Emerging technology provides new challenges for audiological practice

Implications of measuring intracranial pressure

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Technology is now available which allows the intracranial pressure to be measured non-invasively via the ear canal. This in itself may be considered remarkable and greatly broaden the scope of audiological practice. The implications, however, may prove to be more profound. This audiological technique now is being used to provide routine measures of intracranial pressure on patients with hydrocephalus. This can leave no doubt that the inner ear is in direct communication with the cerebrospinal fluid and potentially may be affected by any disorder associated with intracranial pressure.

There are many conditions which cause raised intracranial pressure, and there are a number of instances where audiological manifestations have been reported.[3] Fluctuating hearing loss, tinnitus and vertigo are sometimes found with conditions such as ideopathic intracranial hypertension[12] and various forms of hydrocephalus.[13] In turn, there are many clinical associations of intracranial hypertension including: endocrine dysfunction—pregnancy, menstrual irregularity, oral contraceptives, steroid therapy; venous sinus thrombosis— mastoid or paranasal sinus infection, head trauma; drugs and vitamins—tetracycline, excess vitamin A; haematological—iron deficiency, leukaemia; and familial.[8] All of these may have the potential to cause secondary audiovestibular disorders.

Measurement principle

To understand how the technique works, it is necessary to consider the inner ear as a "backwater" of a relatively large "sea" of fluid which is of the cerebrospinal fluid system. Provided an open connection exists between these, then any change in the pressure of the cerebrospinal fluid will be transmitted through to the perilymph of the inner ear (Fig. 1).

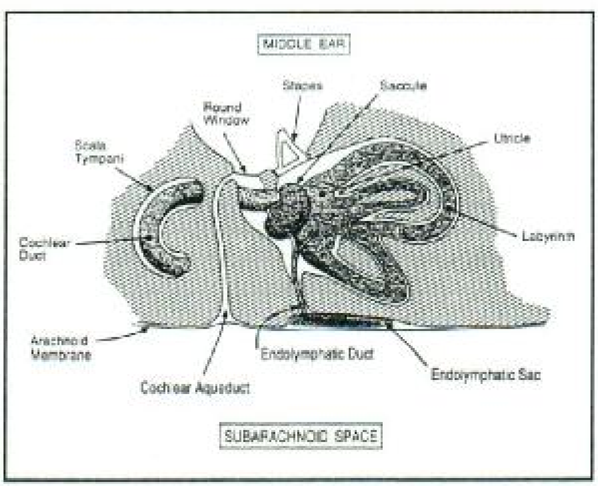

Fig. 1. Schematic showing the fluid pathway between the cochlea and subarachnoid space which contains the cerebrospinal fluid.

Changes in intracranial fluid pressure will be exerted on the cochlear window. It is this effect on the oval window which allows the perilymphatic pressure and, consequently, the intracranial fluid pressure to be indirectly measured. The technique depends on measuring the tympanic membrane displacement in response to contraction of the stapedial muscle. This method relies on the fact that the manner in which the membrane responds is dependent on the resting position of the stapes footplate within the oval window. Since this resting position in turn depends on the cochlear fluid pressure, then a useful indirect measure of pressure can be obtained.[2,10]

A higher than normal cochlear pressure displaces the resting position of the stapes footplate laterally, thereby allowing a greater degree of freedom for motion in the medial direction and correspondingly a more inward-going tympanic membrane displacement on contraction of the stapedial muscle (Fig. 2). Conversely, a lower than normal pressure will displace the footplate resting position medially and produce a more outward-going displacement on muscle contraction.

The apparatus for this test is based on an IBM PC compatible microcomputer to which a headset is connected. It is similar in appearance to the set-up used in acoustic immittance audiometry. Tympanic displacement is induced by acoustical stimulation of the stapedial reflex, and the resulting time history is measured with a special transducer which resolves volume displacements as small as a nanolitre. This transducer is attached to the headset and is connected to a probe which is hermetically sealed into the patient's external ear canal using a standard seal as used for tympanometry.[1]

Non-invasive intracranial pressure measurements depend upon the cochlea being connected to the cerebrospinal fluid system. In most people, the perilymphatic pressure reflects the intracranial pressure by virtue of a connecting pathway known as the cochlear aqueduct (Fig. 1). This pathway has been shown to be normally open at birth but is more likely to be sealed later in life.[7,14]

A comparison of tympanic with direct intracranial/cerebrospinal fluid pressure measurements (e.g., intraventricular or subdural pressure monitoring) has been made. This allows calibration of the tympanic pressure measurements against known intracranial pressure.[9,11] The technique may be used on an individual patient basis to provide a qualitative assessment of whether the cochlear pressure is within normal limits or is abnormal at a pressure in excess of nominally 200 mm saline.[9] Large inter-subject variations preclude absolute pressure measurement on an individual subject basis at the current stage of development. Clinical applications are chosen where possible to take advantage of the fact that the technique is extremely sensitive to relative changes in pressure where the patients act as their own control.

Hydrocephalus and audiological practice

Hydrocephalus usually is associated with raised intracranial fluid pressure and is detrimental to proper function of the brain. It can be life threatening. There are many

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reasons why hydrocephalus can occur, such as congenital abnormalities (e.g., Spina Bifida, meningitis or brain hemorrhage) sustained by some premature babies.

Audiological practice traditionally has not been concerned with the hydrocephalic patient. However, this may become an increasingly important role. Intracranial pressure measurements by means of the tympanic measurement technique have very real advantages in that they are painless and non-surgical. The technique meets a clinical need which for the first time allows almost unrestricted pressure measurements without any health risk to the patient. This promises to provide a substantial benefit to the diagnosis and treatment of hydrocephalus. In particular, this facilitates improved clinical management of the patient in terms of detecting abnormally raised intracranial pressure, ascertaining the success or failure of pressure-corrective surgery, monitoring patient recovery and subsequent long-term health care and assessing the need for further surgery.

In many instances, the audiological practitioner will be the best person to undertake routine assessment of intracranial pressure, since s/he possesses the necessary skills to perform audiological tests on children and has an understanding of the hearing processes involved in the measurement.

One of the main clinical applications is the assessment of whether cerebrospinal fluid shunts, used to surgically treat hydrocephalus and intracranial hypertension, are functioning correctly. Failure to treat raised intracranial pressure may result in long-term complications, permanent brain damage and sometimes even death. Cerebrospinal fluid shunts are effective in minimizing handicaps associated with raised intracranial pressure. Problems with shunts, however, are not infrequent and the tympanic pressure measurement technique fulfills the need for a non-invasive method of detecting shunt malfunction.[4-6] The need for shunt revisions will include those due to suspected blockages, infections and revisions when the child outgrows a shunt fitted when a baby.

Testing hydrocephalic children provides a challenge to the audiological practitioner. These children require regular clinical reviews to obtain good "baseline" measurements when the child is healthy and to provide possible early detection of intermittent shunt malfunction.[6] Shunt malfunction often will have serious consequences, since the lack of drainage of cerebrospinal fluid results in the intracranial pressure increasing to sometimes a life threatening level. Even a partial or intermittent blockage may be serious, causing changes in social behavior (e.g., aggression, educational handicaps or loss of schooling) as a result of one or more of the associated symptoms.

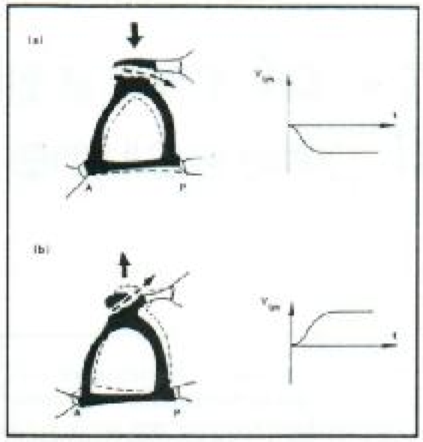

Fig. 2. Stapes movement and resulting tympanic membrane displacement V(t) on acoustically controlled contraction of the stapedial muscle. A) A higher than normal cochlear fluid pressure results in an inward-going displacement. B) Conversely, normal/low cochlear fluid pressure results in a more outward-going displacement.

New insight into audiological disorders

The symptoms and signs of intracranial hypertension are diverse and often non-specific. They may include headaches, nausea, gait and visual disturbances. Audio-vestibular manifestations of this condition may include tinnitus, vertigo, hearing loss which is often more pronounced at the lower frequencies and fluctuates in severity and sensations of aural fullness.[12,13] There is a clear potential for misdiagnosis between true audiovestibular disorders and those which are merely manifestations of intracranial hypertension. This problem is being addressed with the assistance of the tympanic intracranial/cochlear pressure measurement technique. Multicenter trials now are underway with the purpose of dissociating neurological from audiological disorders.

Parallel studies are being conducted in Southampton on patients with audiovestibular disorders as seen in the audiological clinic and those with confirmed intracranial hypertension as seen in neurological departments. Tests appear to show the presence of perilymphatic hypertension in a selected group of patients seen in the audiological clinic with a combination of tinnitus and objective episodic vertigo. By comparison, of the patients tested with confirmed ideopathic intracranial hypertension, 70% will report significant tinnitus and 62% will report balance disturbance of which 31% is objective vertigo.

Intracranial hypertension is the probable cause of the perilymphatic hypertension in most cases. The fluid pressure was estimated to be on average at least 100 mm saline in excess of normal for the group as a whole. This group has other similarities with those patients with ideopathic hypertension in that the patients tested show a preponderance of females to males exceeding 2 to 1. This differs from other audiovestibular pathology, such as Meniere's disease in that the sexes are equally represented. Already the technique is being used to screen patients who require careful consideration in terms of possible intracranial pressure involvement. Much research needs to be undertaken before the complex interactions between the cerebrospinal fluid system and the disorders seen in audiological practice will be fully understood.

Challenges for today and tomorrow

The tympanic technique of measuring intracranial pressure is currently contributing to the long-term health care of hydrocephalic patients and, in particular, children with cerebrospinal fluid shunts. In many instances, it is the audiological practitioner who will be best equipped to undertake these measurements. In the future, our understanding of hearing and vestibular disorders will be modified by the knowledge that conditions which affect the intracranial fluid pressure will directly influence the cochlear pressure. The audiological practitioner must, therefore, be aware of these conditions and the potential for secondary disorders of the ear. ❒

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