は重度難聴例で聴覚活用を進めて音声言語を習得するには，たとえ内耳奇形があっても人工内耳を使用する以外に有効な方法がないことによる．

内耳奇形のうち最も重篤なのは内耳が形成されないMichel型奇形であり，次に位置づけられるのが蝸牛の無形成である．蝸牛と前庭両者の原器は形成されたが，その後の分化がないために内耳が単一の嚢状構造となっているものをcommon cavity奇形と呼ぶ．前庭・半規管と蝸牛がはっきりと分れ，ともにある程度形成されるが，蝸牛において基底回転と上方回転の輪郭はあるものの，各々の隔壁や蝸牛軸がCT上観察できないものをincomplete partition type I（IP-I）とする．さらに分化が進んだものがincomplete partition type II（IP-II）で，蝸牛が1.5回転以上形成され，基底回転と上方回転間の隔壁も明瞭であるが，基底回転より上の部分は嚢状である．蝸牛軸は基底回転で確認できる．IP-IIの前庭系では半規管の奇形は軽微で，前庭の僅かな拡大がある程度であるが，前庭水管の拡大をともなう．この所見は，Carlo Mondiniが1791年に報告した内耳奇形症例の所見に合致する．Mondini奇形は内耳奇形の中で最も有名なものであるが，この用語が現在まで必ずしも厳格な定義に沿って用いられてこなかったため，本来は異なる様々な奇形を一括して指すと理解されがちである．Sennaroglu の研究[9]ではIP-IIという，最も軽い範疇に属する奇形を明確に定義することで，これがMondiniの報告例に正確に当てはまることを示しており，その点においてSennaroglu分類の意義は大きい．

症例4：3歳　男児

新生児聴覚スクリーニングで要精査となり，近くの総合病院耳鼻咽喉科で精密検査を受けた．当科紹介初診時の聴力は右側が120dB，左側が110から120dB．新版K式発達検査での発達指数は，姿勢・運動：100，認知・適応：94，言語・社会：64と，言語社会領域の選択的な遅滞があり，全般的な発達遅滞を伴わない難聴児として典型的なプロフィールである．

症例5：7歳　女児

新生児聴覚スクリーニング検査で両側とも要精査，総合病院の耳鼻咽喉科で両側内耳奇形に伴う中等度難聴と診断された．3歳10カ月時に精査および将来の人工内耳適応検討のために当科を紹介初診．平均聴力レベルは右77.5dB，左92.5dBで，両耳に補聴器を装用して順調に音声言語を習得しており，音声言語に歪を認めなかった．しかし，その後両側とも聴力悪化と改善を繰り返しながら徐々に聴力レベルが低下し，7歳時に特に誘因なく両側聴力が悪化して両側聾となった．ステロイド治療と経過観察の後，左人工内耳埋め込み術を行った．術後の人工内耳による語音聴取は良好である．

IP-IとIP-IIの違い

内耳奇形の診断において，IP-IとIP-IIの鑑別は非常に重要である．これは，両者とも頻度の高い奇形であり形態的な差異が大きくないにも関わらず，人工内耳による治療効果が大きく異なることによる．Fig. 5にIP-IとIP-IIの典型例を示す．IP-I（Fig. 5：a，b）では，生下時から重度の難聴があり，基底回転と上方回転が分離せず，骨性の蝸牛軸が観察できない．上方回転が嚢状に融合している（Fig. 5：b ↓）．人工内耳の効果は概し

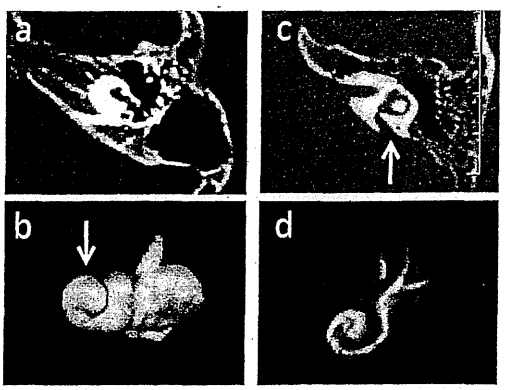

Fig. 5　CT and MRI of IP-I and IP-II inner-ear malformation

て不良であり，蝸牛開窓でgusherをきたす例が多い．一方IP-II（Fig. 5：c，d）では，生下時には一定の残存聴力を有して言語習得できる例が多く，生後に聴力悪化をきたす．蝸牛の上方回転が嚢状に融合しているが基底回転と上方回転が分離している（Fig. 5：d）．骨性の蝸牛軸はCTで一部観察できる．また，原則として前庭水管が拡大している（Fig. 5:c ↑）．人工内耳の効果は良好で，原則として手術時のgusherはない．

症例6：1歳　男児

生後8カ月時にインフルエンザ菌による細菌性髄膜炎に罹患し，小児科入院となった．抗菌薬とステロイド治療で髄膜炎は完治したが，退院前に内耳障害の有無確認のため聴性脳幹反応検査（ABR）を行ったところ，右側の反応がないことが分かり，精査のため当科紹介となった．当科でASSR検査を行うと，左はほぼ正常であるが，右側の閾値は70dB（500Hz）から110dB（4000Hz）と上昇していた．しかし，DPOAE検査では両側ともほぼ正常の反応が確認された．

側頭骨ターゲットCT所見：右側では内耳道底から蝸牛軸への移行部，いわゆる蝸牛神経管の径が1.7㎜であり（Fig. 6：a 拡大写真 矢印），左側の2.4㎜（Fig. 6：c 拡大写真 矢印）より明らかに狭い．その他の内耳，中耳には異常所見を認めない．

MRI所見：右内耳道底部の神経を観察すると，蝸牛神経の描出が不明瞭（Fig. 6：b 矢印）で，左側できれいに観察できる蝸牛神経（Fig. 6：d 矢印）との間に歴然とした差がある．また，内耳道径も右側2.4㎜，左側3.7㎜で，右側が若干狭い．

解　説：内耳道の前下部は内耳道底からやや奥まった構造になっているが，解剖学的構造としての神経管は存在しない．しかし一部の感音難聴例では，この部分が狭く，管状の構造を形成する．このような管状構造はbony canal for the cochlear nerve[10]として報告され，その後は単にcochlear nerve canal[11]と呼ばれることが多くなった．CT画像でその狭窄を伴う高度難聴例ではMRIで蝸牛神経の低形成を認めることが多い．治療の観点からは，蝸牛神経管の狭窄，蝸牛神経の低形成があると人工内耳の効果不良が予測されるため[12]，先天性感音難聴症例における臨床画像診断上の重要な着眼点である．

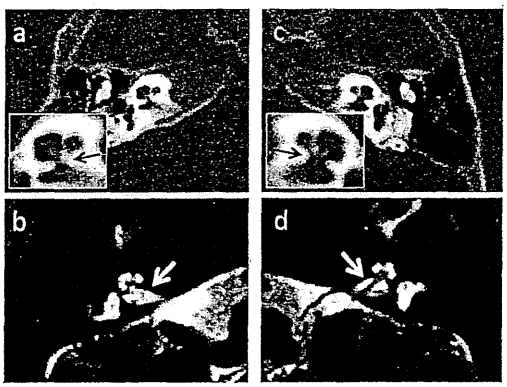

Fig. 6　Temporal bone CT and MRI of right cochlear nerve deficiency

ま　と　め

耳の画像診断では，耳だけでなく頭蓋内や頭蓋底の合併症にも留意が必要である．診断のモダリティとしては側頭骨CTが基本であるが，症状や，想定される疾患に応じて脳CT，MRI，MR-venographyなどを併用する．観察目的を十分に考えて撮像法を選択することが大切であり，治療後の経過観察では低侵襲で簡便な方法を考慮する．

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JOHNS
特集●検査結果をどう読むか?●

聴覚領域の検査

方向感・両耳聴検査

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Yasushi NAITO　Saburo MOROTO

● Key Words ●方向感，両耳聴，カクテルパーティー効果●

はじめに

聴覚に異常をきたす中枢疾患の診断において，CTやMRIなどの画像診断は極めて有用であるが，形態的異常を伴わない病態や，形態変化が明確にならない段階での疾患等を機能的側面から診断するには，個々の機能障害に応じた聴覚機能検査が大きな役割をはたす。また近年，人工内耳の両耳装用効果が注目されてきているが，この適否を検討するには各耳単独での検査を行うだけでは不十分で，両耳聴が関与する高次の聴覚機能も評価する必要がある。

本稿では，両耳で聴くことについての聴覚機能検査のうち，方向感と両耳聴検査についてまとめるとともに，両耳人工内耳の効果判定に用いられる検査についても自験例を含めて概説する。

Ⅰ．両耳聴の定義と生理学的意義

両耳聴（binaural hearing）とは，音刺激が両方の耳に与えられる聴取状態を指す[1]。両方の耳で音を聴くと，片耳の機能が反対側にも加わるだけでなく，両耳からの聴覚情報が上オリーブ核より上位の中枢聴覚路で統合あるいは分離されることで，片耳では得られないより高次の聴覚情報が得られる。

両耳聴の効果としては，

1）両耳で同じ音を聴いたときに片耳の場合より閾値が低下し，ラウドネス，明瞭度が向上する両耳加重現象（binaural summation）
2）両耳に与えられた同種刺激音に位相や時間差がある場合に単一の音像ができる両耳融合現象（binaural fusion）
3）両耳に同時に与えられた異なる音刺激を分離して弁別できる両耳分離現象（binaural separation/discrimination）
4）音源の方向がわかる音源定位（sound localization）

などが挙げられる[2]。

これらの両耳聴機能は日常生活のなかでさまざまな効果として現れており[3]，両耳で聴く方が片耳より若干音が大きく明瞭に聞こえ，背景雑音のある状態での音声聴取が改善し，多数の話者が同時に話している状況で1人の話者の音声を聴取することが容易になる（カクテルパーティー効果）[4]。

Ⅱ．方向感の生理学的機序

音の定位（localization；auditory localization）は，音場において聴覚によって聴取者が感じる距離感と方向感を伴った音源の位置感覚と定義される[1]。音源定位は，頭部に対して垂直方向と水平方向に大別され，各々機序が異なる。垂直方向の定位は，主に頭部や耳介による音の反射や直達音との干渉など頭部の形態による音の修飾・変化（頭部伝達関数，head related transfer function：HRTF）を手掛かりとしており，水平方向の定位はHRTFに加えて両耳に到達する音の違いを利用する。音源定位の手掛かりとしては，これら以外にも対象音の音量や音色，音源と聴取者の間あるいは周囲にある物体による音の反射，吸収，遮蔽なども挙げることができる[5]。

頭部に対する音源の位置に応じて，左右の耳で聴取される音の音圧（両耳間音圧差，interaural

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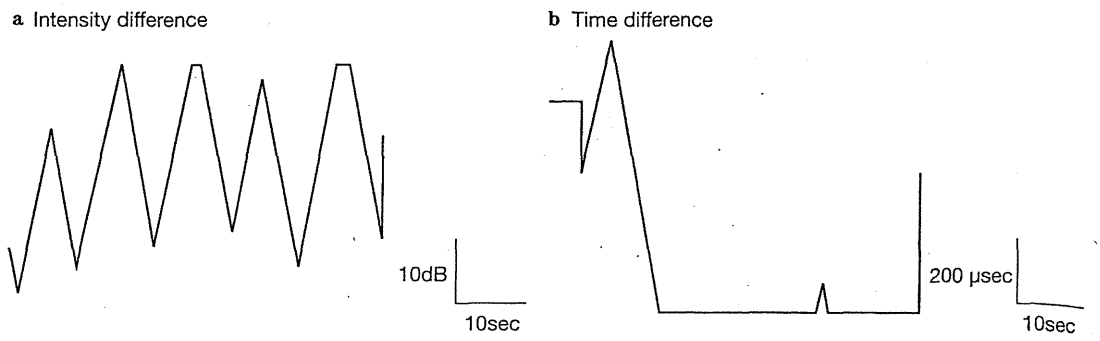

図 1　小児 auditory neuropathy 例の両耳聴検査結果（文献 7 より引用）
IID（a）では音像が一定の幅の中で定位できるが，ITD（b）では時間差が大きくなっても音像が定位できていない。

level difference：ILD あるいは interaural intensity difference：IID），到達時間（両耳間時間差，interaural time difference：ITD），位相などに相違が生じる。ILD/IID は頭部に対して正中から横にずれた方向から音がやってきた場合，音源と反対側の耳が頭の影になり，音が回折して到達するので，直接到達する耳に比べてわずかに減衰した音を聴取するために生じ，この効果は音の周波数が高いほど大きい。一方，ITD は主に低周波数領域で音源方向の効率的な手掛かりになる[3,5]。両耳間の聴取音の相違は，これら種々の手掛かりを通じて，聴者周囲の空間そのものの認知に貢献する[6]。

Ⅲ．方向感と両耳聴の検査

方向感の検査には，無響室内で被験者の周囲に多数のスピーカーを配置して行う方法と，ヘッドフォンを用いて両耳に入力する音の音圧やタイミングを変えて行う方法がある。

前者は HRTF も含んで，より自然な状況での検査であるが，無響室というスペースが必要で，さらに検査室空間内での音場の均一性やスピーカーの配置などに細心の注意を要する。また，このような音場検査では実際の音源を使用するので ILD/IID と ITD を独立して変化させることも困難である。

一方，ヘッドフォンを使用する検査は，頭蓋内に形成される音像の位置を被験者に応答させるもので，実際の音源の方向が変わるのでない分，非生理的であるが，普通の聴力検査室で実施可能であり，ILD/IID と ITD を別個に検査できる利点もある。例えばリオン社の聴力検査装置 AA-75 では ITD の検査が可能で，臨床的検査として実用的である。ITD 検査の臨床応用については多くの報告があるが，例えば Kaga らは，auditory neuropathy 症例で語音弁別能が純音聴力に比して不釣り合いに低下すると同時に，ILD/IID は感知できるが ITD による音像定位ができない事例を報告している（図 1）[7]。この例は，聴神経の病態が中枢聴覚路での時間分析を劣化させ，これが語音弁別能低下につながることを示唆し，興味深い。

Ⅳ．人工内耳装用者での知見

両耳聴検査の意義が問われる病態の 1 つに，人工内耳の両側装用の問題がある。通常，人工内耳の効果を評価するためには静寂下の単音節/単語聴取検査などが行われるが，これらのように片耳でも良好な結果が得られやすい検査では両耳装用の本質的な効果を示しにくく，両耳聴の観点から種々の工夫が必要である。

両耳聴では加重効果があり，健常聴力者で 3〜5 dB 程度閾値が下がるが，両側人工内耳では 1 〜 2 dB とされる。方向感覚では ILD/IID と ITD が主に寄与するが，このうち ITD では左右のわずかな（健常聴力者で 70 μs 程度以下）時間差が利用される。しかし，人工内耳電極アレーの刺激頻度は数

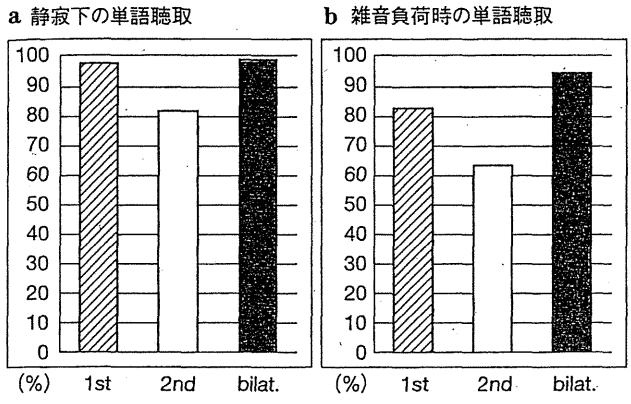

図 2　両耳人工内耳使用小児における静寂下（a）および雑音負荷時（b）の単語聴取成績
1st：最初に手術した側の人工内耳単独での成績。
2nd：2回目の手術で埋め込んだ人工内耳単独での成績。
bilat.：両側の人工内耳を使用して聴取した場合の成績。

百から 1000 Hz までであり，しかも通常は左右のプロセッサが独立して機能している。このため，両耳人工内耳の状態でコードできる ITD は 1 ms のオーダーになり，方向感には活用できない。したがって，両耳人工内耳の方向感は主に ILD/IID によって得られていると考えられる。今後，両耳人工内耳で ITD を活用するためには，左右プロセッサを一体的に同期させた駆動が 1 つの課題になるであろう。

両耳聴の利点の 1 つに“カクテルパーティー効果”があり，人工内耳使用者の評価でもさまざまな方向から雑音と語音を同時に提示し，語音が弁別できる S/N 比や，一定の雑音レベルでの語音弁別能などが計測される。例えばわれわれの施設での両側人工内耳小児例 11 名(検査時平均年齢 5 歳 11 カ月）の単語聴取検査（図 2）において，初回手術の人工内耳単独，2回目手術の人工内耳単独，両耳人工内耳の成績を比べると，静寂下の検査では初回手術耳単独と両耳装用で差が出ない。一方，正面の語音に対して左右 45 度の 2 方向から S/N 比 0 dB で加重不規則雑音を負荷した場合，単耳人工内耳での弁別能は初回手術の人工内耳単独が平均 82%，2 回目手術の人工内耳単独が平均 63%であるのに対し，両耳人工内耳では 94%まで改善し，このような検査ではじめて両耳人工内耳の効果が評価できる。

Dunn ら[8]は成人で単耳人工内耳使用者と両耳人工内耳使用者を比較し，語音（単語）の音源に対して約 60 度離れた方向からスピーチノイズを負荷し，単語弁別成績が 50%になる S/N 比を求めている（図 3）。この実験では両耳人工内耳使用者では単耳人工内耳使用者に比べて 9 dB 低い S/N 比に耐えることが示された。雑音源が複数（左右 2 個）になると全体の弁別成績が下がるが，この状態でも両耳使用者の方が単耳使用者より 5 dB 良好な成績になっている。興味深いのは，この単語弁別課題を視覚認知課題と同時に負荷した場合で，単耳と両耳の差は 11 dB にもなっている。

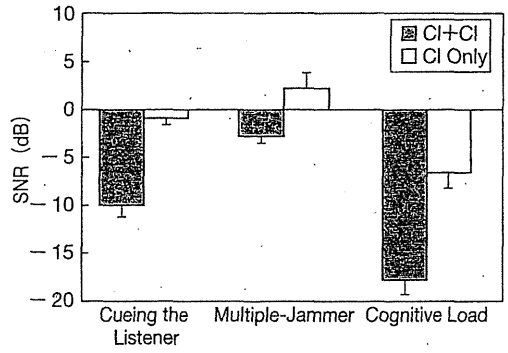

図 3　語音の音源に対して約 60 度離れた方向からスピーチノイズを負荷したときの単耳人工内耳使用者と両耳人工内耳使用者の比較(文献 8 より引用)
語音聴取に側方の離れた角度の単一音源からスピーチノイズを負荷する条件（左グラフ）では，両耳人工内耳使用者（灰色）の方が単耳人工内耳者（白）より低い S/N 比で語音弁別できるが，雑音源が 2 つになると成績が下がって両者の差が小さくなる（中央グラフ）。語音聴取に側方のノイズと，視覚的認知課題を同時に負荷する条件では両耳人工内耳例の方が，より低い S/N 比で聴取可能である（右グラフ）。

日常生活では往々にして聴覚と同時に視覚その他多様な認知処理を並行して行う場面があり，両耳聴の機能を評価するにはこのような複数の認知課題の負荷も考慮すべきである。

両耳人工内耳のカクテルパーティー効果については，否定的意見もある。Loizou ら[9]は雑音負荷下の語音弁別検査をいくつかの条件で行い，妨害雑音が単独で目的音源と離れた角度にあるときは両耳人工内耳の効果が得られるが，雑音原が複数になると単耳と両耳の効果の有意差がなくなり，“カクテルパーティー効果”という観点からは日常生活上でのメリットが少ないと結論している。その機序として，上述したように現在の人工内耳ではITDが活用できない点が大きいが，両耳人工内耳でIID/ILDは活用可能であり，聴覚機能から見た両耳人工内耳の利点と限界を評価するには，さらに精緻な検査が必要であろう。

まとめ

1）両耳聴には両耳からの聴覚情報の加重，融合，分離，さらに音源定位など単耳聴では得られないさまざまな機能がある。

2）方向感覚（音源定位）には多様な音響的手がかりが活用されるが，特に水平方向の定位には両耳で聴取される音のILD/IIDとITDが重要な役割を果す。

3）両耳人工内耳の効果においても限定的ではあるが両耳聴機能が寄与し，その有効性の評価には両耳聴も勘案した検査が必要である。

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ORIGINAL ARTICLE

Clinical features of rapidly progressive bilateral sensorineural hearing loss

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Abstract

Conclusion: Rapidly progressive bilateral sensorineural hearing loss (SNHL) often develops as a symptom of intracranial diseases or systemic vasculitis. For early diagnosis and treatment of these potentially fatal diseases, a history of hearing deterioration within 2 months and associated symptoms may be important. *Objectives:* To reveal clinical features and causative diseases for rapidly progressive bilateral SNHL. *Methods:* The inclusion criterion was patients with bilateral progressive SNHL, who had experienced difficulty in daily conversation within 4 days to 1 year after the onset of hearing loss awareness. This study was a retrospective evaluation of 12 patients with rapidly progressive bilateral SNHL who visited our hospital between 2007 and 2011. *Results:* The causative disease for hearing loss was identified in 11 of 12 patients; intracranial lesions including nonbacterial meningitis, meningeal metastasis of lymphoma, and superficial siderosis in 4 patients, systemic vasculitis in 2, auditory neuropathy spectrum disorder in 1, and an isolated inner ear disorder in 4. Relatively rapid hearing deterioration within 2 months showed a significant association in six patients with an intracranial lesion or systemic vasculitis. Moreover, all these six patients complained of dizziness and/or non-cochleovestibular symptoms such as fever, headache, and/or altered mental state in addition to hearing loss.

Keywords: *Auditory perception, intracranial disease, systemic vasculitis, magnetic resonance imaging, hearing threshold*

Introduction

Sensorineural hearing loss (SNHL) is caused by various disorders, including sudden deafness, presbycusis, hereditary hearing loss, drug-induced hearing loss, and Meniere's disease. Various clinical data are used to diagnose the cause of SNHL, of which the time course of hearing deterioration may be particularly important for estimating the nature of the disorder. For example, sudden deafness has an onset period of < 72 h [1], while presbycusis deteriorates by 1–2.5 dB per year over a long period of time. We also encounter patients with bilateral SNHL whose hearing deteriorates more slowly than that in sudden deafness but more quickly than that in presbycusis. Such patients often have serious complicating diseases, although only a few studies have examined this type of hearing loss. In this study, we report 12 cases of rapidly progressive bilateral SNHL and analyze the clinical features and causative diseases for hearing loss.

Material and methods

The study was a retrospective review of medical records. Of the 908 patients diagnosed with bilateral SNHL who visited the Department of Otolaryngology at Kobe City Medical Center General Hospital from

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Table I. Characteristics of 12 patients with rapidly progressive bilateral sensorineural hearing loss.

Case no.	Onset (age in years)	Time from onset to difficulty in daily life (days)	Gender	Causative disorder	Category of causative disorder	Worst hearing (dB)		Hearing after treatment (dB)		Clinical symptoms
						R	L	R	L	
1	33	4	M	Cryptococcal meningitis	Intracranial lesion	115	115	68.3	25	Fever, headache, altered mentation, dizziness
2	45	60	M	Chronic herpes meningitis + labyrinthitis		115	108.3	No improvement		Fever, tinnitus
3	60	6	M	Meningial metastasis of lymphoma		75	50	45	48.3	Fever, dizziness
4	79	30	F	Superficial siderosis		65	61.7	No improvement		Dizziness, tinnitus
5	73	45	F	Cogan's syndrome	Systemic vasculitis	115	115	No improvement		Fever, headache, dizziness
6	44	4	F	Vasculitis syndrome		93.3	81.7	51.7	38.3	Fever, headache, altered mentation
7	26	7	F	Auditory neuropathy	ANSD	115	113.3	No improvement		Tinnitus
8	63	120	F	Isolated inner ear disorders	Isolated inner ear disorder	65	56.7	No improvement		Tinnitus
9	67	90	M	Isolated inner ear disorders		103.3	103.3	No improvement		Tinnitus
10	69	360	M	Isolated inner ear disorders		95	115	No improvement		Tinnitus
11	69	360	F	Isolated inner ear disorders		80	73.3	No improvement		Tinnitus
12	61	14	F	Undefined disorder	Undefined	53.3	55	41.7	41.7	Fever, backache

January 2007 to December 2011, 12 (1.3%, 5 males and 7 females; Table I) who met the following criteria for rapidly progressive bilateral SNHL were selected: (1) pure-tone audiometry data showing bilateral SNHL and average hearing thresholds at 500, 1000, and 2000 Hz of ≥ 50 dB; (2) difficulty in daily conversation without lip-reading or sign language within 4 days to 1 year after the onset of hearing loss awareness; and (3) exclusion of cases with bilateral Meniere's disease or functional hearing loss. Wegener's granulomatosis [2], Churg-Strauss syndrome [3], and eosinophilic otitis media [4], are also known to induce progressive hearing loss, but were excluded from this study because these diseases lead to mixed hearing loss rather than SNHL. The median age at onset of hearing loss was 62 years (range 26–79 years). The precise deterioration speed of the patients' pure-tone audiometric thresholds could not be calculated because most of them came to our hospital after having moderate or severe SNHL and their initial pure-tone audiometry thresholds before the onset of hearing loss had not been tested. Therefore, we defined progressive bilateral SNHL on the basis of subjective time course of deterioration in auditory perception.

The diagnoses of causative diseases of rapidly progressive bilateral SNHL were based on medical interviews, physical findings, and examinations by otologists, internal medicine specialists, and radiologists. The examinations included blood autoantibody tests, microbiological culture tests, radiographic examinations (CT and MRI), and cerebrospinal fluid (CSF) tests, as well as conventional otological examinations including pure-tone audiometry, distortion product otoacoustic emissions (DPOAEs), and auditory brainstem response (ABR). The causative diseases were categorized into five groups: (1) an intracranial lesion for which CT, MRI, and/or CSF tests revealed an abnormality in the central nervous system; (2) systemic vasculitis, diagnosed by positive blood tests for autoantibodies and systemic inflammation and vasculitis-specific skin lesion, retinal vasculitis, or non-syphilitic interstitial keratitis; (3) auditory neuropathy spectrum disorder (ANSD), diagnosed on the basis of good responses in DPOAE and a lack of obvious responses in ABR; (4) isolated inner ear disorder, with no abnormality on CT or MRI scans and no symptoms other than cochleovestibular symptoms; and (5) an undefined disorder with symptoms other than cochleovestibular symptoms.

The time course of hearing deterioration was evaluated using subjective manifestations. The time course was defined as the time period from the onset of hearing loss awareness to the onset of difficulty in understanding speech in daily life, and it was classified as follows: (1) 4 days to 1 week, (2) 1 week to 1 month, (3) 1–6 months, and (4) 6 months to 1 year. We also focused on clinical manifestations other than hearing loss, which were divided into cochleovestibular symptoms including tinnitus and dizziness and noncochleovestibular symptoms including fever, headache, and altered mental state.

Results

Clinical manifestations

The time course of hearing deterioration was from 4 days to 1 week in four patients, from 1 week to 1 month in two patients, from 1 to 6 months in four patients, and from 6 months to 1 year in two patients. The median hearing level (i.e. the worst value for each patient) of the 12 patients was 94 dB for the right ear and 93 dB for the left ear (Table I). With respect to manifestations related to noncochleovestibular disorders, fever was the leading symptom and was observed in six patients (50%). Among these patients with fever, three also complained of severe headache and two of these further suffered from altered mental state. Tinnitus was observed in seven patients including all six patients without noncochleovestibular symptoms. Dizziness was reported in four patients and three of these were also associated with a noncochleovestibular symptom, but the other complained of only tinnitus and dizziness (Table I).

MRI findings

Brain MRI was performed in nine patients including all six with a noncochleovestibular symptom, one with both tinnitus and dizziness, and two with tinnitus. Association of noncochleovestibular symptoms and dizziness with bilateral SNHL suggests the presence of systemic or intracranial lesions in the former and a retrocochlear or unusual inner ear disease in the latter. In fact, the diagnosis of an intracranial lesion or systemic vasculitis was confirmed or supported by MRI in five of seven patients with a noncochleovestibular symptom or dizziness (Figure 1). In case 4, T2-weighted MRI revealed superficial hypointensity on the surface of the brainstem and cerebellum, which was diagnosed as superficial siderosis. In the other four patients, gadolinium-enhanced T1-weighted MRI showed abnormal enhancement in the inner ear or internal auditory canal. In five cases complaining solely of tinnitus in addition to hearing loss, only two underwent brain MRI. In the other three cases, results of neurological examinations implied that the lesion was restricted in the cochleae and, therefore, careful follow-up of pure-tone audiometry, ABR,

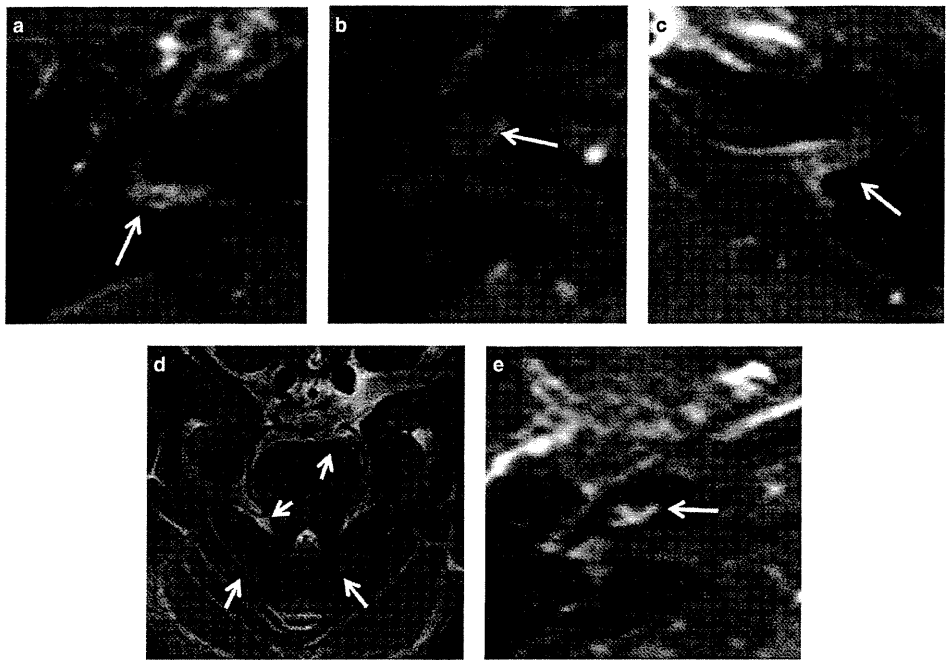

Figure 1. (a) Case no. 1. Cryptococcus meningitis with enhancement of bilateral internal auditory canal (IAC) on gadolinium-enhanced MRI. The enhanced right IAC is shown. (b) Case no. 2. Chronic viral meningitis plus labyrinthitis with enhancement of bilateral cochlea on gadolinium-enhanced MRI. The enhanced basal turn of the right cochlea is shown. (c) Case no. 3. Meningeal metastasis of lymphoma with enhancement of bilateral IAC on gadolinium-enhanced MRI. Enhanced left IAC is shown. (d) Case no. 4. Superficial siderosis with hypointensity along the brainstem and cerebellum on T2-weighted MRI. (e) Case no. 5. Cogan's syndrome with enhancement of bilateral cochlea on gadolinium-enhanced MRI. The right whole cochlea is enhanced.

DPOAE, and/or blood tests for autoimmune antibodies rather than brain MRI were conducted to evaluate cochlear disorders.

Categories of causative diseases

The causative diseases for hearing loss are shown in Table I. Systemic evaluation showed abnormalities restricted to the inner ear in four patients (isolated inner ear disorder). Intracranial lesions were detected in four patients and systemic vasculitis in two, with these disorders diagnosed as the causes of bilateral SNHL. The intracranial lesions included Cryptococcus meningitis, chronic meningitis due to herpes simplex virus, meningeal metastasis of lymphoma, and superficial siderosis. The two patients with systemic vasculitis were diagnosed with Cogan's syndrome and Sjögren syndrome with aseptic meningitis, retinal vasculitis, and skin lesions.

Relationship between category of causative diseases and clinical manifestations

The time course for deterioration in auditory perception was ≤ 60 days in the six patients with an

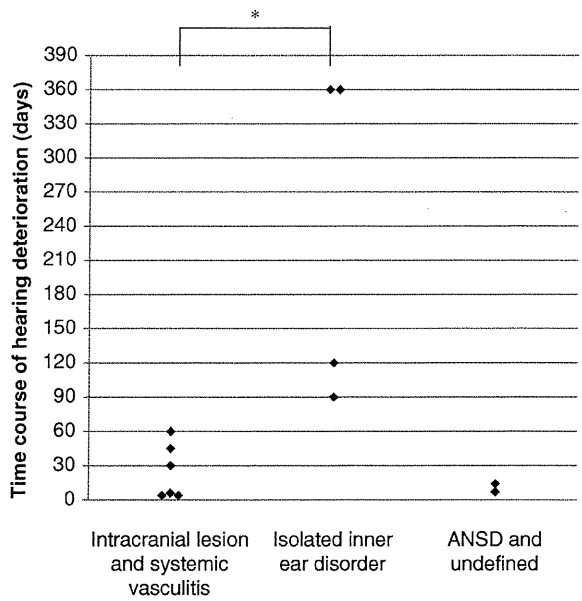

Figure 2. Time course of hearing deterioration in different categories of causative disorders. There was a significant difference between patients with intracranial lesion and systemic vasculitis, and those with an isolated inner ear disorder.
*: $p < 0.05$

Table II. Characteristics of six patients with an intracranial lesion or systemic vasculitis.

Case no.	Diagnosis	Treatment	Time before treatment (days)	Hearing improvement
1	Cryptococcal meningitis	Antifungal drug	3	Improved
2	Chronic herpes meningitis + labyrinthitis	Steroid and anti-HSV agents	Unknown	Not improved
3	Meningial metastasis of lymphoma	Steroid and anticancer drug	6	Improved
4	Superficial siderosis	No treatment		Not improved
5	Cogan's syndrome	Steroid	90	Not improved
6	Sjögren syndrome	Steroid	4	Improved

intracranial lesion or systemic vasculitis and ≥ 90 days in the four patients with an isolated inner ear disorder. The Mann–Whitney U test showed a significant difference ($p < 0.05$) between these groups (Figure 2). As shown in Table I, all patients with an intracranial lesion or systemic vasculitis complained of dizziness and/or noncochleovestibular symptoms in addition to hearing loss. Four of these six patients had dizziness and five of them had fever, headache, or altered mental state. These symptoms were not observed in patients with ANSD or an isolated inner ear disorder, who had only tinnitus as an associated symptom.

Hearing improvement after treatment for the causative diseases

The causative disease was treated in five patients with an intracranial lesion or systemic vasculitis, except in case 4 who had superficial siderosis (Table II). Hearing improved in three patients, who did not require hearing aids in daily life. The delay from the onset of hearing loss awareness to the beginning of treatment was within 1 week in cases 1, 3, and 6, who showed an improvement in hearing. However, it took as long as 90 days in case 5, who showed no change in hearing threshold after treatments. In case 4, the origin of bleeding that caused hemosiderosis was not determined despite radiographic evaluations, including brain and spinal MRI, and the patient showed no improvement in hearing at follow-up. Improvement in hearing loss did not occur in any of the patients with ANSD or an isolated inner ear disorder, despite systemic administration of steroids and/or circulation activators.

Discussion

This study was performed as a retrospective review of 12 cases with progressive bilateral SNHL who complained of difficulty in daily conversation within 4 days to 1 year after the onset of hearing loss awareness. The patients with bilateral SNHL presenting this time course of deterioration were relatively rare and accounted for only 1.3% of those with bilateral SNHL in this study. However, retrospectively, distinguishing this type of SNHL from others was meaningful because 6 of these 12 patients (50%) developed SNHL from an intracranial lesion or systemic vasculitis, which can be fatal without appropriate treatment. It is also noteworthy that all three patients with an intracranial lesion or systemic vasculitis, who showed improvement in hearing, underwent early treatment of the causative diseases, suggesting that accurate diagnosis and appropriate treatments for the causative disease at its early stage may be important to restore hearing as well as to lower the mortality. In the present study, the rapidly progressive SNHL was also caused by ANSD or an isolated inner ear disorder, but clinical manifestations of intracranial lesions and systemic vasculitis were different from those observed in other categories of causative diseases. Our study showed that in patients with intracranial lesions and systemic vasculitis, the time from onset of hearing loss to difficulty in daily life was within 2 months and significantly shorter than that in patients with an isolated inner ear disorder. In addition to the rapidly progressing hearing loss, noncochleovestibular symptoms and/or dizziness were always associated with intracranial lesions and systemic vasculitis, while all five patients with an isolated inner ear disorder or ANSD complained of only tinnitus. Among noncochleovestibular symptoms, fever was the leading symptom (6 of 12 patients), followed by headache and an altered mental state. In all cases with fever, the origin of fever was difficult to identify at first and systemic inflammation or intracranial infection was identified later based on systemic evaluations by otologists, internal medicine specialists, and radiologists. The presence of headache and an altered mental state also suggests that lesions may

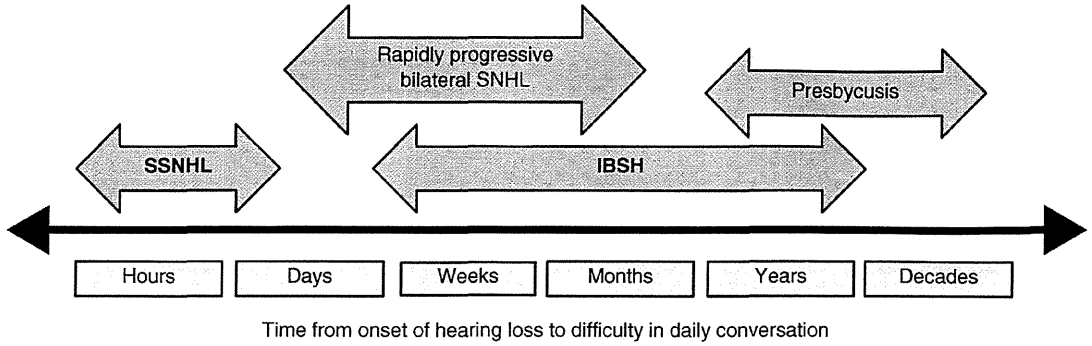

Figure 3. The time course in various types of bilateral sensorineural hearing loss (SNHL). IBSH, idiopathic bilateral SNHL; SSNHL, sudden SNHL.

involve other areas of the central nervous system in addition to the auditory neural pathway. Interestingly, obvious vestibular dysfunction was not observed in patients with an isolated inner ear disease, although four of the six patients with an intracranial lesion or systemic vasculitis had dizziness. The inner ear lesions in the present series may have been limited to the cochlea, with central compensation possibly making the vestibular symptoms less prominent despite the presence of some vestibular involvement.

We performed brain MRI in nine patients including all seven with a noncochleovestibular symptom or dizziness. Headache, altered mental state or other abnormal neurological findings in addition to the eighth cranial nerve dysfunction suggests the presence of an intracranial lesion. In this situation, brain MRI is necessary to evaluate intracranial diseases. Even though the neurological disorders were limited to the eighth cranial nerve, association of dizziness with SNHL might be caused by labyrinthitis or lesions in internal auditory canals and brain MRI may be recommended. Prolonged unknown origin of fever associated with bilateral SNHL is also an indication for brain MRI to evaluate labyrinthitis and nonbacterial meningitis.

In the present study, pure-tone hearing thresholds were improved in case 1 with Cryptococcus meningitis and case 3 with meningeal metastasis of lymphoma after the intracranial administration of antifungal and anticancer drugs, respectively. Hearing recovery is usually difficult in patients with Cryptococcus meningitis [5], although a patient with this disease was reported to show partial recovery of hearing after treatment [5]. Hearing improvement after treatment has also been reported in patients with bacterial and viral meningitis [6,7]. Vasculitis causes SNHL in patients with connective tissue diseases such as systemic lupus erythematosus and polyarteritis nodosa [8], with this type of hearing loss reported to improve following plasmapheresis or immunosuppressive therapy using steroids or cyclophosphamide [2,9]. In our study, case 6, who had Sjögren syndrome, showed hearing improvement after steroid treatment. In contrast, hearing loss in case 5, who had Cogan's syndrome, was not improved by steroids. Although hearing improvement has been described in a patient with Cogan's syndrome [10], it is often difficult to improve hearing loss in such patients.

Previous case reports indicate that the etiology of bilateral SNHL, which deteriorates more slowly than sudden deafness and more quickly than presbycusis, also includes meningeal carcinomatosis [11], metastasis of carcinoma in the bilateral internal auditory canal [12], mitochondrial neurogastrointestinal encephalopathy (MINGIE) [13], and polyarteritis nodosa [14]. These diseases were not found in the present study due to the small size of the study. The rapidly progressive bilateral SNHL can be induced by various types of diseases with different etiologies described above and, moreover, within each type of a disease, severity of symptoms may vary widely between patients. Therefore, further study investigating more patients with rapidly progressive bilateral SNHL is needed to lead to definite conclusions about the importance of clinical manifestations and indications for MRI for diagnosis of the causative diseases.

The definition of rapidly progressive SNHL in previous reports varies, including SNHL deteriorating in days [15] or in weeks to months [14,16–18]. However, the disease entity described in these reports is almost identical, which is the SNHL that progresses more slowly than sudden deafness and more rapidly than presbycusis. Thus, in line with those previous reports, we defined rapidly progressive SNHL as the one that deteriorates in days to months. The time course of rapidly progressive bilateral SNHL compared with that of other types of common bilateral SNHL is illustrated in Figure 3. Idiopathic bilateral SNHL (IBSH) is a progressive bilateral SNHL of unknown etiology and

was proposed as a clinical entity in 1976. In IBSH, hearing loss usually progresses over several years; therefore, deterioration in hearing loss is slower than that observed in the current patients [19], suggesting different etiologies. In the current study, the four patients with isolated inner ear disorders showed a significantly slower deterioration in hearing loss compared with the other patients. IBSH sometimes shows rapid progression of hearing loss within several days or weeks; therefore, patients with similar pathology to that observed in IBSH could meet our criteria for rapidly progressive bilateral SNHL if they visit a hospital in the rapid phase of the disease.

A noteworthy aspect of the patients reported in this study was that early treatment of intracranial lesions and systemic vasculitis improved hearing loss, suggesting the importance of early diagnosis of the causative disease, although further investigation of large numbers of patients is necessary to prove the effectiveness of early treatment. Early diagnosis is also important because the causative diseases for rapidly progressive bilateral SNHL include fatal conditions such as meningitis or malignant diseases, or diseases that may result in irreversible neurological deficits such as superficial siderosis. In patients with superficial siderosis, decreasing the risk for a poor outcome requires early diagnosis of the disease and identification and ablation of the bleeding source [20].

Conclusion

Rapidly progressive bilateral SNHL is rare, but it often develops as a symptom of intracranial disease or systemic vasculitis, both of which are potentially fatal. Hearing may recover in patients who undergo treatment at an early stage of the causative disease. This indicates that early diagnosis followed by appropriate treatment of the causative disease is critical for the management of these patients.

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Notice of correction

The Early Online version of this article published online ahead of print on 21 Nov 2013 was missing information about the authors.
The corrected version is shown here.