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ACOUSTICS AS A DIAGNOSTIC AID IN DISEASES OF THE EARS, NOSE AND THROAT

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Collaboration between ear, nose and throat specialists and acousticians during recent years has resulted in important advances in the early diagnosis of various disorders, not only those affecting hearing and speech, but also in the diagnosis of neurological conditions which endanger life. It is with tests of hearing that most progress has been made. Less than 35 years ago there was little acoustics could offer for hearing examination but rather poorly standardised pure-tone audiometry, mainly with air-conducted sound. Today some 500 audiology technicians and nearly 50 audiological scientists are working within, and alongside, the National Health Service to apply a wide range of carefully standardised test procedures using acoustic techniques to examine various aspects of hearing function. These procedures now enable the site of a defect to be located accurately whether it is in the external, middle or internal parts of the ear, in the hearing nerve, or in the brain. Increasingly, as new techniques are introduced, the location of the defect becomes more certain and more precise within particular parts of the hearing mechanism. Thus the otological surgeon is enabled to intervene at an earlier stage with much greater prospect of a successful outcome than previously. Where surgery is not possible, audiological physicians can offer other medical treatment and audiological scientists and technicians can deal with the patient's rehabilitation - usually with various forms of hearing aid.

The Test Room

One of the essential requirements is a suitably quiet sound-treated environment for the measurements and tests that are to be performed whether they relate to speech or hearing. In the examination of speech and other man-made sounds such as breath sounds, tinnitus etc. as well as in examination of hearing sensitivity, masking by ambient noise would invalidate the measurements. It is regrettable that too few acousticians have been involved with the design and construction of audiometric rooms, for many costly mistakes have been made. A recommendation that the noise level in such rooms should not exceed 30dB(A) with the ventilation plant running was accepted by DHSS (1974) and has proved adequate in practice.

Standardization

An account of the relevant acoustic standardization which has been agreed nationally and internationally was given by Knight (1976) in a similar review. The main addition since has been the IEC (1979) standard which has updated the original requirements for audiometers.

Pure-Tone Audiometry

Given a suitably quiet audiometric room, a calibrated audiometer and a trained technician, the basic test of hearing remains the pure-tone threshold test for air and bone-conduction. This successfully identifies middle-ear disorders from all others and enables quantification of the hearing loss to be made. A variation of the technique which relieves the technician of much interpretation of the patient's response is provided by self-recording audiometry. Here the patient is trained to control the sound stimulus to hunt around the threshold while frequency is slowly varied. All decisions are recorded on a chart or they can otherwise be stored for subsequent analysis. Haughton (1980) has reviewed the physical principles involved in audiometry and in a number of the following procedures.

Acoustic Impedance Measurements

A knowledge of the acoustic impedance of normal ears is necessary in connection with calibration of the sound stimuli that are normally applied by an external earphone in most hearing tests, and this is well established. Lately, however, a wealth of diagnostic information concerning disordered hearing has been obtained objectively (i.e. without the patient's active co-operation)through acoustic impedance or admittance measurements of the sealed ear canal while it is subjected to a range of small positive and negative excess pressures. Relatively fine diagnostic distinctions can be drawn in this way, particularly with regard to disorders of the middle ear. Further information on the behaviour of the internal ear and its connections with the central nervous system are obtained from measurements of the acoustic reflex threshold with pure tones and noise, and of decay of the reflex under sustained acoustic stimulation.

Present acoustic impedance instruments have reached a high degree of sophistication and are rapidly being introduced to supplement pure-tone audiometry in audiology clinics. Usually a low probe-tone frequency around 220Hz is employed in simple instruments to measure only the reactive component of impedance. More advanced apparatus offers 660Hz in addition to 220Hz and also measures the resistive component at these frequencies which is of interest in certain cases. The details are given by Feldman and Wilber (1975), Chalmers and Knight (1979), and Knight and Chalmers (1979). Bennett and Weatherby (1979) have reported some interesting results of reflex measurements with multiple probe frequencies ranging from 220 to 2000Hz.

Evoked Response Audiometry and Electrocochleography

Another means of examining hearing objectively which has applications in special cases, including children who are suspected of having hearing problems, depends on the properties of the small electrical portentials available in response to acoustic stimulation from electrodes placed in the region of the ear and the brain. Averaging computers are used to improve the signal-to-noise ratio when the signals can be traced along the pathways from the internal ear to the brain and any possible interruption of the signal detected. Beagley (1979) includes detailed accounts of these methods and, with his colleagues (Beagley et al, 1979; Sayers et al, 1979), has applied phase-spectral pattern analysis to an entirely objective evaluation of the evoked potentials.

Ultrasonic Bone-Conduction Audiometry

These paradoxical measurements at frequencies up to 200kHz have been used diagnostically in the USSR for some years (Sagolovich and Melkumova 1966).Nowell (1973), after investigating a number of cases in this way at Salford University, concluded that a full assessment of their value remained to be made. A further study is being undertaken at the Institute of Laryngology and Otology.

Tinnitus

Other investigations are proceeding in the measurement of noises in the ear, or head, that trouble many people, in order to understand the underlying causes with a view to its treatment. In some cases the noises can be heard by others - so-called objective tinnitus, while the most common kind is self-contained, or subjective. Recent findings by Kemp (1978, 1979 a and b) have shown that the internal ear is active acoustically and thus it is conceivable to record subjective tinnitus from a microphone placed in the external ear canal.

Assessment of Occupational Deafness

A State scheme for compensation for occupational noise-induced hearing loss, or deafness as it is termed officially, was introduced following the Industrial Injuries Advisory Council Report (DHSS, 1973). It applied only to a restricted group of workers and it has been extended once (DHSS,1978) and is already due for consideration again. These claims that are now common require most careful examination of the claimant and the hearing deficiency. The characteristics of this form of hearing loss affect predominantly the high-tones centred around 4,000 or 6,000Hz in the early stages, with the loss for bone conduction equal to the loss for air conduction. Usually the lower audiometric test frequencies are hardly affected but the handicap increases as the initial notch deepens and widens with further exposure to noise and the added effect of age.

Hearing deficiencies from a great number of other causes affect the general population and older people have a greater chance of hearing loss. Workers in noise are not immune and a small proportion of those claiming compensation are found to suffer from hearing disorders that are unrelated to noise and which may even have protected their internal ears from noise damage suffered by their colleagues. Other claims have been made by workers where noise at the work in question is unlikely to have been responsible and where previous noise exposure at another job might have caused the damage. Sometimes an undetected genetic cause for the hearing loss can mimic the noise-induced form and therefore on occasions it is justified for the full range of diagnostic examinations to be carried out. It is in these circumstances that the Health and Safety Executive (1978) produced a document on techniques proposed for industrial audiometry and the indications for an audiometric programme. Over the past several years, a number of organisations have set up similar schemes; it is evident that the audiometric rooms necessary, the audiometers and their calibration, and the skill of those conducting the tests must be of the highest quality to ensure that there exists no weak link in this necessary, but expensive, procedure.

Other Applications

So far this report has concentrated on aspects of acoustics and hearing as the greatest effort is directed to ear disorders. However, the ear, nose and throat field is also concerned with speech defects. With acoustic analysis techniques, disordered speech and laryngeal activity can be examined, leading to improved diagnosis and possible earlier detection of serious abnormalities of the vocal folds.

The source of energy for speech is the lungs and, for some time, chest physicians have been interested in the acoustic analysis of breath sounds as an aid to diagnosis. A review of these applications was given by Knight (1976) and a following paper will deal with the measurement of breath sounds.

It is firmly believed that there is a great potential for the wider application of acoustic analysis to other specialties including psychiatry where 50 years ago, Zwirner (1930) attempted to quantify the monotony in speech of depressives.

REFERENCES

H.A. BEAGLEY (Editor) 1979 Auditory Investigation: The Scientific and Technological Basis. Clarendon Press.Oxford.
H.A. BEAGLEY B.McA.SAYERS and J.ROSS 1979 Acta Otol. 87, 270.
M.J. BENNETT and L.A. WEATHERBY 1979 Scand. Audiol. 8, 233.
P. CHALMERS and J.J.KNIGHT 1979 Proc.IV Int.Sympos. on Acoustic Impedance Measurements.Lisbon (In Press)
DEPARTMENT HEALTH & SOCIAL SECURITY 1973 Occupational Deafness Cmd.5461 HMSO
1974 Hospital ENT Services - A Design Guide
1978 Occupational Deafness Cmd.7266 HMSO
A.S. FELDMAN and L.A. WILBER 1975 Acoustic Impedance and Admittance Measurements: The Measurement of Middle-Ear Function. Williams and Wilkins, Baltimore.
P.M.HAUGHTON 1980 Physical Principles of Audiology. Hilger. Bristol.
HEALTH AND SAFETY EXECUTIVE 1978 Audiometry in Industry HMSO
INTERNATIONAL ELECTROTECHNICAL COMMISSION 1979 Publication 645 Audiometers.
D.T.KEMP 1978 J.Acoust. Soc. Am. 64, 1386.
1979a Arch.Otolaryng. 224, 37.
1979b Scand.Audiol. Suppl. No.9.
J.J.KNIGHT 1976 Acoustics and Vibration Progress 2, 59.
J.J. KNIGHT and P. CHALMERS 1979 Proc.Inst.Acoust.Paper B12 Autumn Conference
E.NOWELL 1973 The Perception of Ultrasound in Humans. Unpublished M.Sc.thesis, Salford University.
B.M. SAGALOVICH and G.G. MELKUMOVA 1966 Biophysics II, 175.
B.McA. SAYERS, H.A. BEAGLEY and J.RIHA 1979 Audiology 18, 1.
E. ZWIRNER 1930 J.Psychiatric Neurol. 41, 43.