Modern Trends in

Diseases of the Ear, Nose and Throat—2

Edited by
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Preface

In the eighteen years since the first volume appeared there has been a marked change in the incidence of some diseases and a complete revolution in the treatment of others. The lessening impact of acute infections, stimulated by the discovery of new antibiotics, has almost eliminated diseases like acute suppurative mastoiditis and the more severe forms of acute sinusitis. It may not be unconnected with the perhaps too free use of too many antibiotics that other diseases are becoming clinical problems, such as, perhaps, middle ear effusion in children.

Chronic aural suppuration is still a problem, but the more florid cases are seen less frequently in developed countries. It is probably a disease of the socially deprived and can be expected to lessen in incidence with improvement in social conditions. In its surgical treatment conservation and reconstruction are now the aims, made possible by the enormous improvements in surgical instruments and especially the operating microscope.

Technical advances in radiotherapy have been striking and successful, and continuing progress in electro-physics will undoubtedly improve on these results. Exciting work in basic research into the nature of cancer has revealed the possibilities inherent in immunological techniques. Although no tangible clinical advance has yet been achieved the future is bright with promise.

Electro-physics has also contributed to the development of audiology as a growing point in aural research. A placid acceptance of noise has given place to a furious condemnation of it as an ecological pollution, and this surging emotion has engendered massive research into the essential mechanism of hearing. Deafness also is no longer accepted with resignation. The management of sensorineural deafness in adults and especially in children is now almost a specialty in itself, while there are some who see a future in the surgical treatment of this condition. It had been hoped to include a brief discussion on this matter as well as a chapter on the present and future management of otosclerosis, but owing to unforeseen circumstances these chapters have not been forthcoming.

There has never been a time when so much of our work was in such a state of flux, with hope in every movement.

The Editor is again happy to acknowledge the help given by the publishers, and their patience. The willing collaboration of his colleagues has once more been readily available and the Editor's gratitude will, he hopes, be shared by many others.

M.E.

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1 Diagnosis of Sensorineural Hearing Loss

H. A. BEAGLEY and RONALD HINCHCLIFFE

The diagnosis of sensorineural hearing loss and the classification of various types of loss has been considerably improved by the introduction in recent years of more refined tests.

SELF-RECORDING (BÉKÉSY) AUDIOMETRY

Automatic self-recording audiometry is linked with the name of Békésy who first developed an audiometer of this type over 20 years ago. It has, however, only recently come into regular clinical use, largely because of Jerger's investigations. The audiometer has a motor-driven control which smoothly increases the frequency of the tone from the lowest limit to the highest so that it traverses most of the audible frequency range for a normal subject. This is known as the ' sweep frequency ' mode. The motor drive can also be interrupted and the frequency dial set by hand so that the instrument will continue to emit its test tone at the selected frequency. This is called the ' fixed frequency ' mode. The test tone employed is either continuous (sustained) or a pulsed (intermittent) tone and both may be used in Békésy audiometry.

The intensity of the tone delivered is also controlled by a motor-driven attenuator which the patient regulates by means of a press button. The motor permits the tone to become steadily louder until the patient becomes aware of it, whereupon he presses the button. This reverses the motor allowing the tone to become quieter again. By following the instruction ' press when you hear, release when you don't ' the patient is able to record his hearing level which is written out automatically by the audiometer, the ink line repeatedly crossing and re-crossing the patient's auditory threshold. One well known instrument can ' sweep ' from 100 to 10,000 Hz in eight minutes, the rate of attenuation being 2 dB/second. The tester may choose to conduct the test over a more restricted range of frequencies and can also operate the machine at selected fixed frequencies. Most subjects can be tested satisfactorily by Békésy audiometry, only a very few being unable to follow the instructions adequately, including most young children under the age of seven years.

Békésy audiometry gives results essentially similar to those produced by manual audiometry, but it has a number of other applications. Jerger (1960) classified the various patterns of continuous and pulsed tracings into four groups (*Figure 1*). The patterns he described are briefly as follows:

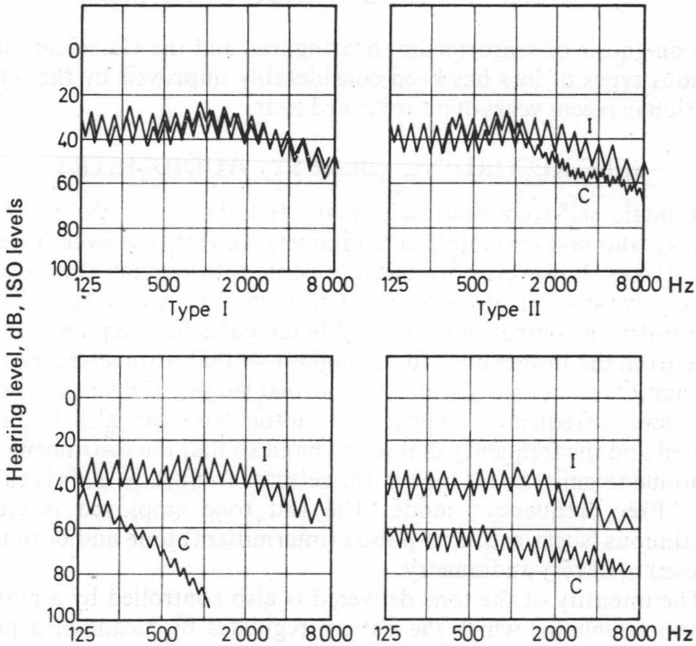

Figure 1. Jerger's original four types of Békésy audiograms. I = intermittent (pulsed) test tone; C = continuous (sustained) test tone

Type I, where continuous and pulsed traces are superimposed, is seen in conductive hearing losses and in presbyacusis.

Type II as seen in end-organ lesions such as Menière's disease, where above about 1,000 Hz the continuous trace shows a higher threshold by 5–10 dB and a smaller amplitude than the pulsed test tone trace. As ears that produce this type of trace generally show recruitment of loudness, the two have been equated by some otologists. However, this is untenable as recruitment is not a threshold phenomenon and is not restricted to frequencies above 1,000 Hz. The reduction in amplitude possibly represents a fatigue phenomenon.

Types III and IV are seen in certain types of neuronal lesions, such as stato-acoustic schwannomas and demyelinating lesions. They are

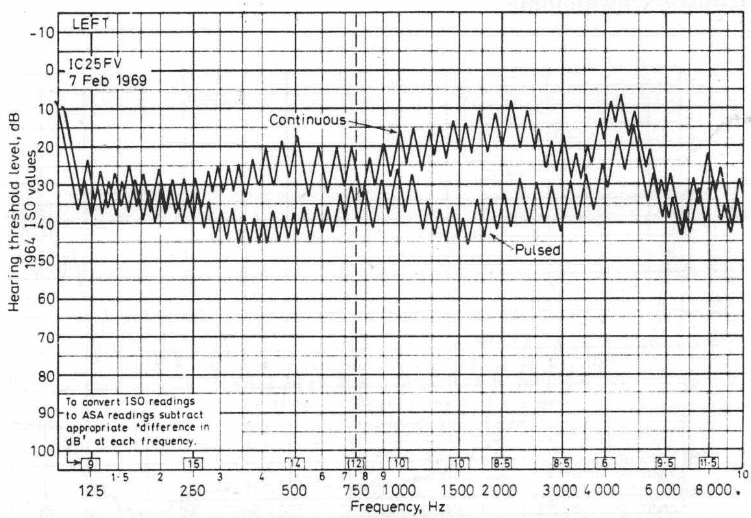

Figure 2. Sweep frequency Békésy recordings using, first, a pulsed test tone and then, secondly, a continuous test tone for a 25-year-old woman who had a non-organic hearing loss involving this tested ear (after Hinchcliffe, 1970)

characterized by a raised threshold for continuous tones, but the amplitude of the latter is not restricted as in a Type II trace. The only difference between a Type III and a Type IV trace is that in the former the continuous trace diverges dramatically from the pulsed trace, whereas in the Type IV the two run parallel, but with an appreciably greater separation (20 dB or more) than is the case with Type II traces. The continuous tone is more fatiguing to the impaired nerve fibres than the pulsed tone, accounting for the drift in the threshold. Subsequently, Jerger and Herer (1961) described a Type V tracing. In this pattern the threshold for the continuous test tone is better than that for the pulsed test tone for some or all frequencies. This type occurs in non-organic hearing loss (*Figure 2*).

Many Békésy tracings, however, fall outside Jerger's scheme. A continuum of changes does exist and is due in part to the fact that many of the cases are not purely end-organ or neuronal lesions, but a combination of both.

Applications of Békésy Audiometry

(1) It can be used simply to establish the auditory threshold. To do this we first conduct a sweep frequency test with a pulsed tone, and *Figure 3* shows the trace of a man of 38 years with a stato-acoustic schwannoma.

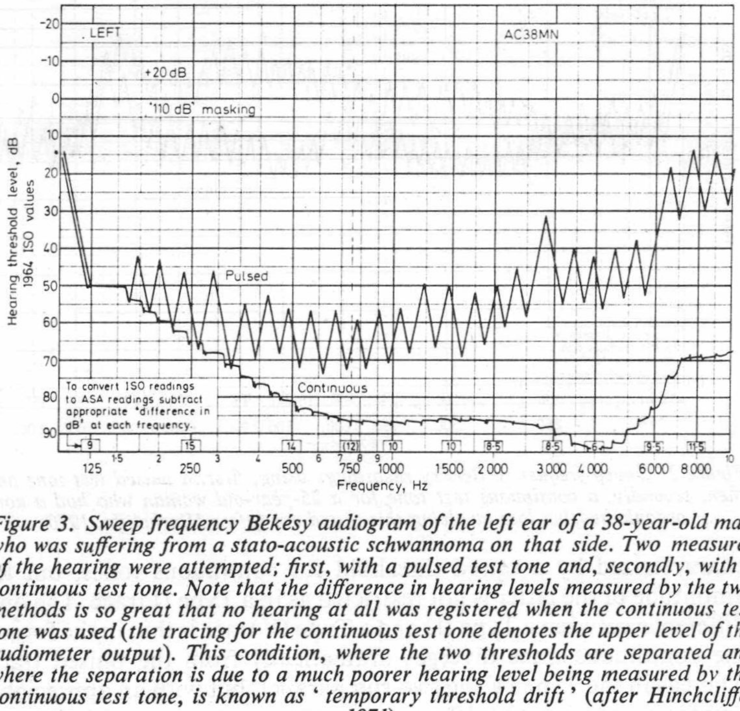

Figure 3. Sweep frequency Békésy audiogram of the left ear of a 38-year-old man who was suffering from a stato-acoustic schwannoma on that side. Two measures of the hearing were attempted; first, with a pulsed test tone and, secondly, with a continuous test tone. Note that the difference in hearing levels measured by the two methods is so great that no hearing at all was registered when the continuous test tone was used (the tracing for the continuous test tone denotes the upper level of the audiometer output). This condition, where the two thresholds are separated and where the separation is due to a much poorer hearing level being measured by the continuous test tone, is known as ' temporary threshold drift ' (after Hinchcliffe, 1971)

(2) It can help to localize a lesion which caused hearing impairment. For instance, the patient mentioned above with a stato-acoustic schwannoma, when tested with a continuous tone showed such an elevation of threshold that his hearing could not be measured with this type of sound at all owing to marked threshold fatigue. It

is also desirable in cases such as this to clarify the findings of the sweep frequency tests by using the fixed frequency modes as well lest the divergence of pulsed and continuous traces be confused with possible artefacts due to changes of time and frequency during the sweep frequency mode of operation. The fixed frequency tests for the patient mentioned above are shown in *Figure 4*.

The tendency for the auditory threshold to rise during testing has been described under various names, such as 'pathological adaptation', 'relapse', 'threshold fatigue' 'tone decay' (usually elicited by manual audiometry). A better term might be 'temporary

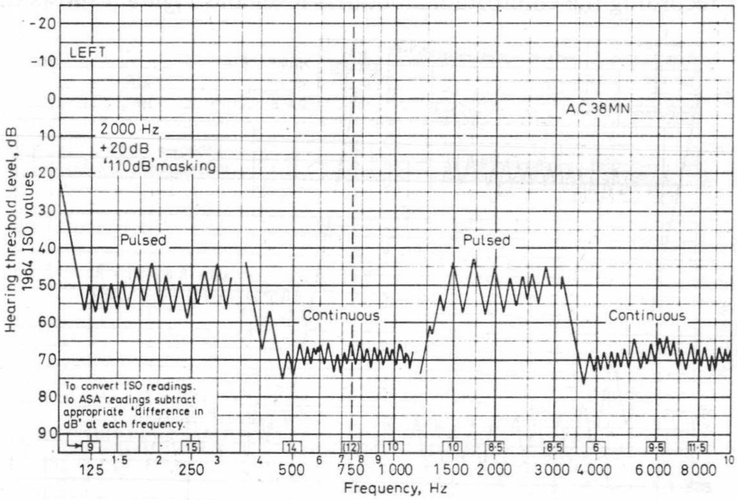

Figure 4. Fixed frequency recording for a tone of 2,000 Hz for this same subject. Here, thresholds for pulsed and continuous test tones are measured alternatively (after Hinchcliffe, 1971)

threshold drift' (TTD). It is thought to result from a lesion of the first or second order neurones due to the pressure of a tumour or demyelinization by a localized plaque of multiple sclerosis. Simple degenerative changes such as ageing do not produce this phenomenon. Békésy audiometry in the fixed frequency mode is the ideal method of demonstrating this threshold drift. In all cases, even with normal thresholds by the sweep method using a pulsed tone, it is desirable to check for threshold drift at 8,000 Hz, using both continuous and pulsed tones, as at this frequency it may be the only abnormality demonstrable in an early case of auditory dysfunction.

(3) The ' comfortable loudness level ' may be used as an indicator of the phenomenon of recruitment of loudness (Hinchcliffe, 1971). The test can be used in one ear only and is more versatile than the classical Fowler test. Hood and Poole (1966) have reported on the value of what they term the ' loudness discomfort level ' and which previous authors have termed the ' uncomfortable loudness level '. Basically, the findings are that these loudness levels may be much the same in an ear with a ' recruiting ' type of sensorineural hearing loss as in a normally hearing ear, indicating that an equivalent growth of loudness has been compressed into a narrower range of intensities, as actually occurs in recruitment. Békésy audiometry is very suitable for recording the comfortable loudness level and *Figure 5* shows the

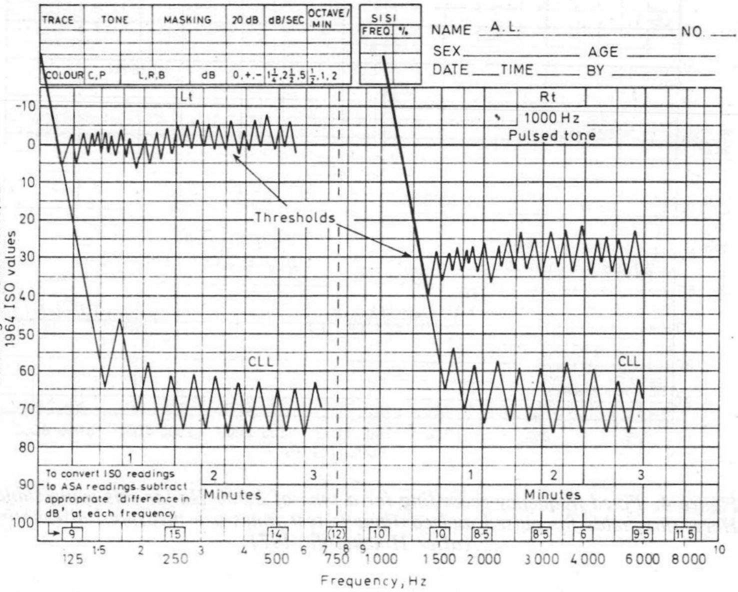

Figure 5. Fixed frequency (for a tone of 1,000 Hz) recordings for a pulsed test tone for both auditory threshold and for comfortable loudness level (CLL) for both ears of a man who is afflicted with endolymphatic hydrops on the right side. Note that, although a difference in thresholds between the two ears is recorded at this frequency, the comfortable loudness levels are identical. This indicates that loudness recruitment has occurred on the involved side (after Kacker and Hinchcliffe, 1970)

tracings of a 55-year-old man with right-sided endolymphatic hydrops. Although he shows a hearing loss at 1,000 Hz, the comfortable loudness level is identical on the two sides, indicating complete loudness recruitment.

(4) Threshold notches, such as the well known 4,000 Hz dip of noise-induced hearing loss, can be detected earlier and more readily by use of the Békésy sweep test. This is especially the case if the notch occurs slightly away from 4,000 Hz, e.g. 3,500 or 5,000 Hz, as sometimes happens. Manual audiometry would fail to reveal such a notch until it had deepened and widened appreciably. The speed with which data can be collected and the virtual elimination of observer error also make Békésy and similar automatic audiometry very useful in programmes of hearing conservation in noisy industries.

(5) Békésy audiometry can help in the evaluation of cases of non-organic hearing loss as we mentioned earlier.

Although it has been said that automatic self-recording audiometry does not provide more information than manual audiometry, there seems little doubt that our understanding of hearing disorders is greatly increased by its use, and the Type V tracing has no exact counterpart in conventional manual audiometry.

EVOKED RESPONSE AUDIOMETRY (ERA)

In evoked response audiometry, the development of which owes much to the efforts of Hallowell Davis (1965), use is made of the fact that it is now possible to extract the weak electrical potentials generated in the cerebral cortex by sound stimulation of the ear. In evoked response audiometry (or ' electric response audiometry ' to use the latest term favoured for this type of test), an averaging computer extracts the small signals created in the cortex, and picked up by scalp electrodes, from the larger EEG waves which obscure them, due to the fact that the potentials thus produced are ' time-locked ', i.e. they are phase related to the stimulus, whereas normally the EEG waves are in random phase with respect to the stimulus. The computer can summate the repeated time-locked responses efficiently, whereas the more random EEG components summate very inefficiently. The specific time-locked signals thus grow in amplitude and become clearly visible and distinct from the EEG background, indicating that the auditory stimulus has produced a neural response in the cerebral cortex (*see Figure 6*).

In adults there is a reasonably good correlation between the ERA and the subjective thresholds, the ERA being about 5 dB less sensitive on average (Beagley and Kellogg, 1969). To carry out the test only the passive co-operation of the subject is required; the patient does not have to decide whether or not he can hear. He simply sits quietly, usually reading a book, while the tester records his evoked responses at various intensities of auditory stimulation and

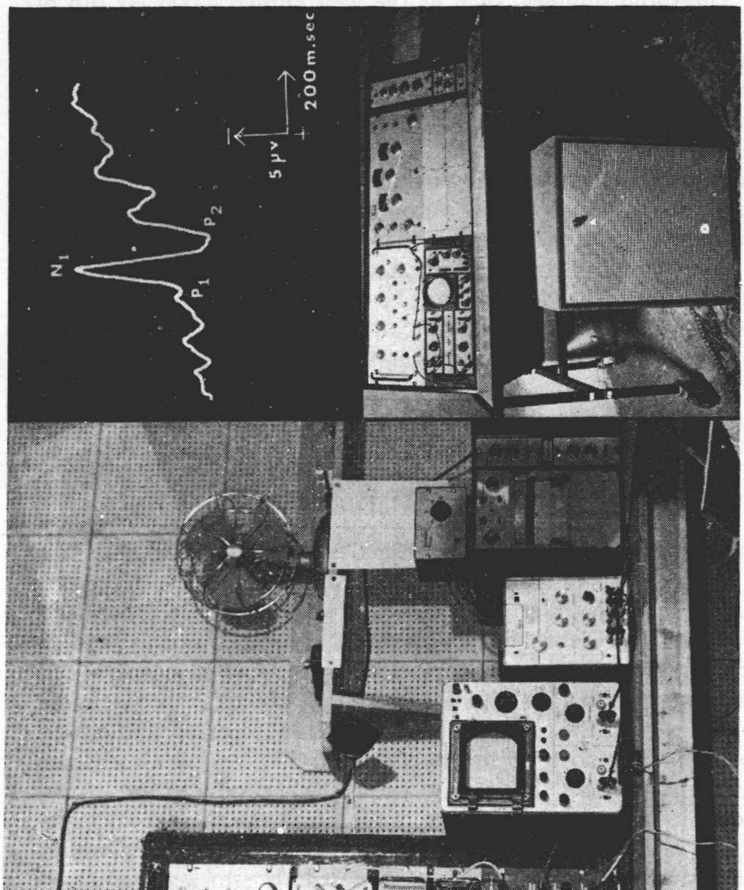

Figure 6. *Electrical response audiometry. Left: a view of the equipment used for electric (evoked) response audiometry at the Institute of Laryngology and Otology, London. Right, upper: trace of an auditory evoked response from a 6-year-old spastic child whose hearing it had been impossible to assess by conventional pure tone audiometry. Right, lower: a contemporary British evoked response audiometer (photograph reproduced by courtesy of Devices, Ltd., Welwyn Garden City, Herts.)*

so plots the patient's ERA threshold. Given reasonable co-operation, school-age children can be tested with accuracy, but below four years of age the ERA threshold rises from an average value of about 10 dB to about 30 or even 40 dB (with respect to normally hearing adults) in the first year of life (Taguchi *et al.*, 1969; Suzuki and Origuchi, 1969). Tests of young infants can be carried out if they are co-operative, but often this is only possible during sleep, sometimes aided by sedation, and the best results are achieved in the deeper stages of sleep characterized by a high EEG amplitude, rather than in the light stages.

Uses of ERA

Electric response audiometry is still mainly a research technique, but it has been valuable in a number of clinical situations:

(1) To confirm the appropriate hearing level in cases where wildly differing thresholds are obtained in successive pure-tone audiograms. The ERA threshold will indicate which of the several curves is likely to be the correct one.

(2) It is very useful in the investigation of suspected non-organic hearing loss (*see later*). There is as yet no evidence that hysterical or voluntary suppression of the auditory evoked response can occur, although one must be alert to the possibility in view of reports in respect of other sensory modalities.

(3) It is useful in children who cannot be tested by other methods and in whom the threshold is in doubt, as the ERA threshold can be obtained if necessary with sedation and may be the only objective finding. Many problems remain to be solved in the testing of very young children, including the effects of sedation and depth of sleep, the relation of the evoked response to the subjective threshold (if this can be obtained either at the time or subsequently) and the effect of neural abnormalities such as brain damage. Severe brain damage may invalidate the findings and paroxysmal activity such as epilepsy certainly can. Further research will clarify the indications and limitations of this technique in very young children.

(4) Blind children suspected of a hearing loss are notoriously difficult to test by conventional methods and ERA has proved invaluable in a number of such cases.

Cross Modality Testing

A repeated visual or tactile stimulus will also evoke a cortical response and this can be valuable in testing children. A child who gives no response to an auditory signal, but produces a response to a visual signal (stroboscopic flash) or a tactile signal (vibrator applied to finger tips) is almost certainly deaf.

ACOUSTIC IMPEDANCE MEASUREMENTS

Tests based on acoustic impedance measurements are becoming extremely important in present-day clinical practice, and although many of the applications of impedance testing relate to middle ear disorders others are important in the investigation of sensorineural hearing loss.

When a sound wave strikes the tympanic membrane, some of the acoustic energy is reflected from the membrane and can be measured by means of an acoustic impedance bridge. The extent to which such a reflection does occur is related primarily to the acoustic impedance of the membrane and the ossicular chain. Acoustic impedance is analogous to the electrical impedance encountered by an alternating electrical current as it passes through a conducting medium, as sound (especially a pure tone) fluctuates in a similar manner to an alternating current. Such an alternating electrical current is impeded in its passage through a substance by various properties of that substance, namely the *resistance* and the *reactance*. Reactance is further subdivided into inductive reactance and capacitative reactance, which exert a complex change on the current and voltage, altering both the amplitude and phase of the signal, while the resistance has no such effect upon phase.

In the same way that electrical impedance depends upon the electrical resistance, inductance and capacitance of a circuit, so acoustic impedance depends upon the acoustic resistance, effective mass and compliance of the system. In the case of the ear, the most important component of the acoustic reactance is the compliance. The acoustic impedance of the ear can therefore be satisfactorily measured by restricting attention to the acoustic resistance and the compliance.* Pathological changes in the internal ear have not yet been shown to produce significant changes in the acoustic impedance of the ear. The volume of the external acoustic meatus, however, does influence the measured compliance of the ear, but corrections can be made for this. Thus the acoustic impedance bridge can be used to measure changes in the acoustic impedance of the ear that result from pathological conditions of the middle ear.

Various type of acoustic impedance bridges have been devised, but the best known types are: (*a*) the acoustic (or mechano-acoustic)

* The compliance of the ear is expressed by the volume of a hard-walled air-containing cavity of equivalent compliance.