Recent Advances in Otolaryngology

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Preface

It is now fifteen years since the last edition of Recent Advances in Otolaryngology was published, during which time spectacular changes have taken place within the specialty. We are now passing through a phase of evaluation. It is therefore timely that this book should now be written, although some delay was inevitable following the premature death of Mr. Boyes Korkis, to whose pen this work should have fallen.

The present editors have changed the form of the book, believing that advances in the various sub-specialties are best covered by contributors with a particular interest in each topic.

The material chosen for discussion cuts across the spectrum of otolaryngology, and an effort has been made to include many related subjects, in which a knowledge is either essential or highly desirable. Therefore chapters on anaesthesia, antibiotics, haematology, radiology, radiotherapy and virus diseases have been incorporated. Some of the subject matter may also be covered in standard textbooks, but is included where there has been controversy or a change in thinking, and as far as the post-graduate student is concerned, Recent Advances must be considered as complementary to the standard works. Whereas these however present the established knowledge and accepted views in the specialty, this book endeavours to suggest the growing points in which further work and research may prove fruitful.

Even with the advent today of published symposia and excellent monographs, mainly from the U.S.A. and Scandinavia, no apology is made for this presentation, as there are few enough publications in otolaryngology giving an overall British emphasis, and in which many growing points are gathered together between the covers of one book.

Each contribution is complete in itself, but the editors must take responsibility for the final content. In the chapter on space medicine, the terminology used may be almost another language to some, but these are terms which will be known in the future.

We would like sincerely to thank all our contributors for the work they have done, and also gratefully to acknowledge the additional assistance given on specialised topics by Dr. Maini, Consultant

Physician to Charing Cross Hospital and St. Stephen's Hospital; by Dr. Alan Benson, Head of the Vestibular Physiology Section, R.A.F. Institute of Aviation Medicine, Farnborough; and by the late Dr. Gordon Signy.

Mr. R. Scott Stevenson and Mr. F. Boyes Korkis, both of whom were our predecessors at the Metropolitan Ear, Nose and Throat Hospital, were the authors of the first two and the third editions respectively: to them otolaryngology will always owe a debt for their lucid presentations of the Recent Advances of their times.

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PART FOUR: SUBJECTS RELATED TO OTOLARYNGOLOGY

PART I: OTOLOGY

1 Advances in Audiometry

J. Ransome

The field of audiology is now regarded in some countries as a specialty in its own right. The volume of literature is enormous, and equipment and tests of auditory function continue to proliferate. Some of these tests have enabled the otologist to establish the anatomical site of a lesion affecting hearing with greater accuracy. Others, such as impedance audiometry and electric response audiometry, have provided truly objective tests in that they are independent of the patient's own observations, though the otologist may still have to make a value judgement on the recorded result.

What follows is an attempt to abstract from this vast field those advances which are already of proved clinical value, or which seem to have real potential for further development, and to present these advances in a form comprehensible to the ordinary practising otologist who has not worked in a major audiological centre. This brief survey will not be sufficiently detailed for those who have already made a special study of the field. The aim is to stimulate further interest in the greatly improved diagnostic facilities available, especially in view of the proposed legislation on compensation for noise-induced hearing loss, which may tax the skills of the otologist and audiology technician.

NEW EQUIPMENT

Impedance audiometry

Tests based on the acoustic impedance of the ear are becoming increasingly important in routine clinical practice because of the wide range of information they provide. This includes differentiation between conductive and sensorineural hearing loss, differential diagnosis of conductive lesions, measurements of middle ear pressure and of Eustachian tube function, information on the presence of recruitment, on the site of the lesion in facial paralysis, and early evidence of retrocochlear disease.

Principles

The acoustic impedance of an object is the resistance it offers to sound waves, and depends on the vibrating characteristics of the object.

When sound waves strike a normal tympanic membrane, most of the energy is absorbed causing the membrane to vibrate, but a small percentage is reflected (or impeded). The essence of impedance audiometry is that what is being measured is this sound *reflected* from the tympanic membrane, whereas in all other forms of audiometry, it is sound energy which is absorbed by the ear and converted into nerve impulses which is measured. The interest in measuring this reflected sound lies in the fact that, in representing the impedance of the ear, it is governed almost entirely by the stiffness of the middle ear transformer mechanism: consequently any alteration in the tympanic membrane, ossicular chain, or pressure of air in the middle ear cavity can alter the stiffness of the whole system, as can contractions of the intratympanic muscles.

The term 'stiffness' has been used to denote the quality of the middle ear system which governs its impedance. In practice otologists are more interested in the mobility, or compliance of the system, and it is in terms of compliance, which is the reciprocal of stiffness, that the results are mainly expressed.

One other physical principle needs to be stated so that the system of measurement can be understood. If a sound of a particular intensity is introduced into a closed cavity, a certain sound pressure level develops which is constant as long as the impedance of the space remains constant. In ear impedance measurements a sound probe sealed into the exteral auditory meatus is used (see Fig. 1). Thus the test tone is delivered into a closed cavity bounded by the tympanic membrane, the meatal walls, and the cuff which seals in the probe. Using the test tone at a constant intensity, the sound pressure level of the cavity will be dominated by variations of the impedance of the ear drum, and any event which alters the load on the transformer mechanism, for instance stretching the tympanic membrane by artificially increasing or decreasing the pressure in the external meatus, will alter its impedance, and hence its reflecting capacity and the sound pressure level which will develop outside the tympanic membrane. This level is continuously monitored and changes recorded (see page 3).

The measurement of impedance was first introduced into clinical practice by Metz (1946), and developed by him and other workers in the nineteen-fifties, especially Terkildsen and his associates, who developed an electro-acoustic impedance bridge, upon which the widely used Madsen bridge is based. A mechano-acoustic bridge was designed by Zwislocki with which it is possible to measure impedance in absolute values at various frequencies. However these values vary quite markedly, even in normal ears, and in clinical practice it is more useful to record relative impedance changes following experimentally induced loading of the transformer mechanism, by varying the air pressure in the external canal, and by eliciting contractions of the intra-tympanic muscles. The Madsen bridge does however permit an absolute measurement of compliance at the single test frequency of 220 Hz.

Method

Ear impedance measurement using a Madsen-type electro-acoustic bridge (Fig. 1) is carried out by introducing a test tone at frequency 220 Hz and at constant intensity into the external auditory meatus. The

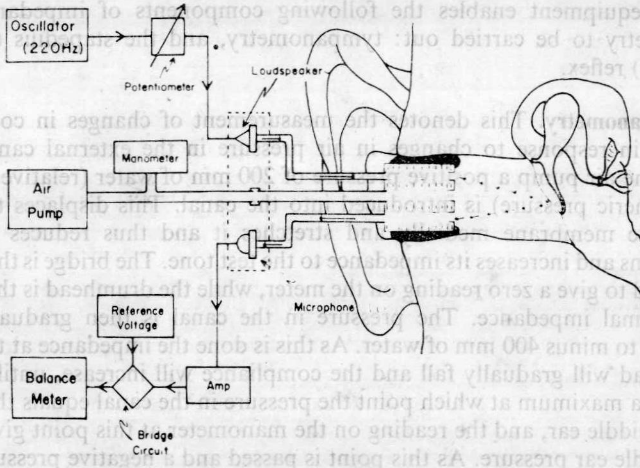

FIG. 1. *Diagram of principal components of the electro-acoustic impedance bridge*. (*From Jerger, 1970.*)

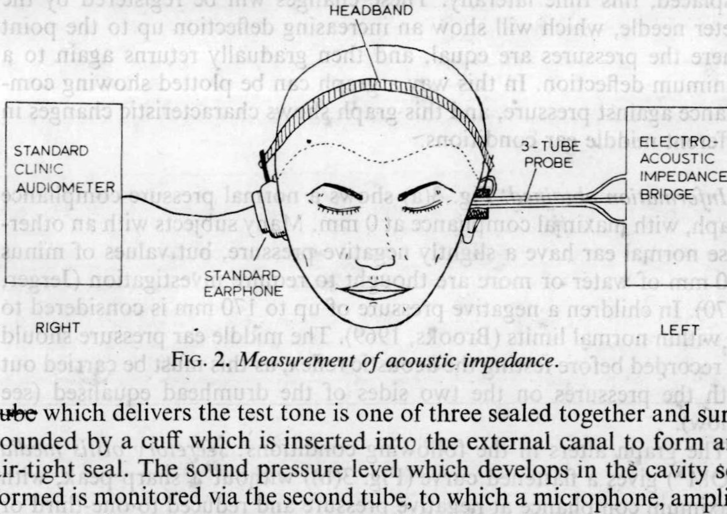

FIG. 2. *Measurement of acoustic impedance*.

tube which delivers the test tone is one of three sealed together and surrounded by a cuff which is inserted into the external canal to form an air-tight seal. The sound pressure level which develops in the cavity so formed is monitored via the second tube, to which a microphone, amplifier and balance meter are connected. The third tube is connected to a small air pump and manometer and by this means small measured variations of pressure can be introduced into the closed cavity.

The three-tube probe is attached to a headband at the opposite end of which a conventional earphone is mounted, which is connected to an audiometer (Fig. 2). This is used to deliver sound stimuli of varying frequency and intensity to the ear opposite to the one in which the probe is sealed, in order to elicit the stapedius reflex.

This equipment enables the following components of impedance audiometry to be carried out: tympanometry, and the stapedius (or acoustic) reflex.

Tympanometry. This denotes the measurement of changes in compliance in response to changes in air pressure in the external canal. Using the air pump a positive pressure of 200 mm of water (relative to atmospheric pressure) is introduced into the canal. This displaces the tympanic membrane medially and stretches it and thus reduces its vibrations and increases its impedance to the test tone. The bridge is then balanced to give a zero reading on the meter, while the drumhead is thus at maximal impedance. The pressure in the canal is then gradually lowered to minus 400 mm of water. As this is done the impedance at the drumhead will gradually fall and the compliance will increase, until it reaches a maximum at which point the pressure in the canal equals that in the middle ear, and the reading on the manometer at this point gives the middle ear pressure. As this point is passed and a negative pressure develops in the canal, the impedance at the drumhead will again be increased and its compliance diminished because it is again stretched and displaced, this time laterally. These changes will be registered by the meter needle, which will show an increasing deflection up to the point where the pressures are equal, and then gradually returns again to a minimum deflection. In this way a graph can be plotted showing compliance against pressure, and this graph shows characteristic changes in different middle ear conditions.

Information obtained. Fig. 3(a) shows a normal pressure-compliance graph, with maximal compliance at 0 mm. Many subjects with an otherwise normal ear have a slightly negative pressure, but values of minus 100 mm of water or more are thought to require investigation (Jerger, 1970). In children a negative pressure of up to 170 mm is considered to be within normal limits (Brooks, 1969). The middle ear pressure should be recorded before testing the acoustic reflex, as this must be carried out with the pressures on the two sides of the drumhead equalised (see below).

The graph alters in the following conditions: *secretory otitis media* (SOM*) gives a flattened curve (Fig. 3(b)) without a sharp peak, with maximum compliance at negative pressure and reduced to one-third or less of normal (Brooks, 1968); *otosclerosis* gives a curve similar to the normal but usually with reduced compliance due to the stiffening effect

* A key to abbreviations is given at the end of the chapter.

of footplate fixation (however values for otosclerotics may overlap with normals); *disruption of the ossicular chain*, and also an *abnormally mobile drumhead*, produce increases in compliance values (see Table 1).

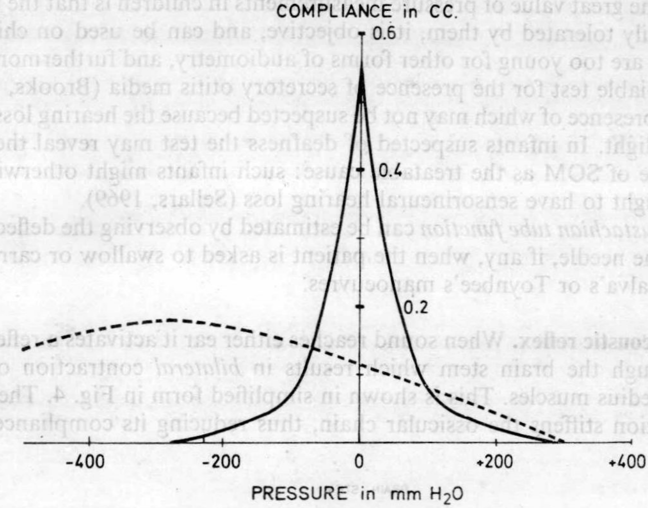

FIG. 3. *Middle ear pressure—compliance function.* (a) *Continuous line shows normal graph, with compliance rising rapidly to a peak at or near 0 mm.* (b) *Dotted line shows flattened graph characteristic of secretory otitis media, with a marked decrease in compliance, maximal at negative pressure.* (*After Brooks, 1968.*)

Table 1. Use of tympanometry in diagnosis of conductive lesions

	Otoscopy	*Pressure*	*Compliance*
Otosclerosis	Normal	Normal	Reduced or within normal limits
Ossicular discontinuity	Normal, or scarring of TM	Normal	Increased
Secretory otitis media	Variable	Negative	Marked reduction

N.B. Compliance-pressure graphs showing a double maximum in cases of ossicular disruption as described by Lidén (1969) are not found when the probe frequency employed is 220 Hz, as in the Madsen bridge (Jerger, 1970). Lidén used a probe frequency of 800 Hz.

The great value of pressure measurements in children is that the test is readily tolerated by them, it is objective, and can be used on children who are too young for other forms of audiometry, and furthermore it is a reliable test for the presence of secretory otitis media (Brooks, 1968) the presence of which may not be suspected because the hearing loss may be slight. In infants suspected of deafness the test may reveal the presence of SOM as the treatable cause: such infants might otherwise be thought to have sensorineural hearing loss (Sellars, 1969).

Eustachian tube function can be estimated by observing the deflections of the needle, if any, when the patient is asked to swallow or carry out Valsalva's or Toynbee's manoeuvres.

Acoustic reflex. When sound reaches either ear it activates a reflex arc through the brain stem which results in *bilateral* contraction of the stapedius muscles. This is shown in simplified form in Fig. 4. The contraction stiffens the ossicular chain, thus reducing its compliance and

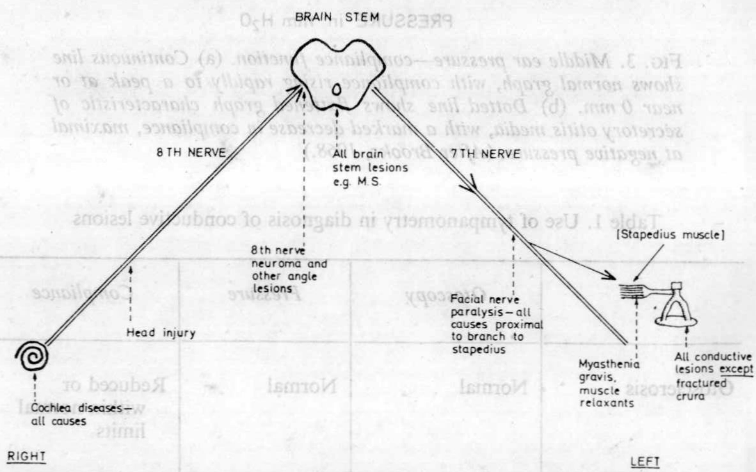

FIG. 4. *Factors affecting the stapedius reflex. N.B. For simplicity the efferent pathway is shown on one side only. The response is bilateral.*

producing a measurable deflection on the meter. It is convenient to deliver the sound stimulus from an audiometer into one ear, while testing the reflex response in the opposite ear (see Fig. 2). It must be remembered that when the audiometer is connected to the right ear the afferent side of the arc is being tested on the right, while the integrity of the efferent side is tested on the left.

Acoustic reflex threshold (ART). The meter is balanced to zero, then acoustic stimuli are delivered to the opposite ear at a hearing level above 70 dB. If the stimulus is loud enough to elicit the reflex, a noticeable upward swing of the meter needle will occur. The stimulus is then diminished until a just perceptible deflection is obtained. The audiometer output at this point gives the ART. This is repeated at various frequencies. In normal ears the ART occurs with an output of 70–110 dB, with an average of 85 dB. In other words it occurs at 70–110 dB above the hearing threshold.

Information obtained: Diagnosis of sensorineural deafness. The very fact that an acoustic reflex can be recorded at all is of immense value, as it is a 'sensitive objective index of normal middle ear function' (Klockhoff, 1971) in the ear containing the probe, and permits the conclusion that if deafness is present in that ear, it is sensorineural. This is because any conductive lesion suffiicent to produce a hearing loss of 15 dB or more, mechanically blocks the action of the stapedius muscle (Klockhoff, 1961). The only exception to this is in fracture of both stapedial crura (Fig. 4).

For these reasons it is necessary to measure the middle ear pressure first, and then carry out ART measurements with the canal pressure equalling the middle ear pressure; otherwise an undiagnosed negative pressure may give a false negative response.

Sometimes it is necessary to elucidate the cause of an absent stapedius reflex. Eliciting the tensor tympani reflex can then be useful. Strangely, this muscle is not activated by acoustic stimuli in man. Instead an 'orbital air jet' is used. For an account of this test see Klockhoff (1971).

An objective test of recruitment. Normally the gap between pure tone and acoustic reflex thresholds is 70 dB or more. If however the patient's pure tone threshold is elevated but the ART is still at an intensity level of 80–90 dB, then the gap between the pure tone and reflex thresholds is narrowed, or in other words the patient's loudness scale has been compressed and recruitment is present (Fig. 5). The test is accurate, objective, and quick and easy to perform. Its limitations are those of most tests of recruitment—see section on pitfalls in audiometry.

Investigation of facial paralysis. If in the case of a left facial paralysis, a tone to the right ear elicits an acoustic reflex on the left, then the efferent limb of the arc is intact and the facial nerve lesion is distal to the origin of the branch to the stapedius (Fig. 4). (However, if the acoustic reflex were absent, it would be necessary to exclude a conductive lesion on the left before assuming the facial nerve lesion to be proximal to the nerve to stapedius—see above.)

An objective test for non-organic hearing loss. Suppose a patient states that he is totally deaf in his right ear. If a tone of 70 dB to the right ear (see Figs. 2 and 4) elicits an acoustic reflex in the left ear, then the hearing level in the right ear for that frequency cannot be less than 70 dB, though if recruitment is present the hearing may be well below normal.

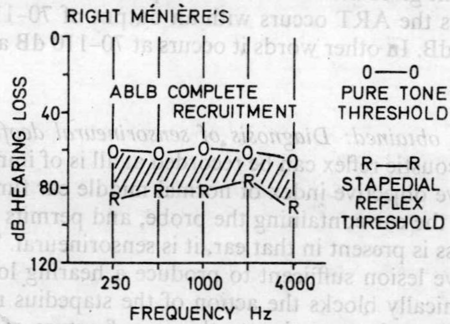

FIG. 5. *Pure tone threshold and ART in an ear with Ménière's syndrome. Note narrowing of the gap between the two graphs.* (*From Alberti and Kristensen, 1970.*)

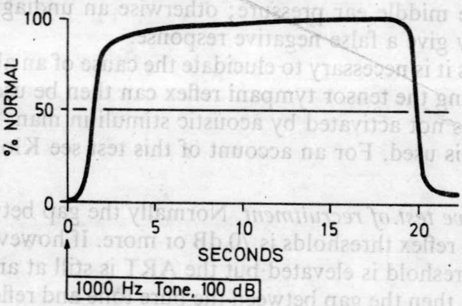

FIG. 6(a). *Stapedial reflex in a normal ear: 1,000 Hz tone at 100 dB (10 dB above reflex threshold). There is no decay in a 20 second period while the tone was being presented. Madsen ZO 70 impedance meter, Madsen TB 60 audiometer, Clevite Brush 220 recorder.* (*From Alberti and Kristensen, 1970*).

Acoustic reflex decay. Anderson *et al.* (1970) studied 21 patients with verified eighth nerve or posterior fossa tumours and presented evidence of 'reflex decay', in which the stapedius contraction amplitude is halved in about 3 seconds when the test tone is presented continuously. This can be the earliest audiometric sign of a retrocochlear lesion.