可能である。
ところが、実際に試験を行うと次のような問題が判明した。

・低域の出力が少なく音響特性がよくない。
・音漏れ→筐体が振動して周囲への音波が漏れる。
・支柱で支える構造は機械的な衝撃に弱い。
・小型化に不利な構成

筐体の材質、寸法の変更、支持方法らいくつかの対策を検討したが、抜本的な解決には至らず何らかのブレークスルーが必要になった。

1-2　振動子被覆型

ソナーや魚群探知機などの水中で使用される超音波振動子は、防水の目的以外に水の音響インピーダンスとの差を埋める為にゴム系の物質で被覆されている。報告者らはこの構成をヒントにして、圧電バイモルフを有機物で被覆する構成を検討した。
被覆する厚みや硬度により音響特性を制御できることも判明した。この構成を図３に示す。

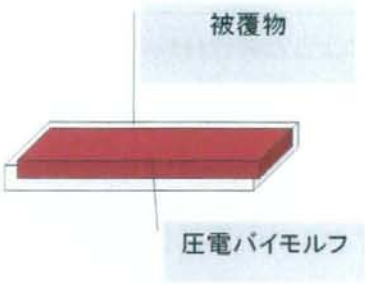


図３　振動子被覆型の構成

図４は実験結果の一部を示すもので表１の被覆する材質や厚みで音響出力の周波数特性が変化することを確認した。

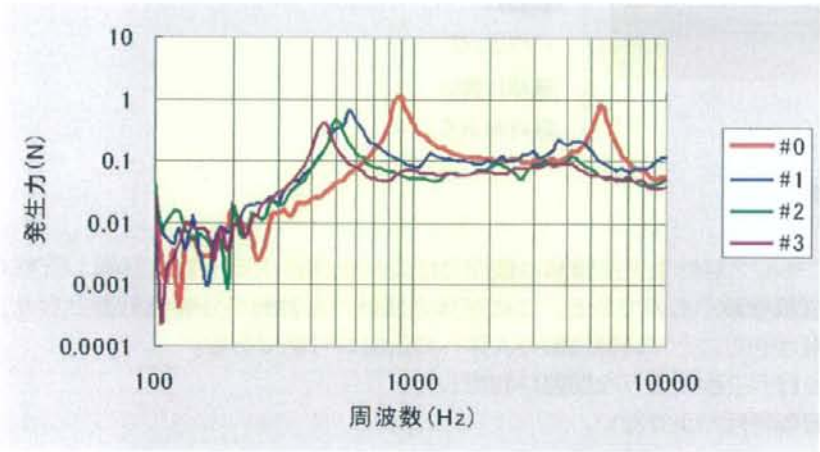


図４　被覆条件と音響性能

試料	被覆材料	弾性係数 Y (Gpa)	被覆厚み Tc (mm)
#0	被覆なし	—	—
#1	シリコンゴム 信越化学KE66	0. 0035	1. 3
#2	シリコンゴム 信越化学KE66	0. 0035	2. 0
#3	東レSE1866	0. 0012	1. 3

表１　被覆条件

いくつかの試験を行ったが、この構成は骨伝導スピーカとして以下のような利点が見つけられた。

・硬度９０程度のウレタンゴムで被覆してもその音響性能を維持できる。この結果、筐体などの保護構造は必要なくそのままで強度を保つことが出来るので小型・軽量化に有利である。

・被覆により、バイモルフ型振動子の単位長さあたりの重量が増えるが、ウレタンとバイモルフを構成する圧電セラミックやシム金属層に比べてヤング率が４桁ほど異なるために全体の曲げ弾性係数は重量分が寄与して共振周波数が低下する。この結果、不足だった低域部分の出力が改善された。

・有機物被覆は振動子の機械的Ｑを大幅に低減させることが出来、共振周波数部分での音響特性の不自然さを緩和することが確認できた。

・筐体型の欠点であった音漏れが激減した。

・振動体自体が有機物で厚く被覆されているために音響インピーダンスが人体に近づいた。この結果、外耳道入り口周辺の軟骨部に接触させて駆動すると音声の明瞭な伝搬が確認出来た。

2. 骨伝導スピーカのデザイン

報告者らの開発した圧電式骨伝導スピーカは、基本的に圧電バイモルフそのものであるが、その被覆材質や形態を変えることで種々の応用に向けたデバイスに発展させることが可能である。写真１は試作した各種の有機物被覆型の骨伝導スピーカを示す。

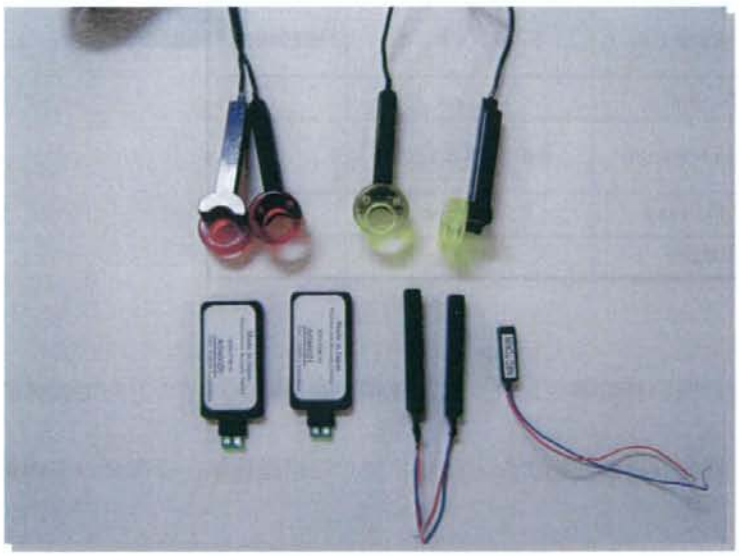


写真１　試作した各種形態の振動子被覆型骨伝導スピーカ

図５は基本的な仕様の音響性能について人工マストイドで測定した結果を示す。

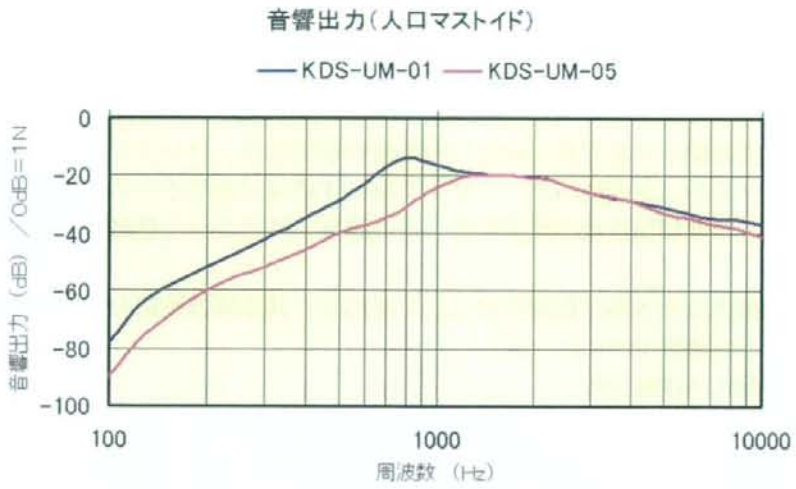


図５　骨伝導スピーカ仕様名 KDS-UM-01 の音響出力

また、表２には他の各種特性項目を示す。

	項目	KDS－UM－01	KDS－UM－05	備考
1	外観	写真参照	写真参照	
2	サイズ	３３×１８×３	３４×５×４．５	端子部除く
3	重量	３．６ｇ	２．１ｇ	
4	端子間静電容量	１．２μＦ±１５％	８００ｎＦ±１５％	
5	最大駆動電圧	７．５Ｖｒｍｓ	７．５Ｖｒｍｓ	
6	音響出力	下図参照	下図参照	参考値

表２　基本仕様の特性項目

開発した軽量で形状の自由度の高い骨伝導スピーカは、各種の骨伝導デバイスとして具体的な応用検討がなされている。

写真２は音楽用ヘッドセット、写真３は同時通訳などに応用できる超軽量型ヘッドセットの例である。

写真２　音楽用ヘッドセット

写真３　超軽量ヘッドセット（７ｇ）

また、各種分野での応用に期待できるものは振動体の一端にリング状のパーツが固定された骨伝導イヤフォンである。このリングは外耳道入り口の窪みに丁度嵌る形状になっており外耳道の入り口にイヤフォン状に装着できる。リングに直結する棒状の振動体が音響振動をすると、この振動が外耳道入り口の軟骨に効率よく伝搬出来る構造になっている。一方このリングは外耳道を塞ぐことはなく、気導音を一切妨げない機能を有している。

このリングを含め全体のデザインをブラッシュアップしたものが写真４で耳への装着性を改善したものである。

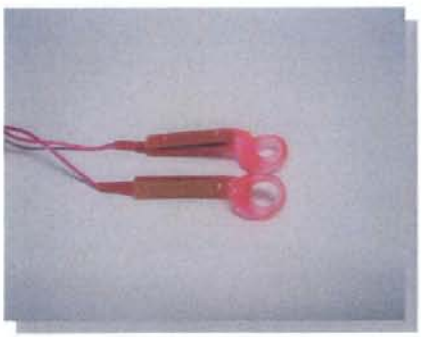


写真４　リング付き骨伝導イヤフォン

3. 結論

開発した軽量で軽い接触で効率よく音声を聴覚神経に伝えることができる有機物被覆型軟骨伝導スピーカは各種の応用が期待できる。この音声伝搬様式は、健聴者にとっては産業分野、アミューズメント分野で活用でき、健康福祉面では聴覚補助、視覚障害者のための音声ガイドらの場で有効に活用できるものと期待できる。

特に、外耳道近傍の軟骨との軽い接触で効率よく音声を伝達できる特徴は軟骨伝導と仮称する新規な音声伝達形態であり、既存の骨伝導では困難であった領域の聴覚補助手段として期待できる。

G．研究発表

1. 論文発表

未発表

2. 学会発表

未発表

H．知的財産権の出願・登録状況

（予定を含む。）

1. 特許取得

なし

2. 実用新案登録

なし

3.その他

なし

厚生労働科学研究費補助金（感覚器障害研究事業）
分担研究報告書

軟骨伝導補聴器の試作

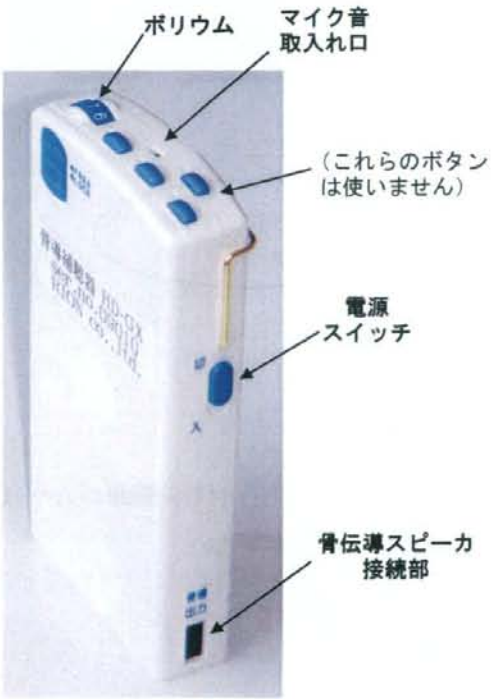
研究分担者　舘野　誠　リオン株式会社　部長

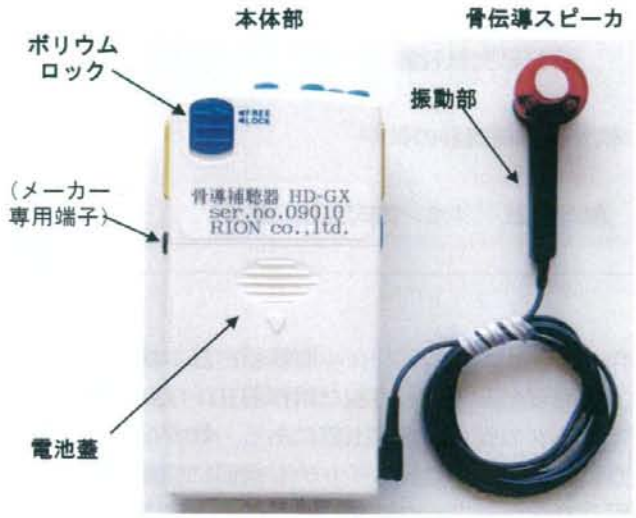
研究要旨

箱型の軟骨伝導補聴器を試作した。リオンのデジタル補聴器を基本構造として用い、軟骨導振動子を組み込んで補聴器として使用可能な試作器HD-GXを開発した。新開発の補聴器はポケット型でマイクの音口は本体上部にある。軟骨伝導スピーカの接続部は側面下面となるように設計した。電源スイッチも側面に装着した。ボリウムは上面にあり、側面にはボリウムロックをつけた。胸ポケットに入れて落ちないように固定用のクリップをつけた。

仕様は、ボリウム可変幅を約15 dB、消費電流約13 mA、使用電池はアルカリ乾電池単4形3本、フィードバックキャンセラ機能有りとした。外形寸法は46 mm（幅）×89 mm(長さ)×16 mm（厚さ）で、質量は本体69 g（電池込み）、骨伝導6 gである。

1. 構成と名称



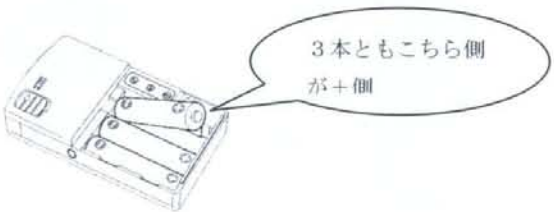


2. 使い方

2－1　電池の入れ方

（1）電池ふたを下図のように親指で少し押しながら、矢印方向にスライドさせて、開けます。

（2）電池の＋、－に注意して、電池を入れ、ふたをもとに戻します。

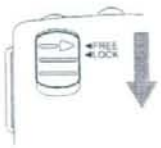


2－2　電源の ON-OFF

（1）電源スイッチを右図のように下（矢印の方向）にスライドさせると電源が入り（ON）、上にスライドさせると電源が切れます（OFF）。

２－３　ボリウムの操作方法

（１）ボリウムロックの操作：　ボリウムロックボタンの矢印が「FREE」のときはボリウムを自由に回すことができます。ボリウム位置を固定して使用したいときは、ボリウムロックを右図の矢印の向きにスライドさせて、「LOCK」の位置にします。ロック状態でボリウムを無理に回さないでください。故障の原因になります。



（２）ボリウムは、ボリウムロックが「FREE」の位置のときに自由に調整できます。ただし、ボリウムが「４」の位置にくると、カチッと音がして、ボリウムが回りにくくなります。少し力を入れれば、前後に回すことができます。

２－４　補聴器の使い方

（１）骨伝導スピーカのコネクタを本体に接続します。

（２）電源スイッチを OFF にして、電池を入れます。

（３）ボリウム位置を確認して、いつもの使用位置に設定します。初めてのときは「４」程度にしてください。

（４）骨伝導スピーカのリングの部分を耳の耳甲介部に引っ掛けます。

（5）電源スイッチを“入”（ON）にします。

（6）音が小さいときは、ボリウムを大きくします。ボリウムを聴きやすい位置に調整します。

（7）ピーピーとハウリングしているときは、本体を骨伝導スピーカから遠ざけてください。

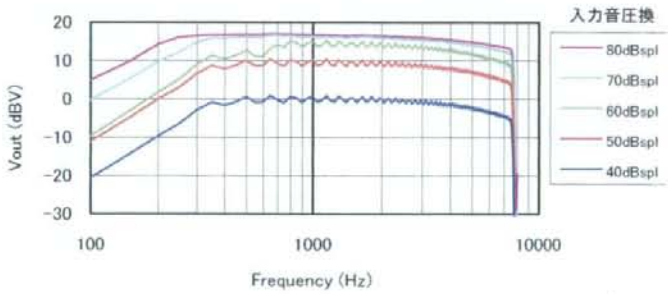
（8）使い終わったら、電源スイッチを“切”（OFF）にします。

3. 性能

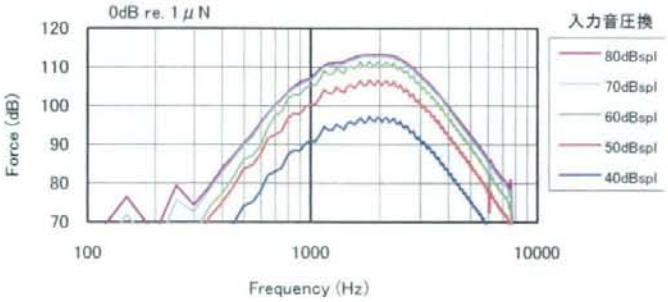
本器はデジタル補聴器用の IC 出力を圧電デバイス駆動用 IC を使用してさらに増幅して、骨伝導スピーカを駆動しています。骨伝導スピーカを耳に装用して使用した場合、振動による骨伝導音だけではなく、骨伝導スピーカの振動によって音も同時に発生します。

以下の特性は、骨伝導音のみの出力特性で、40 dB - 80 dB の入力音圧（マイクロホンの感度を-52 dB で換算した値、マイクロホン感度 0 dB：1 V / 0.1 Pa）に対する出力特性です。

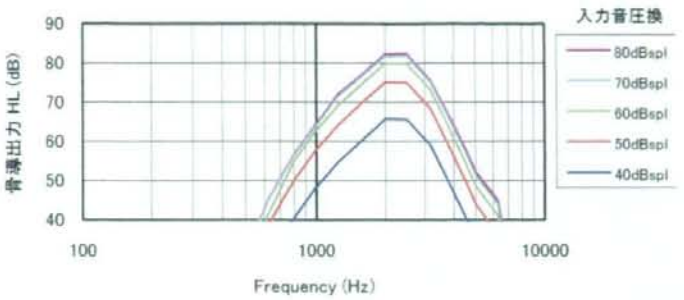
各入力音圧に対する本器の出力電圧特性（ボリウム最大時）



各入力音圧に対する骨伝導スピーカのフォース（力出力）レベル（ボリウム最大時）（IEC 60373 に規定のメカニカルカプラを使用して求めたフォースレベル）

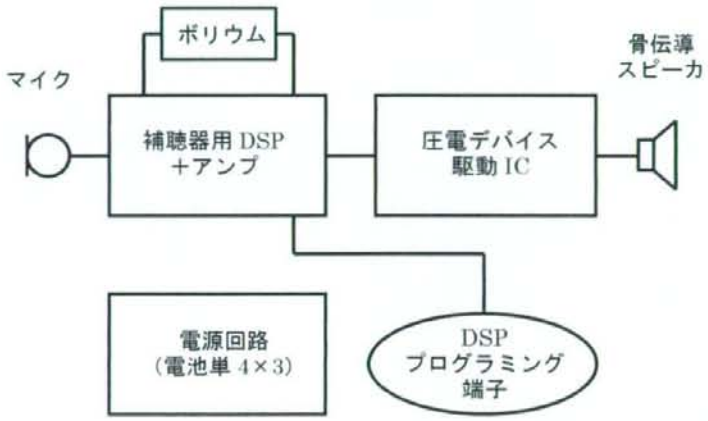


各入力音圧に対する骨伝導スピーカの出力の聴力レベル HL 換算値（ボリウム最大時）（ISO 389-3 に規定の骨導域値を使用）



4．仕様

4－1　ブロック構成図



4－2　出力特性：　　3 の性能参照
（IEC 60373 メカニカルカプラで出力評価した場合）

4－3　フィードバックキャンセラ機能：　　有

4－4　ボリウム可変幅：約 15 dB

4－5　消費電流：　　約 13 mA（静音時）
（この電流の場合の電池寿命は、約 90 時間）

4－6　使用電池：　　アルカリ乾電池、単 4 形×3 本

4－7　外形寸法：　約 46 mm（幅）× 約 89 mm（長さ）× 約 16 mm（厚さ）

4－8　質量：　本体　約 69g（電池込み）
骨伝導スピーカ　約 6g

G．研究発表

1．論文発表

未発表

2．学会発表

未発表

H．知的財産権の出願・登録状況

（予定を含む。）

1．特許取得

なし

2．実用新案登録

なし

3.その他

なし

III. 研究成果の刊行に関する一覧表

雑誌

発表者氏名	論文タイトル名	発表誌名	巻号	ページ	出版年
Takefumi Sakaguchi, Hiroshi Hosoi	Acoustical analysis of tympanoplasty with soft posterior meatal wall reconstruction	The Mediterranean Journal of Otology	Vol. 4, Supplement 1	137-138	2008
Tadashi Nishimura, Hiroshi Hosoi	Progressive hearing loss in intracochlear schwannoma	Eur. Arch. Otorhinolaryngol.	Vol. 265	489-492	2008
Yamashita A, Nishimura T, Nakagawa S, Sakaguchi T, Hosoi H.	Assessment of ability to discriminate frequency of bone-conducted ultrasound by mismatch fields	Neurosci Lett.	2008 Jun 20; 438 (2)	260-262	2008
Yoshiki Nagatani, Katsunori Mizuno, Takashi Saeki, Mami Matsukawa, Takefumi Sakaguchi, Hiroshi Hosoi	Numerical and experimental study on the wave attenuation in bone – FDTD simulation of ultrasound propagation in cancellous bone	Ultrasonics	48	607–612	2008
長谷芳樹，橘亮輔，阪口剛史，細井裕司	親密度別単語了解度試験用音声データセット(FW03)単音節音声ラウドネス校正	日本音響学会誌	Vol. 64, No. 11	647-649	2008
阪口剛史，斉藤修，細井裕司	軟骨導音の方向感に関する基礎的検討	日本音響学会2008年秋季研究発表会講演論文集		447-448	2008
阪口剛史，細井裕司	軟骨導補聴の基礎的検討	第53回日本聴覚医学会学術講演会予稿集	Vol.51 No.5	375-376	2008
西村忠己	突発性難聴の診断と治療	奈医報	21(1)	17-22	2008
西村忠己，細井裕司	語音聴力検査	JOHNS	Vol. 24, No. 5	719-723	2008
西村忠己，山下哲範，細井裕司	老年性難聴	神経内科	68(5)	436-441	2008

発表者氏名	論文タイトル名	発表誌名	巻号	ページ	出版年
西村忠己，岡安唯，細井裕司	補聴器の基本知識	medecina	Vol. 45, No. 7	1303-1306	2008
西村忠己，細井裕司	補聴器の最新知見　補聴器外来の実態と将来のあるべき姿-大学病院の補聴器外来-	JOHNS	Vol. 24, No. 9	1333-1336	2008
西村忠己，吉田悠加，細井裕司	高齢者の補聴器装用希望者の聞こえに関する自己評価と家族評価	Audiology Japan	51	123-129	2008

IV. 研究成果の刊行物・別刷

Objectives: To investigate hearing 1 and 3 years after cholesteatoma surgery performed at the Otosurgical Section at the Department of Otolaryngology in Uppsala. 135 patients at all ages undergoing cholesteatoma surgery were investigated.

Surgical technique: All patients were operated with total or partial removal of the posterior bony canal wall with reconstruction of the bony wall, ear drum, ossicular chain and obliteration of the mastoid cavity.

Surgical outcome: 8 % of the patients underwent a columella revision surgery. In half of these a revision surgery was indicated due to recurrency, and in half due to residual cholesteatoma. All patients were audiologically evaluated pre- and postoperatively after 1 and 3 years. All patients were examined by the same surgeon.

Conclusion: Our results show that with the reconstruction technique used in connection with cholesteatoma surgery a good and long-lasting improvement in hearing may be obtained.

OP213 - Hearing Result of the Surgery for Cholesteatoma [216]

[1]Okuno Taeko

[1]*Mitsui Memorial Hospital - Japan*

Objective: Hearing result of the surgery for cholesteatoma was studied.

Material and methods: Two hundreds and thirty nine ears with middle ear cholesteatoma were operated in our hospital from July 1993 to October 2003.Hearing result of the surgery was studied according to the type of the cholesteatoma.

Results: There were 142 male and 97 female ears. The average age of the subjects was 41.1 years with a standard deviation of 19.7 years. The range was from 3 to 74 years.

Forty seven per cent of the cases had attic type cholesteatoma. Marginal type cholesteatoma was found in 17 %, central perforation with cholesteatoma in 8 %, and congenital cholesteatoma in 13 %. Average age at the time of ear surgery of attic cholesteatoma group was 43.2 years, average age of marginal group was 48.5 years, average age of central perforation with cholesteatoma group was 57.6 years and average age of congenital cholesteatoma group was 22.8 years. Tympanoplasty type I was carried out in 16%, type II in 3%, type III (including type III interposition and type III with columella) in 49%, and type IV (including type IV with columella) in 20%. Tympanoplasty for attic cholesteatoma ear resulted in a successful hearing rate of 76.8%. Tympanoplasty for marginal cholesteatoma ear resulted in 63.2 % of successful rate and tympanoplasty for central perforation with cholesteatoma resulted in 70.0%.

OP214 - Ear Status after Cholesteatoma Surgery - Interim Results of a Long Term Prospective Study [132]

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Objectives: To evaluate ear condition of children and adults undergoing cholesteatoma surgery in a referral otologic center.

Design: Demographic and clinical data was collected from 132 consecutive cholesteatoma surgeries. Ear status was established at the last patient's follow up visit to the out-patient clinic.

Results: 79 children (mean age 11.9 years) and 53 adults (mean age 40.3 years) were included. 39.4% of patients had a previous surgery before presenting to our department. Canal-wall up mastoidectomy with tympanoplasty was performed in 46% of the children and 30% of adults, canal wall down mastoidectomy with tympanoplasty (modified radical) was performed in 25% and 6% respectively, and canal wall down (radical) mastoidectomy was performed in 29% and 64% respectively. A planed second look was performed in 76.8% of children and 63.2% of adults. A revision of the radical cavity was done in 39.1% of children and 14.7% of adults. After a mean follow up period of 3.4 years (range 0.5-9.1), 9% of children and 7.5% of adults were lost to follow up, a dry ear was achieved in 78.5% of children and 73.6% of adults.

Conclusions: Pre-operatively all patients had a chronic discharging unsafe ear. Meticulous follow up is essential for achieving the goals of treatment but heavily depends on the cooperation of the patient, the family, the primary care physician and the medical insurance, which must fully internalized the absolute need for a life long dedicated follow up. The results show that it is possible to achieve a relatively comfortable ear in most patients, but unrealistic to assure dry ear for all cholesteatoma patients, even when cholesteatoma is eradicated. Suboptimal patient's compliance for periodic long term post-follow up visits was identified as a crucial obstacle for better results.

Keywords: cholesteatoma, post operative, follow up, compliance

OP215 - Acoustical Analysis of Tympanoplasty with Soft Posterior Meatal Wall Reconstruction [221]

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In the tympanoplasty, soft or hard materials are used in reconstructing posterior meatal wall. We have performed tympanoplasty with reconstruction of the soft posterior meatal wall for the prevention of post-operative retraction pocket formation for 18 years. Our method is characterized by the reconstruction of the soft posterior meatal wall, nonobliteration with permanent or temporary materials, including Gelfoam, no use of a Palva flap and the use of fibrin glue for attaching the fascia to the posterior meatal skin. None of the patients experienced post-operative narrow-neck retraction pocket formation, and whenever aeration of the middle ear was disturbed after the operation, a balloon-like retraction in various degrees which depends on each patient's aeration disturbance was observed.

Some suggests possibility of larger energy loss to bring about when the posterior meatal wall is reconstructed by soft materials compared to by hard ones. Hence, we calculated the transmitted acoustic power in the auditory pathway for both soft and hard posterior meatal walls in order to

elucidate the difference between these two in sound conduction effect.

We made three types of models which represented a hard wall, a soft wall without balloon-like retraction (i.e. normal position) and a soft wall with balloon-like retraction. We used a finite-difference time-domain method to calculate the acoustic power on both the ear drum and the columella for 500 Hz, 1 kHz and 2 kHz pure tone inputs. As a result, we did not find any obvious difference among these three conditions in efficiency of sound conduction.

OP216 - Evaluation of Prognostic Factors and Middle Ear Risk Index(MERI) in Tympanoplasty [334]

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Objective: The aim of this study was to examine the effects of the prognostic factors and MERI on success rate of tympanoplasty.

Materials and Methods: The charts of 231 patients who underwent tympanoplasty operations between January 2002 and September 2007 were reviewed in this study. Patients were evaluated after 6 months postoperatively. Prognostic factors such as age, sex, presence of systemic diseases(diabetes mellitus and hypertension), site and size of perforation, duration of dry period, presence of hyaline plaque within tympanic membrane, operation type, status of the opposite ear, score of the MERI at presentation were investigated.

Results: The overall success rate was 74.4 %. Based on the univariate analysis, site and size of perforation, status of the opposite ear, absence of hyaline plaque within tympanic membrane, duration of dry period,operation type and low MERI score were found to be a statistically significant prognostic factors affecting success rate ($p<0.05$). Multivariate analysis was carried out on these significant prognostic factors and yielded the following results: healthy opposite ear(OR:5.64), size of perforation (OR:8.11), absence of hyalin plaque within tympanic membrane (OR:4.01), duration of dry period (OR:0.21) and low MERI score (OR:87.1).

Discussion: The goals of successful tympanoplasty are the removal of the pathology and achievement of a mucosal-lined middle ear cleft with an intact tympanic membrane. There are various prognostic factors reported in the literature influencing the success rate. Kartush introduced the MERI for tympanoplasty prognosis. The MERI combines the known preoperative and intraoperative risk factors. Multiple studies cited success rate from 60 to 90% in tympanoplasty, success rate was found 74.4% in this study.

Conclusion: Based on the results of this study, size of perforation, healthy opposite ear, absence of hyaline plaque within tympanic membrane, dry ear and low MERI were found to be a significant prognostic factors. Physician should be kept in mind these prognostic factors preoperatively to increase the success rate of tympanoplasty.

Keywords: tympanoplasty, prognostic factors,Middle Ear Risk Index (MERI)

OP217 - Long Term Functional Outcome of Canaloplasty in Congenital Atresia [680]

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Objective: To evaluate the long term functional outcome of canaloplasty in congenital (partial) atresia of the outer ear canal. In atresia cases it is necessary to carefully weigh the pro's and cons of reconstructive surgery, because bone anchored hearing aids and active middle ear implants offer a possible alternative and because of the well documented short and long term morbidity of reconstructive surgery.

Materials and methods: Our database of 116 patients (148 ears) with congenital canal atresia was retrospectively evaluated. The long term functional outcome of canaloplasty was evaluated, in two classes of stenotic ear canals: the completely stenotic (atretic) canals versus the partially (filiform) canals.

Results: A total of 33 ears with completely (atretic) or partially stenotic (filiform) outer ear canals were treated by canaloplasty for functional purposes. The long term result (mean follow up of 8 years) showed an improvement of the PTA with 16 dB for the whole group (n=33), of 10 dB for the atretic group (n=24) and 33 dB for the filiform group (n=9).

Discussion: In our experience reconstruction of completely atretic ear canals only yields short term satisfactory results. The absence of migratory behaviour of the skingrafts, transplanted to cover the medial part of the new canal, prevents a normal self cleaning of the canal. This causes chronic myringitis resulting in scar tissue formation and partial restenosis of the canal.

The initially present functional gain deteriorates. In contrast, if a filiform canal is present, these skin remnants are carefully preserved to cover part of the new canal. Those ears keep their normal self cleaning mechanism in the long term. As a consequence these ears remain anatomically and functionally stable.

Conclusion: Therefore we only apply reconstructive surgery in cases with a filiform ear canal. All completely stenotic cases are only offered the option of a bone anchored hearing aid.

Keywords: atresia, agenesia, functional surgery, canaloplasty, long term results, BAHA.

OP218 - Analysis of the Properties and Treatment Outcomes of Acquired Cholesteatoma in Children Compared with Adults [640]

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It is recognised that cholesteatoma behaves differently in children compared to adults.

Objectives: The aim of this study is to quantitatively analyses the characteristics of pediatric cholesteatoma and compare its behaviour with that of adults. A further aim of this study is to compare the response to intact canal cholesteatoma surgery of pediatric and adult ears.

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CASE REPORT

Progressive hearing loss in intracochlear schwannoma

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Abstract Intralabyrinthine schwannomas are rare tumors. It is difficult to diagnose them, and their hearing disturbance has not been sufficiently elucidated. Recently, however, the development of the imaging technology enables the diagnosis of intracochlear schwannoma before operation. We experienced a case of intracochlear schwannoma diagnosed with mild hearing loss. Pure tone audiometry (PTA) showed hearing loss at mid-frequency, with a mean threshold of 33.3 dB. Magnetic resonance imaging (MRI) revealed an abnormal lesion in the cochlea. Finally, PTA showed profound deafness and MRI revealed invasion of the schwannoma into the fundus of the internal auditory canal. Considering the progress and the results of audiometric examinations, hearing disturbance by intracochlear schwannoma is investigated in this report.

Keywords Intracochlear schwannoma · Magnetic resonance imaging · Auditory brainstem response

Introduction

Acoustic neuromas usually arise from the vestibular nerve within the internal auditory canal (IAC) and cerebellopontine angle. Intralabyrinthine schwannomas are uncommon and difficult to diagnose. They are usually diagnosed accidentally during labyrinthectomy for Meniere's disease [1, 2], vestibular neurotomy [3], cochlear implantation [4], or autopsy [5]. Therefore, hearing disturbance by intralabyrinthine schwannomas has not been sufficiently elucidated. We present a case of intracochlear schwannoma diagnosed with mild hearing loss. In this case, hearing loss had progressed to profound deafness over approximately 2 years.

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Case report

A 48-year-old woman with idiopathic thrombocytopenic purpura (ITP) noticed the sudden onset of right hearing loss and tinnitus. Ten days after the onset, she visited a hospital to have her hearing assessed. Pure tone audiometry (PTA) showed a notch at 500 Hz in the right ear (Fig. 1). She received a 2-week short tapered course of high-dose steroid therapy from the hospital. One week after the therapy, her hearing loss became worse, and she was referred to our department.

When she first visited our department, she presented with hearing loss, tinnitus and fullness of the right ear. No vestibular or neural symptoms were present. Otoscopic examination of the ear revealed normal tympanic membranes. Pure tone audiometry showed hearing loss at mid-frequency, with a mean threshold of 33.3 dB (the average of 500, 1,000 and 2,000 Hz) (Fig. 1). Speech discrimination scores in the right and left ears were 90% at 50 dB and 100% at 40 dB, respectively. Although fixed-frequency Bekesy audiometry showed Type I, alternate binaural loudness balance (ABLB) test revealed complete recruitment (Fig. 2). Transient evoked otoacoustic emission (TEOAE) levels in the right and left ears were 6.4 (reproducibility was 69%) and 8.2 dB (reproducibility was 77%), respectively. Distortion product otoacoustic emission (DPOAE) levels at 1 kHz were in the region of uncertainty in the right ear (Fig. 3). Auditory brainstem response (ABR) threshold

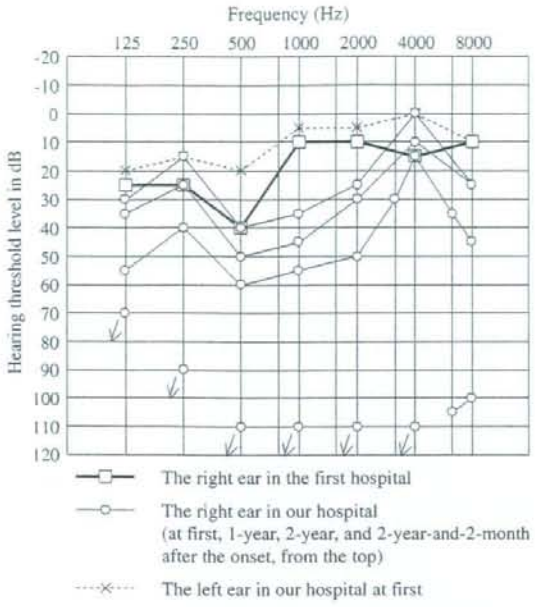

Fig. 1 Changes in pure tone audiometry for approximately 2 years before profound deafness. The *arrows* at the bottom of audiogram mean no response

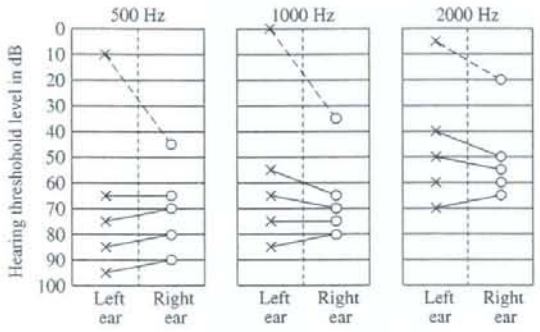

Fig. 2 Plot of loudness balance results by laddergram

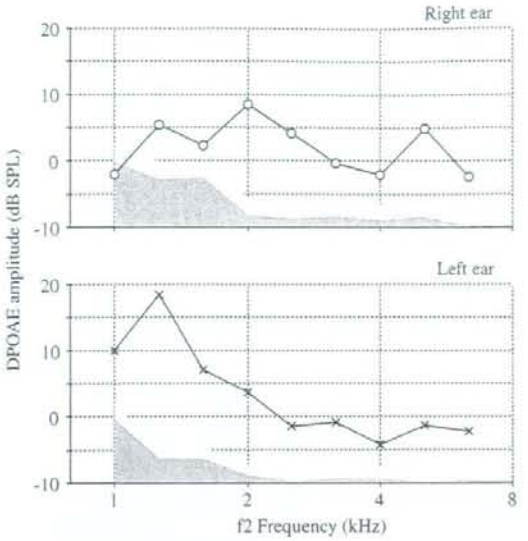

Fig. 3 Mean amplitude of distortion product otoacoustic emissions and noise floor at each *f2* frequency. The *colored* areas near the bottom indicate the average background noise floor levels

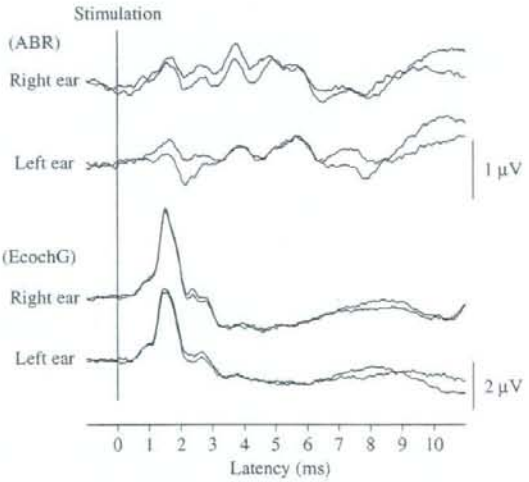

Fig. 4 Auditory brainstem response and electrocochleogram (EcochG) evoked by clicks at the intensity of 80 dB nHL

in the right ear was 20 dB nHL, equal to the left. No increases in absolute peak latency (waves I, III and V) and interpeak latency (I–III, III–V and I–V) were obtained (Fig. 4). Electrocochleogram showed normal waveforms (Fig. 4). Laboratory studies were normal except for a low platelet count due to ITP. Although another short tapered course of high-dose steroid and additional prostaglandin E1 therapy were performed, her hearing did not improve.

Three months after onset, magnetic resonance imaging (MRI) was performed. Although no abnormal lesion was obtained on T1- and T2-weighted images, gadolinium-enhanced MRI showed a small enhancing lesion in the cochlea (Fig. 5). Constructive interference in the steady-state (CISS) sequence, which can provide high-resolution images with good contrast between cerebrospinal fluid and solid structures, revealed the absence of a fluid signal in the middle turn of the cochlea, while no abnormal fluid signal was evident in IAC (Fig. 6). The lesion was interpreted as being either a small schwannoma or inflammation. Since the same enhancement was obtained on the second MRI

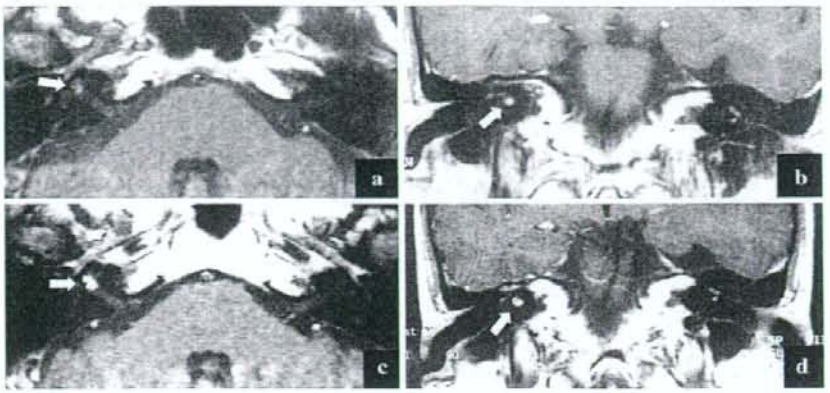

Fig. 5 Magnetic resonance imaging with gadolinium contrast showing axial (**a**, **c**) and coronal views (**b**, **d**). Upper (**a**, **b**) and lower (**c**, **d**) images were obtained at 2 months and 2 years and 2 months after onset, respectively. *Arrows* indicate enhancing lesions

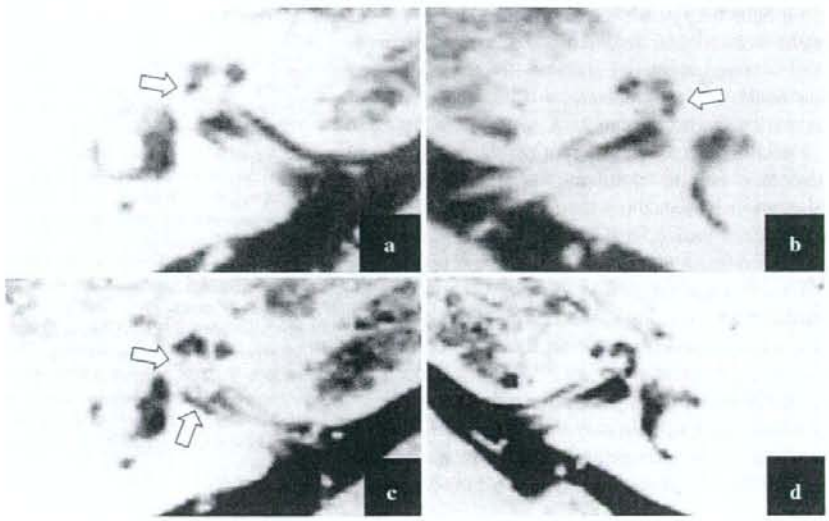

Fig. 6 Constructive interference in steady-state sequence obtained at 2 months (**a**, **b**) and 2 years and 2 months (**c**, **d**) after onset. In image **a**, the *arrow* indicates the absence of fluid signal in the middle turn of the cochlea that is not obtained on the normal side (**b**). In image **c**, the absence of fluid signal is clearly evident not only in the cochlea but also in the fundus of the internal auditory canal

performed 3 months later, we diagnosed this case as intracochlear schwannoma.

During the 2 year follow-up, the threshold in the right increased gradually (Fig. 1). Two years after the first episode, she reported progressive loss of hearing and a third MRI was performed 2 months later. In gadolinium-enhanced MRI, two enhancing lesions were distinguishable, one in the cochlea and the other in the fundus of the IAC (Fig. 5). Furthermore, the absence of a fluid signal on the CISS sequence spread in the middle turn of the cochlea and in the fundus of the IAC (Fig. 6). At the time, PTA showed profound hearing loss in the right ear. TEOAE and DPOAE were absent. Auditory brainstem response was not recorded at 100 dB nHL. She received high-dose steroid therapy, resulting in no improvement in her hearing. Considering the lack of vertigo episodes and the risk of operation due to ITP, she chose follow-up with serial MRI.

Discussion

In cases of schwannoma in IAC, audiometric examinations generally show no cochlear disorders but retrocochlear disorders; however, in our case, retrocochlear disorders were not evident on audiometric examination. Recruitment was obtained in the ABLB test and low response in DPOAE was obtained in the range which was almost consistent with hearing loss in PTA; therefore, hearing disturbance in our case was considered as a cochlear disorder, probably involved by occupation of the cochlea by schwannoma. Our case suggests that the presence of cochlear disorders in audiometric examinations, such as recruitment, does not rule out the possibility of intracochlear schwannoma.

One of the most important audiometric examinations for the diagnosis of schwannoma is the ABR test. For schwannoma in IAC, the ABR test usually shows an abnormal response associated with retrocochlear disorders;