Tympanometry in Middle Ear Disease

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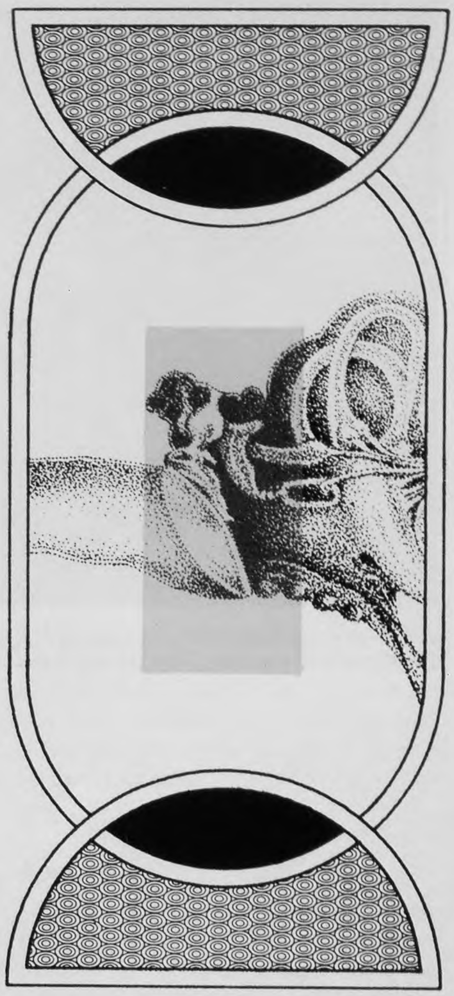

Tympanometry is an objective procedure which can aid in the identification of middle ear disease and eustachian tube dysfunction. This paper reviews its rationale, operation, and applications. The test procedure is simple and can be performed by trained personnel. The test is valid and reliable and can be used with children without discomfort. The results of tympanometry are quantifiable, recordable, and easy to interpret. The routine use of tympanometry in the family physician's office would offer a valuable tool in the identification and management of middle ear problems.

A continuing challenge for all family physicians is the early detection of eustachian tube dysfunction and middle ear disease. A valuable procedure which can assist in the identification of such problems is tympanometry. Since its introduction in Europe as a clinical test about 15 years ago, it has rapidly gained wide acceptance in North America. Extensive reports in the otologic literature have demonstrated that tympanometry is a reliable and valid procedure for detecting middle ear disease and abnormal middle ear air pressure.[1-3]

Tympanometry is a technique for measuring eardrum compliance (mobility) as a function of mechanically varied air pressures in the external ear canal. The movement of the eardrum in response to air pressure variations is of importance since it is known that almost any pathology located on or medial to the eardrum will influence its movement. While pneumatic otoscopic procedures generate unknown air pressures in the canal, dependent upon the examiner's pressure on a rubber bulb, tympanometry uses a calibrated air pressure system. The response of the eardrum to these air pressure changes is evaluated by the examiner in pneumatic otoscopic procedures. Tympanometry, on the other hand, utilizes electronic circuitry to measure eardrum mobility.

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Equipment

The instrument used for tympanometry is an electroacoustic impedance meter. The type of device used by otologists and audiologists is quite sophisticated and is designed to perform other diagnostic impedance tests besides tympanometry. Several manufacturers have recently introduced screening impedance devices intended mainly for tympanometry. In addition to being less costly than the larger devices, these screening instruments are portable, easy to operate, and provide information which is easy to interpret. Several types of screening devices are shown in Figure 1.

Attached to the main instrument is a probe tube, which is either hand-held or attached to a headset. The earphone on the headset is not used for tympanometry but can be used for audiometric screening.* The probe tube has

*Several of the new screening impedance devices include a pure-tone screening audiometer so that tympanometry can be done on one ear and audiometric screening on the other ear.

American Electromedics Tympanometer Model AE 85 (Courtesy of American Electromedics Corp., Dobbs Ferry, NY)

Grason-Stadler Portable Otoadmittance Meter Model 1721 (Courtesy of Grason-Stadler Co., Bolton, Mass)

Figure 1. Four types of electroacoustic impedance devices.

Madsen Portable Impedance Audiometer Model ZS75-1 (Courtesy of Madsen Electronics Canada Ltd., Oakville, Ontario)

Teledyne Avionics Portable Acoustic Impedance Meter Model TA-1D (Courtesy of Teledyne Avionics, Charlottesville, Va)

three tiny holes in it which are connected to:

1. An air pressure pump – calibrated in equivalent mm of water with a range of ±400 mm H_2O.
2. A low pitch probe tone (220 Hz) – introduced into the ear canal.
3. A recording (pick-up) microphone – measures the sound level of the probe tone reflected off of the eardrum.

Rationale

The principle underlying tympanometric measurement rests on the fact that the compliance (mobility) of the eardrum is best when air pressures on both sides of the eardrum are equal. When the air pressure in the external canal equals that in the middle ear, the eardrum moves optimally as it is in an unstressed state. However, when the eardrum is placed under either a positive or negative air pressure load, it is stretched with a consequent loss of mobility. In tympanometry, the introduction of a positive or a negative air pressure into the ear canal effectively stiffens the middle ear system so that a large part of the probe tone introduced into the canal is reflected and picked up by the recording microphone. As air pressure approaches atmospheric pressure in the canal, the normal eardrum moves at its best and less of the probe tone is reflected, as more is transmitted to the middle ear system. Since the compliance of the eardrum is greatest when air pressures are equal on both sides of the eardrum, tympanometry provides an indirect measure of the existing middle ear pressure by identifying the air pressure in the external canal at which the eardrum shows a peak of maximum compliance. The systematic variation of air pressures in the ear canal from +200 mm H_2O down to −400 mm H_2O makes it possible to determine the middle ear air pressure and the relative compliance of the eardrum.

Procedure

The test procedure for tympanometry is quite simple and can be easily learned by trained non-medical personnel. After the probe tip is sealed airtight into the ear canal with a small eartip, the compliance of the eardrum is monitored as air pressure is varied in the canal. Air pressure is initially increased to +200 mm H_2O and then gradually reduced down to −200 mm H_2O or −400 mm H_2O. When the recording meter on the main instrument indicates that the eardrum is most mobile, the examiner checks the air pressure meter to determine the air pressure in the canal at that point. This point of maximum mobility equals the existing middle ear pressure. Tympanometry can be done on both ears in less than five minutes.

The Tympanogram

The results of tympanometry are recorded manually or automatically on a graph called a tympanogram. Air pressure is plotted on the horizontal axis and the resulting changes in eardrum mobility on the vertical axis. Figure 2 displays a normal tympanogram. As expected, the eardrum has poor mobility in the positive and negative air pressure ranges. The sharp peak near 0 mm H_2O (±100 mm H_2O) is called the point of peak compliance and equals that point where the eardrum moves optimally. In other words, the point of peak compliance indicates where the air pressure in the external canal equals that in the middle ear. This type of curve is obtained in persons with normal eardrum mobility and normal middle ear air pressure, including persons with a pure sensorineural hearing loss.

A second type of tympanogram curve is illustrated in Figure 3. Although this curve resembles a normal curve in shape, the point of peak compliance is shifted into the negative air pressure region (greater than −100 mm H_2O). The eardrum now moves optimally when the air pressure in the canal is in the negative range. This curve is obtained when the eardrum is retracted, due to negative middle ear pressure. Middle ear fluid occasionally may be present with this type of curve.

Figure 4 shows a third type of tympanogram curve. This is quite different from the previous two types as there is no point of peak compliance. Throughout the entire air pressure range, the compliance of the eardrum is markedly reduced and the air pressure generated in the canal never approximates that in the middle ear. This type of curve is characteristic of fluid in the middle ear; however, it can also be obtained in an ear with cerumen impaction or with a perforated eardrum.

Table 1. Advantages of Tympanometry

1. Objective – no voluntary response required
2. Reliable and valid
3. Quantifiable and recordable
4. No discomfort to the patient
5. Simple to perform – can be done by trained nonmedical personnel
6. Simple to interpret test results
7. Freedom from interference by background noise
8. Extraordinary sensitivity in the detection of negative middle ear pressure or effusion
9. Far more sensitive than air conduction audiometry in detecting middle ear effusion
10. Moderate cost ($1,000 – $1,500)

Applications

Some of the advantages of tympanometry are listed in Table 1. Tympanometry is of great value in those patients where conventional otoscopy is equivocal or difficult to perform. A restless patient, narrow ear canals, a scarred eardrum, or a poor seal of the otoscope in the canal can make the otoscopic examination unsatisfactory. In such cases, the information provided by tympanometry is quite helpful. Perhaps one of its most salient features is that it can be used with children about as easily as with adults. This is especially significant due to the high incidence of middle ear disorders in young children. A very restless child was recently referred to the E.N.T. Clinic with a question of bilateral perforated eardrums. He was difficult to evaluate due to very small ear canals and poor cooperation. Tympanometry revealed normal curves bilaterally, thus ruling out eardrum perforations or significant middle ear disease.

Tympanometry is also helpful in confirming a diagnosis based on other findings. In those patients where otoscopy suggests middle ear fluid, a tympanogram showing a flat, noncompliant curve can confirm the otoscopic evaluation. An otoscopic impression of eardrum retraction can

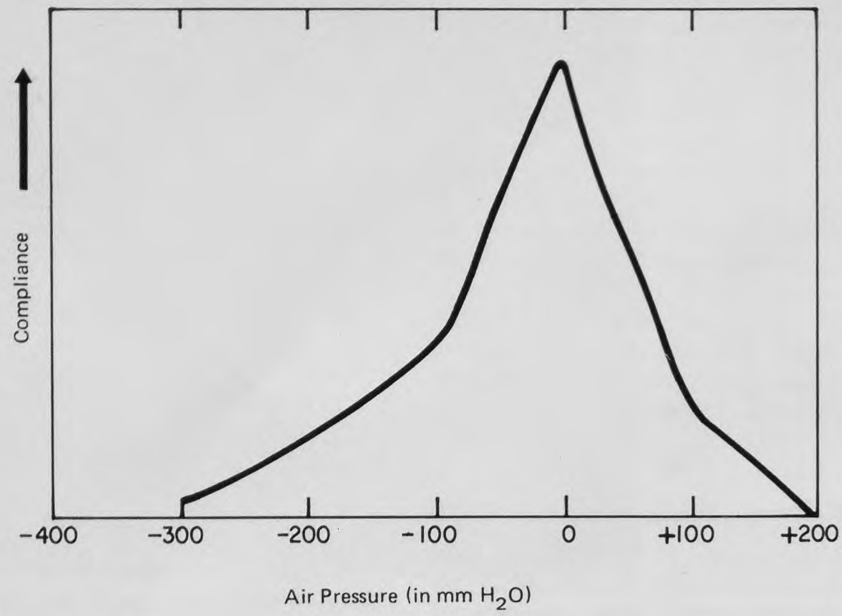

Figure 2. A normal tympanogram showing the point of peak compliance to be in the region of 0 mm H_2O. This tympanometric curve is obtained in ears with normal middle ear pressure and normal eardrum mobility.

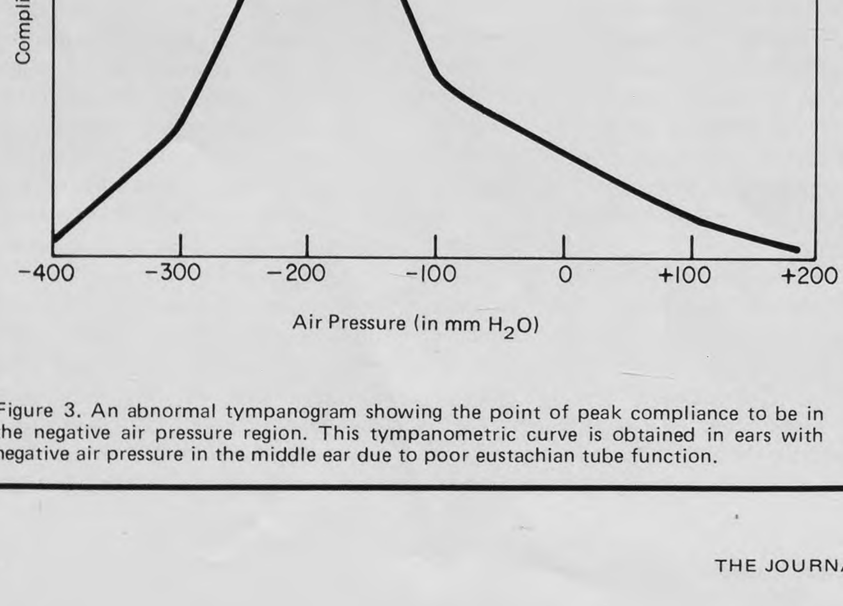

Figure 3. An abnormal tympanogram showing the point of peak compliance to be in the negative air pressure region. This tympanometric curve is obtained in ears with negative air pressure in the middle ear due to poor eustachian tube function.

be easily confirmed by a tympanogram demonstrating negative middle ear pressure.

Slight retraction of the eardrum caused by negative middle ear pressure is very difficult to evaluate using a conventional otoscope, even when pneumatic massage is utilized. Tympanometry has extraordinary sensitivity in the detection of negative middle ear pressure. It has been suggested that any child with a tympanogram showing a point of peak compliance greater than -100 mm H_20 should be considered at risk of developing otitis media even if asymptomatic.[4] They should receive periodic otologic and tympanometric evaluations over a reasonably protracted period. Copies of these tympanograms should be placed in the child's medical record so that changes in tympanogram shape and middle ear pressure are available for comparison. Thus, an objective record is available which can aid in determining whether the middle ear condition is improving or worsening.

Another application of tympanometry relates to its use as a screening device for middle ear disease. An increasing number of public school systems and health screening clinics are now using tympanometry in conjunction with otoscopy and audiometric screening. Reports have demonstrated that tympanometry is a valuable component of a screening battery, especially in those populations where the incidence of ear disease is high.[5,6]

Tympanometry has been demonstrated to be quite helpful in evaluating the effectiveness of medical treatment in those patients being followed for eustachian tube dysfunction or otitis media. In middle ear effusions, produced by occlusion of the eustachian tube, the tympanogram pattern can follow the entire course of the disease, from the initial progression to the final resolution. Under normal healthy conditions, a normal tympanogram will be obtained. When the process of middle ear aeration is halted, due to dysfunction of the eustachian tube, the air pressure in the middle ear drops because of inadequate ventilation and the tympanogram reveals a point of peak compliance in the negative air pressure range. If allowed to continue untreated or without spontaneous resolu-

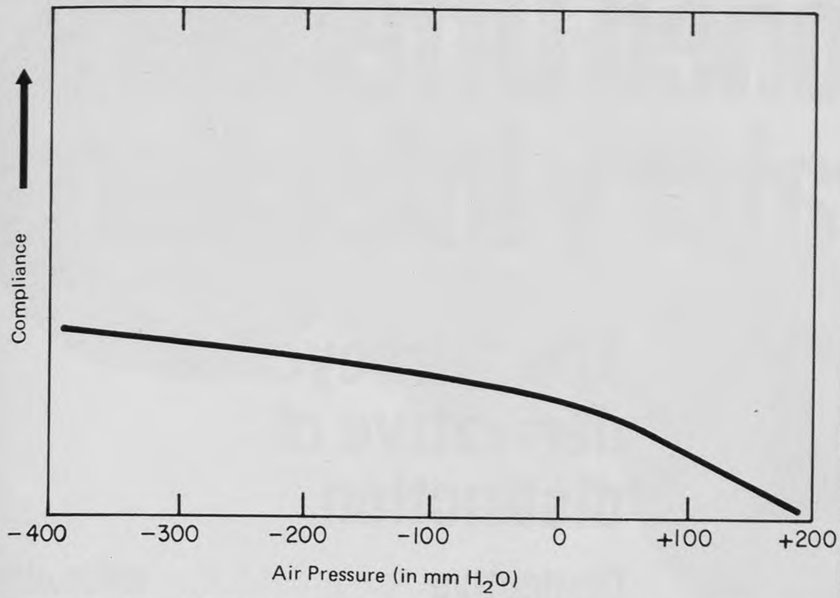

Figure 4. An abnormal tympanogram showing no point of peak compliance throughout the air pressure range from +200 mm H_2O to −400 mm H_2O. This tympanometric curve is obtained in ears with middle ear fluid.

tion, the negative middle ear pressure causes transudation of fluid in the middle ear which yields a flat tympanogram without a point of peak compliance. If prescribed medications or treatments are effective and the fluid condition begins to resolve, the tympanogram shifts from a flat curve to one showing negative middle ear pressure. Finally, a normal tympanogram is obtained when the middle ear returns to its normal healthy condition.

Successive tympanograms on repeated office visits can prove to be quite helpful in evaluating medical therapy. If abnormal tympanograms are obtained on repeated office visits, a referral can be made to an otolaryngologist with the documented history of eustachian tube dysfunction as shown by the abnormal tympanograms. On the other hand, if during the course of medical therapy, the tympanogram returns to normal, this gives support for the resolution of the middle ear problem if confirmed by otoscopy. As an example, a six-year-old girl was treated medically for bilateral otitis media and followed with successive tympanograms. During a two-month period, the middle ear function in the left ear improved considerably, as the tympanogram changed from a flat curve to one with a negative middle ear pressure of −230 mm H_2O and finally to a normal curve with a middle ear pressure of −20 mm H_2O. The right ear, however, yielded flat curves on all tests, suggesting the continued presence of middle ear fluid. A subsequent right myringotomy yielded serous fluid, thus confirming the accuracy of the abnormal tympanograms.

Discussion

Although tympanometry is a relatively new procedure, it is now recognized as a significant advance in the identification of middle ear disease. It has received considerable attention in the otologic literature and is used in many E.N.T. clinics and offices. The application of tympanometry, however, should receive more use in a non-E.N.T. office. The otolaryngologist typically has sophisticated equipment at his disposal, including a binocular microscope and calibrated audiometric equipment. Above all, the otolaryngologist has extensive experience and expertise in the identification of middle ear disease. Even with pneumatic otomicroscopy, air and bone conduction threshold audiometry and clinical acumen, the otolaryngologist often finds that tympanometry is an aid in the diagnosis of middle ear disease.

The family physician usually must rely on conventional otoscopy in the evaluation of otologic complaints. Pneumatic otoscopy often is used to evaluate the mobility of the eardrum, however, this is often difficult or unsatisfactory for various reasons. At times, the primary physician may use tuning-fork tests or audiometric screening to assist in the diagnosis. Tuning-fork tests, however, are quite subjective and are often prone to misinterpretation. Audiometric screening is also subjective and is difficult to accomplish with young children. While pure-tone screening is effective in the identification of sensorineural hearing loss, it is not a valid criterion measure in the identification of middle ear disease. It has been reported that over 50 percent of children with middle ear disease can have "normal hearing" by screening audiometry.[7] For these reasons, tympanometry should be used routinely in the primary physician's office. The moderate cost of the equipment, the ease and rapidity of its use by non-medical personnel, and the simplicity of interpretation of test results make the routine use of this procedure in the office of the family physician quite feasible.

Tympanometry is not meant to replace conventional otoscopy, but rather to supplement it. In addition, it cannot replace pure-tone audiometry in the identification of hearing loss, as tympanometry does not measure hearing.

The first line of defense in the detection of middle ear disease rests with the primary care physician. The routine use of tympanometry would offer a tremendous advantage for allowing the proper identification and management of middle ear problems.

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