



GenRad



a
guide
to
tympanometry



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Tympanometry is a measurement of the mobility of the middle ear as a function of the differential pressure across the eardrum.

This booklet has been prepared to assist those who wish to learn something about tympanometry in middle-ear measurements. We have included sufficient basic information about tympanometry as an electroacoustic method for middle-ear examination and information about the data that can be obtained to demonstrate its diagnostic usefulness. This booklet will be helpful to those who have not had previous exposure to tympanometry but wish to obtain a sufficient grasp of the subject to enable them to consider tympanometry as a helpful tool in the practice of medicine. Further, it will serve as a brief review for those already having an understanding of the subject.

foreword

Since tympanometry is a method of examining the middle-ear function, it is appropriate to review the functioning of the ear to gain an insight as to how tympanometry becomes a useful measure. Briefly stated, rapidly fluctuating air-pressure changes in the ear canal (referred to as sound) cause vibration of the eardrum. The vibratory movement of the eardrum is conveyed to the oval window by means of the ossicular chain. The freedom of the drum to vibrate and the resultant amplitude of vibration depend to a large extent on having no air-pressure differential across it. In the normal ear, this zero pressure condition is maintained by the ventilatory functioning of the eustachian tube which, although usually closed, opens momentarily during swallowing to permit the air pressure in the middle-ear space to equilibrate the atmospheric pressure at the outer surface of the drum. Also of interest to us in the middle ear is the stapedial tendon, inserted at the incudostapedial joint and innervated by a branch of the facial nerve. When the ear is exposed to intensely loud sounds this tendon contracts, resulting in reduced mobility of the ossicular chain. Later on we will discuss useful measurement techniques relating to this phenomenon.

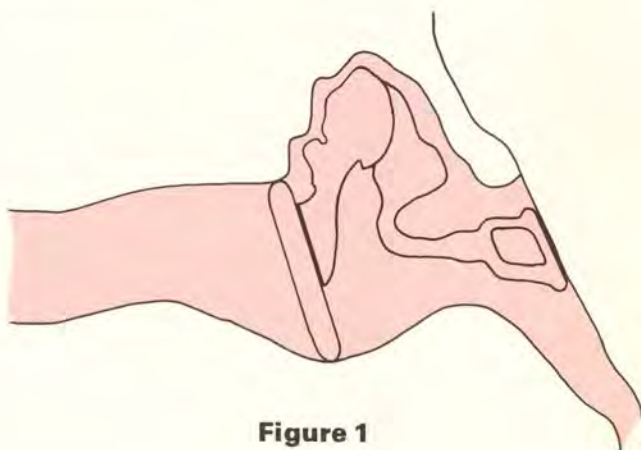


Figure 1

i. middle-ear function

As we have seen, the freedom of vibration of the eardrum depends to a large extent upon the pressure differential across it. As the pressure differential becomes greater, the drum becomes correspondingly stiffer. In the healthy middle ear, there is a range of pressure values over which the amplitude of vibration will vary for a given sound intensity. In the pathologically-stiffened ear, the variation in vibration amplitude will be less. At the other end of the scale, the variation of amplitude of vibration will be greater whenever there is hyperflaccidity. Figure 2 shows the relationship of vibration amplitude to pressure differential for three possible general conditions that can be detected by tympanometry. These curves are referred to as tympanograms.

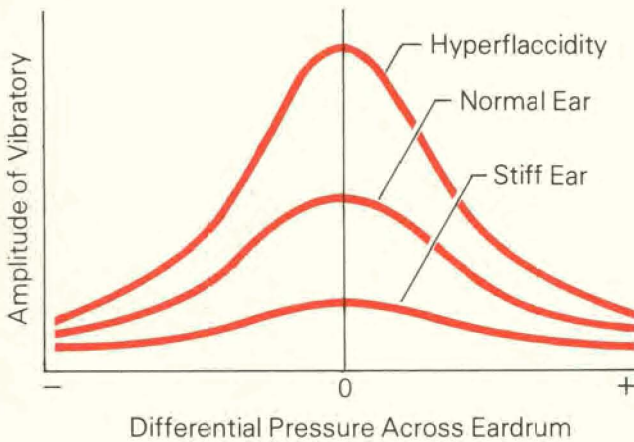


Figure 2

ii. what is tympanometry?

Having seen that a relationship exists in the vibration amplitude of the eardrum and the differential pressure across it, how can this relationship be examined? This is the function of tympanometry. Keep in mind that the eardrum absorbs energy from the sound waves in the ear canal and this energy is transmitted to the oval window via the ossicles. If the middle-ear system is stiffened for any reason or if this system is partially or wholly not intact, the amount of energy transmitted to the oval window will be altered. Something must, and does, happen to the energy which is not transmitted. Thus, if we can induce a known amount of sound into the ear canal and measure whatever part of this energy is not absorbed by the ear, or reflected from the drum, we then have a measure of mobility. To do this, a securely fitting probe is inserted into the ear canal, Figure 3. This probe is part of an assembly consisting of a tiny loudspeaker that emits a known amount of sound (referred to as the probe tone) at a specific frequency (220 Hz) and a microphone that measures the

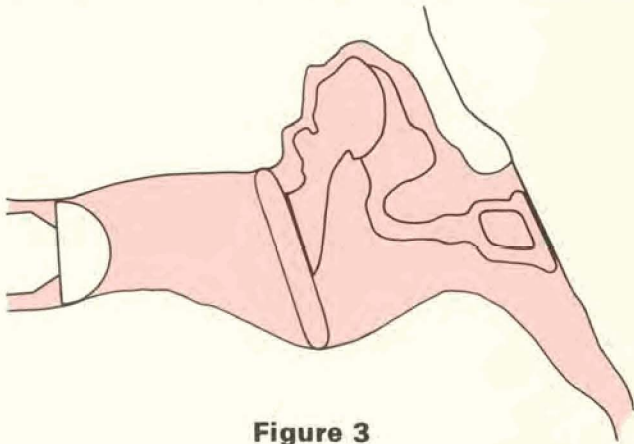


Figure 3

iii. how is tympanometry accomplished?

intensity of the sound in the ear canal. The intensity of the sound increases as the eardrum becomes stiffer and decreases as it becomes more mobile. One can imagine that the amount of energy being reflected from the drum contributes to the intensity of the probe tone. The probe also has a means of introducing variable air pressure to stress the drum over a range of values from -300 mm H₂O to $+200$ mm H₂O.

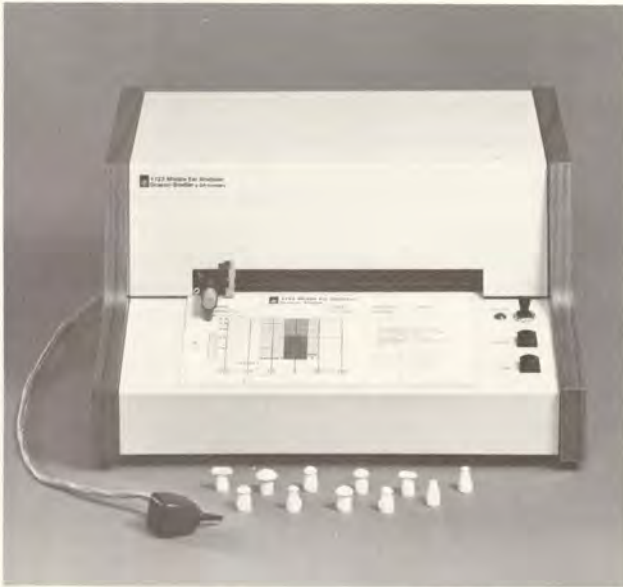


Figure 4

In the normal healthy ear, as the air pressure in the ear canal is varied over this range, the drum will reflect the least energy when the ear-canal pressure is at or near atmospheric or zero pressure at the point of maximum drum mobility. The 1722 Middle-Ear Analyzer, Figure 4, is an instrument which automatically performs this function, drawing the tympanogram on a chart depicted in Figure 5. Figure 5 is an example of a normal tympanogram since the peak occurs at atmospheric pressure.

The air-pressure range is represented by the horizontal axis of the chart with negative pressure at the left, zero or atmospheric pressure toward the middle and positive pressure at the extreme right, Figure 6(A). The vertical axis can be thought of as a scale of mobil-

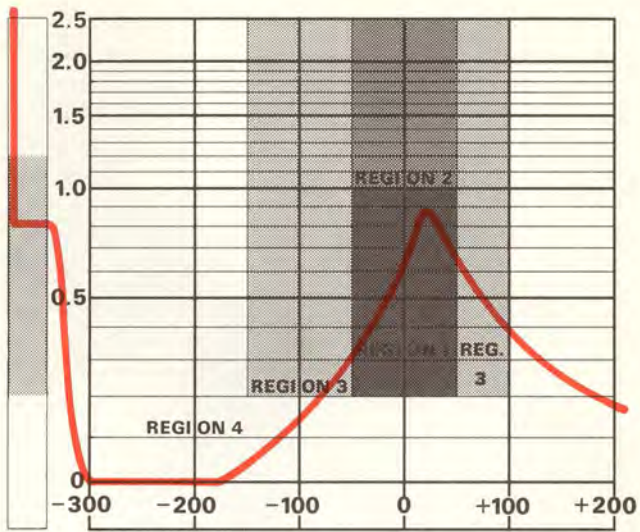


Figure 5

ity from 0 - 2.5, Figure 6(B). From this chart, two assessments about the status of the middle ear are easily seen:

1. The mobility of the eardrum
2. The middle-ear pressure

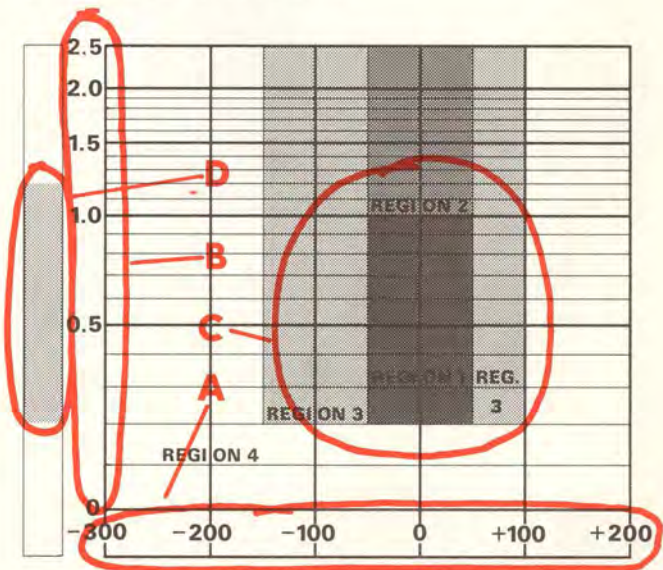


Figure 6

Note that the chart has been divided into four regions, Figure 6(C), to assist in the assessment of the results. These regions have been determined on the basis of data gathered over many years of middle-ear testing and are defined as follows:

Region 1—Normal

Region 2—Hyperflaccid

Region 3—Questionable, ear should be tested again at a later date

Region 4—Medical referral recommended.

Also, at the left of the chart there is a slender vertical bar with a shaded center section. The shaded section of this bar represents the normal range of volumes of ear canals (0.2 - 1.2 cc), Figure 6(D).

This information allows the operator to determine whether or not the probe is properly inserted and if there may be an open perforation of the drum which would indicate a large volume, as shown in Figure 7.

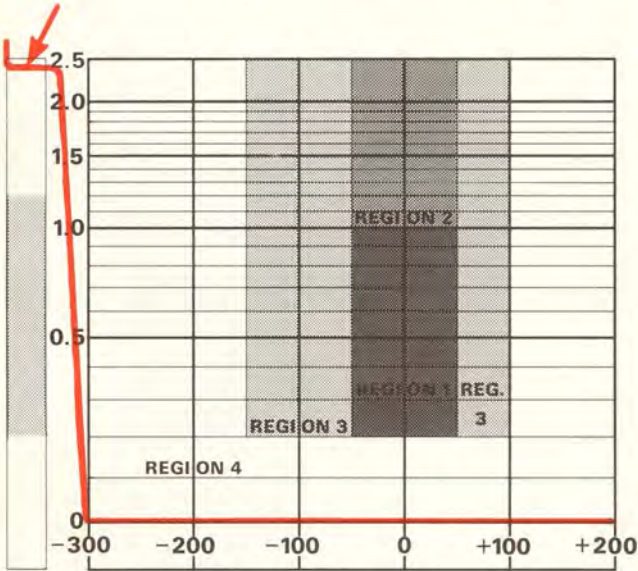


Figure 7

Before a patient is tested, a chart is placed on the chart table and the pen carriage is moved to the extreme left-hand position. The operator then selects an appropriate eartip from one of eleven available sizes supplied with the 1722. The tip is then slipped over the tip of the transducer assembly, Figure 8.

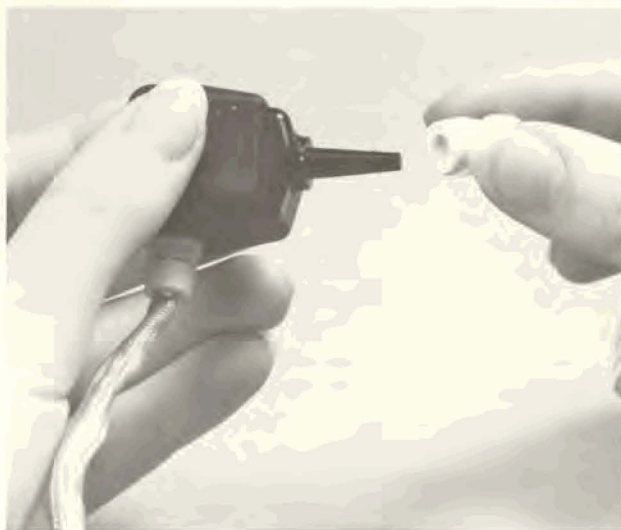


Figure 8

The pinna is gently pulled upward while the eartip is inserted in the ear canal with a slight twisting motion. Sometimes it may be necessary to support the probe assembly with the hand, but many times the assembly will be self-supporting. Next, the START button is pressed. This causes the pen to move downward slightly while the pressure in the ear canal is brought to -300 mm H₂O. If the ear canal is not properly sealed, the pen will move back to the top of the chart indicating that there is a pressure leak. The operator then may select a different eartip or readjust the probe in the ear canal. If the ear canal is properly sealed, the pen will move vertically downward and

iv. operation of the 1722 middle-ear analyzer

then horizontally across the width of the vertical bar, Figure 6(D), and will then move to the bottom of the chart. The short horizontal line, Figure 9(A), drawn by the pen indicates the volume of the ear canal. If the line appears below the shaded area, this should alert the operator to the possibility of the presence of excessive cerumen. If, on the other hand, the horizontal line appears near the top of the chart, followed by a flat tracing across the "0" line of the chart, this indicates the possible presence of an open perforation of the eardrum. After plotting the horizontal line, the pen moves to the bottom of the chart, Figure 9(B), and begins the tracing of the tympanogram, with the eardrum stressed outward by the -300 mm H₂O pressure. The pressure is then continuously swept upward through zero with the drum being stressed inward until a pressure of $+200$ mm H₂O is reached. At some point between the pressure limits, providing the ear has some mobility, the tympanogram will reach a peak. This peak will occur at a point where the pressure in the ear canal is equal to the middle-ear pressure, Figure 9(C). The height of the tympanogram indicates the mobility of the ear.

Following the completion of the tympanogram, the 1722 performs the acoustic reflex test where a second and louder sound is presented to the ear. This test occurs when the pen crosses the two slender vertical boxes at the right-hand side of the recording

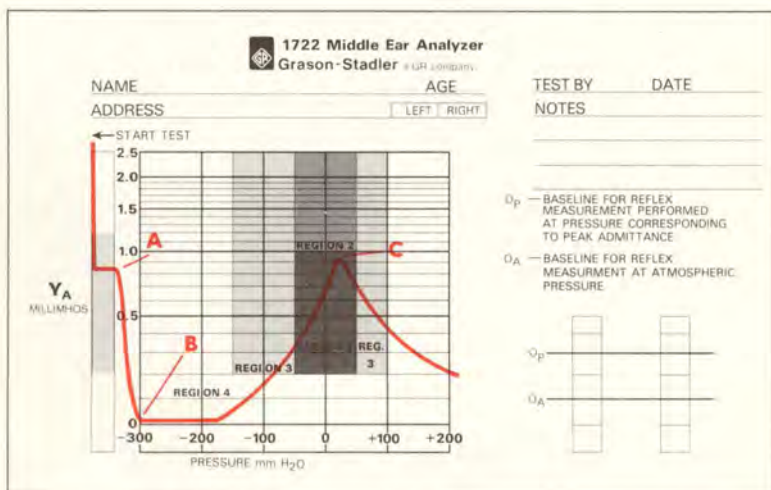


Figure 9

chart, Figure 10. The louder sound is presented for two, one-second periods separated by a two-second rest period.

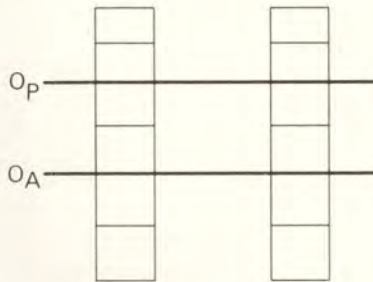


Figure 10

In Figure 11, the reflex tracing results from the action of the stapedial tendon, which causes a stiffening of the eardrum during the presentation of the stimulus. Such a test result corroborates the mobility demonstrated by the tympanogram and also indicates that the auditory pathway is intact. The result shown in Figure 11 is not surprising in view of the good mobility demonstrated by the tympanogram at the left of the chart.

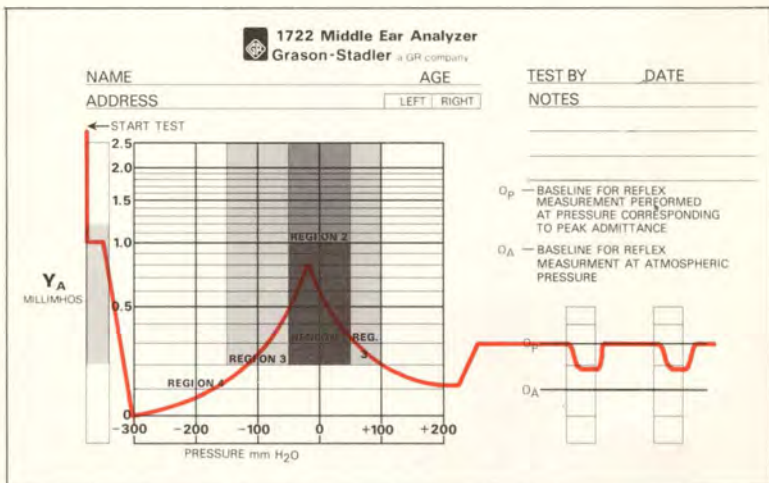
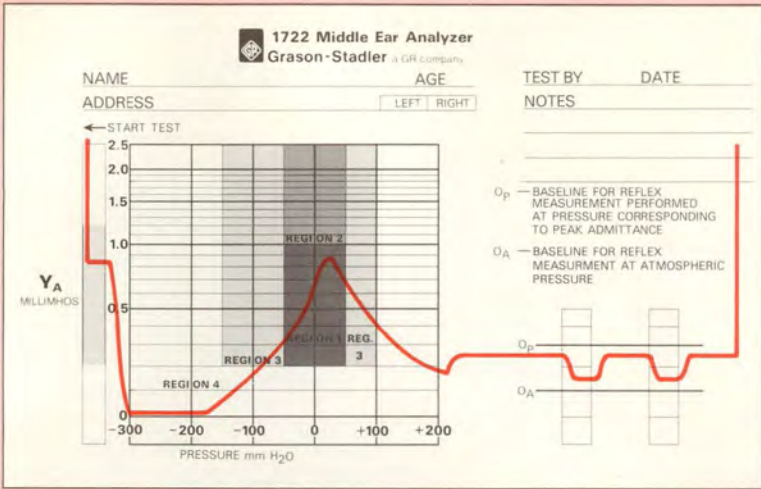


Figure 11

From the foregoing, we have seen that tympanometry and the reflex test as performed by the 1722 in less than 30 seconds-per-ear provides information relative to the mobility and pressure status of the ear. The following examples show several possible test results relating to various middle-ear conditions. In each case, the tracings are looked at with respect to:

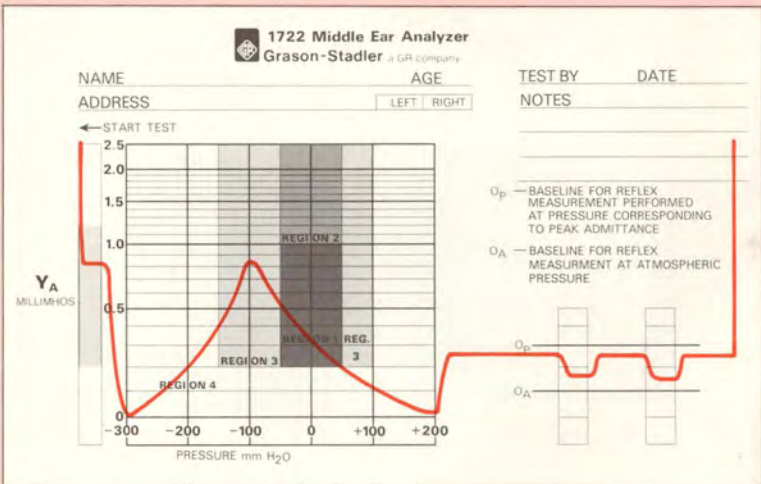
1. ear-canal volume
2. middle-ear pressure
3. mobility
4. and presence or absence of the acoustic reflex

v. what can be learned with tympanometry?



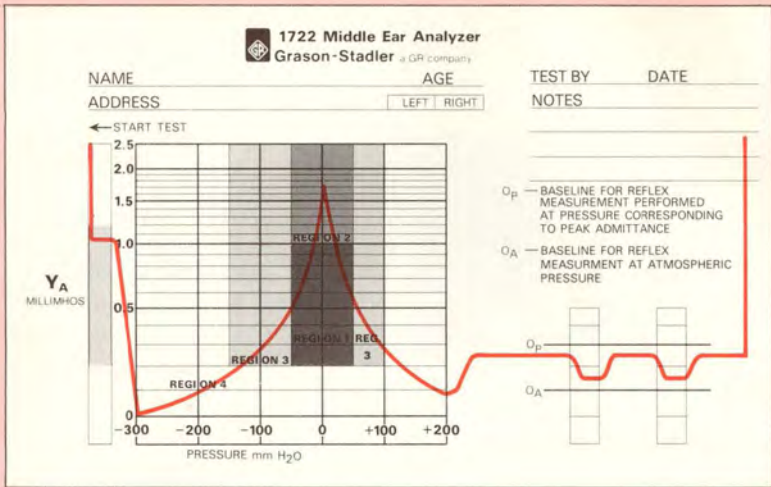
1. "Normal" Tympanogram

- Ear-canal volume within normal range
- Middle-ear pressure within normal range
- Mobility within normal range
- Acoustic reflex present



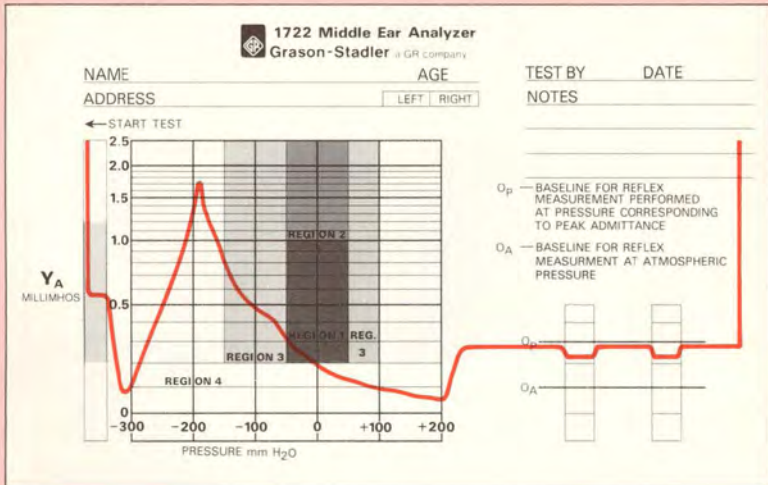
2. Partially Blocked Eustachian Tube

- Ear-canal volume—OK
- Slightly negative middle-ear pressure
- Good membrane mobility
- Acoustic reflex present



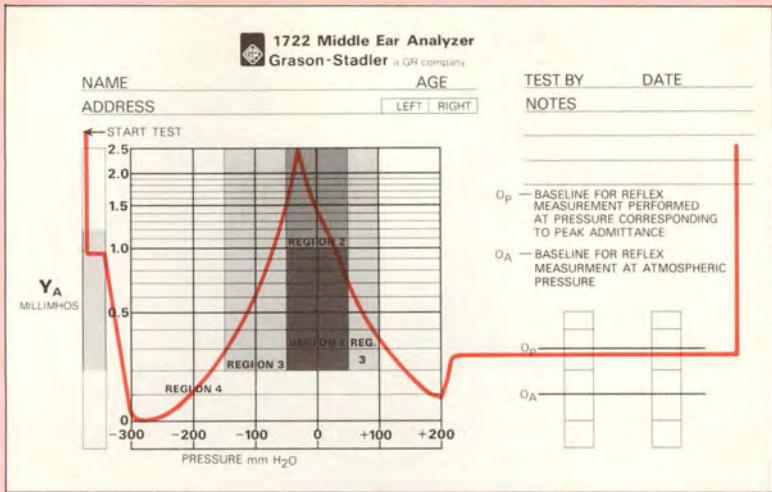
3. Flaccid Eardrum

- Ear-canal volume—OK
- Middle-ear pressure—OK
- Membrane mobility—flaccid
- Acoustic reflex present



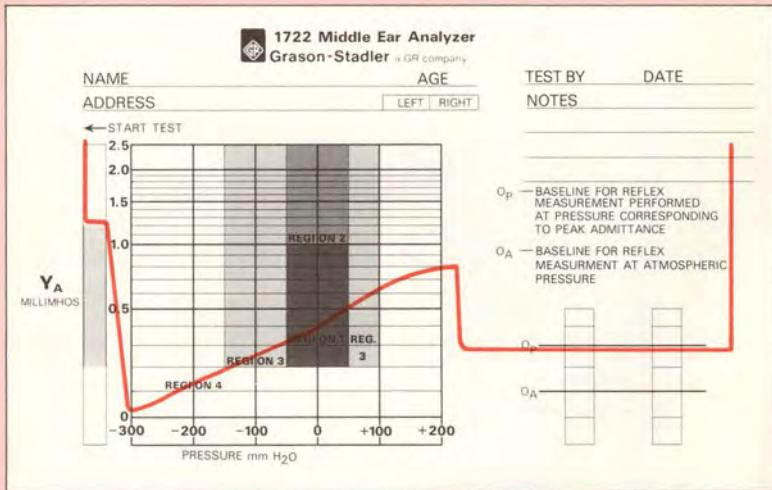
4. Poor Eustachian-Tube Function with Flaccid Eardrum

- Ear-canal volume—OK
- Middle-ear pressure—significantly negative
- Membrane mobility—flaccid
- Acoustic reflex present



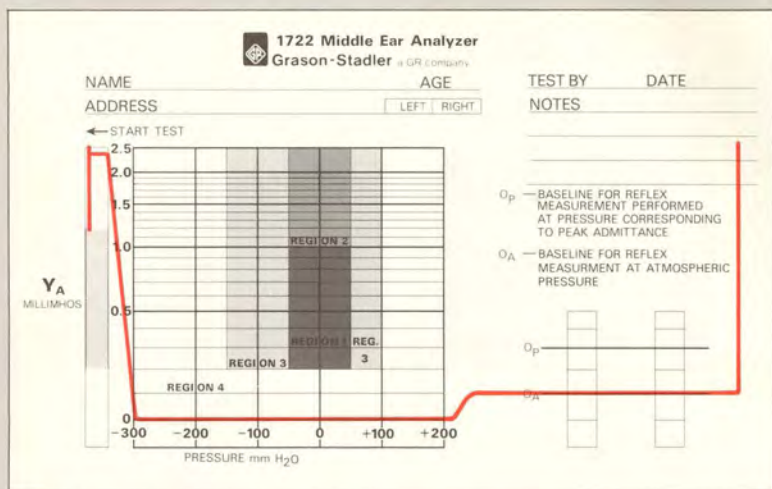
5. Very Flaccid Eardrum and No Acoustic Reflex—Possible Disarticulation

- Ear-Canal volume—OK
- Middle-ear pressure—OK
- Membrane mobility—very flaccid
- Acoustic reflex absent



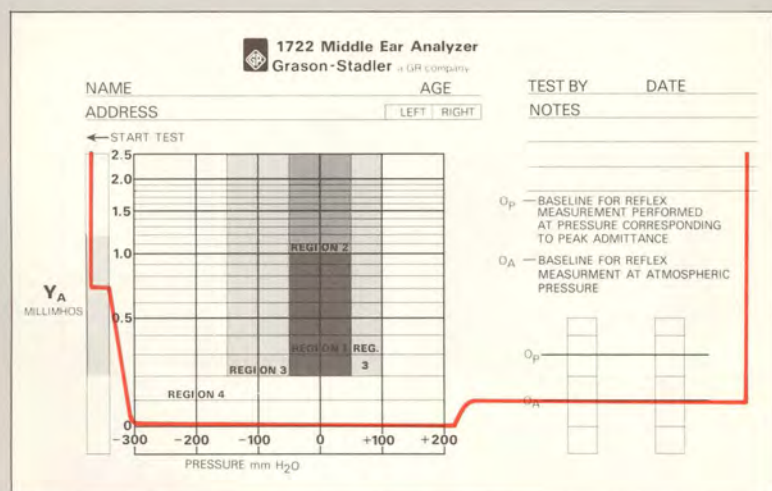
6. Very Positive Middle-Ear Pressure and No Acoustic Reflex—Patient had a cold

- Ear-canal volume—OK
- Middle-ear pressure—very positive
- Membrane mobility within normal range
- Acoustic reflex—absent



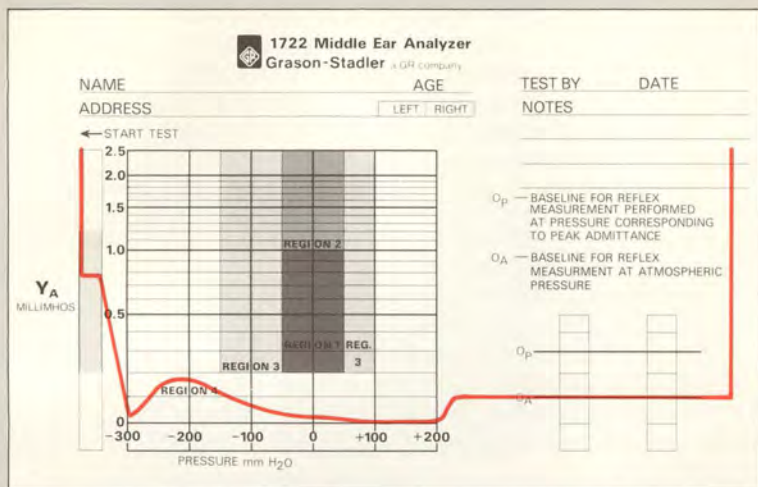
7. Possible Perforation—Tympanic Membrane

- Ear-canal volume—larger than “normal” range
- Middle-ear pressure—no peak present
- Membrane mobility—none
- Acoustic reflex—absent



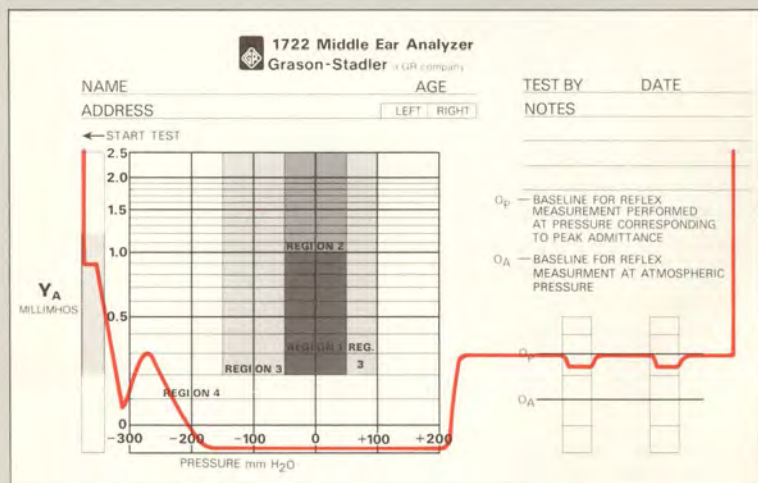
8. Serous Otitis Media—Middle Ear Completely Fluid Filled

- Ear-canal volume—OK
- Middle-ear pressure—no peak present
- Membrane mobility—none
- Acoustic reflex—absent



9. Serous Otitis Media—Small Air Pockets Present

- Ear-canal volume—OK
- Middle-ear pressure—significantly negative
- Membrane mobility—very stiff
- Acoustic reflex—absent



10. Middle-Ear Pressure Very Near -300 mm H₂O

- Ear-canal volume—OK
- Middle-ear pressure—significantly negative—very poor eustachian-tube function
- Membrane mobility—very near normal

If you know that this individual's other ear canal volume is .6 cc, you could approximate the true mobility to be .3 cc more than recorded (Reason: Ear-canal volume is determined at -300 mm H₂O and then zeroed out. With middle-ear pressure very near -300 mm H₂O, a portion of the membrane mobility near the pressure peak will be zeroed out as well.)

- Acoustic reflex—present

We have described tympanometry, how it is accomplished and the clinical results obtained by using it. Other methods have been widely used and accepted in the examination of the ear. Principal among these are audiometry and otoscopy. Why is tympanometry useful?

Several studies have been made which demonstrate that audiometric screening as it is carried out in many school systems fails to reveal the presence of middle-ear disease. Lamb and Dunkel,* citing many previous studies, state that a child with bone conduction thresholds at or below audiometric zero (re: ANSI, 1969 Standards) might have a 20-30 dB conductive hearing loss due to otitis media or some other middle-ear anomaly and still pass a standard "sweep" screening test.

Otoscopy has been and is the widely accepted method of ear examination and, when used pneumatically as with the Siegle otoscope, provides a means of assessing not only the structure and color of the eardrum but its mobility as well. This instrument in the hands of the trained and skillful professional provides an excellent means of middle-ear assessment.

The accuracy of diagnosis, however, can sometimes suffer because of subjective judgement, on which

*Lamb, L. E., and D. C. Dunkel. "Acoustic Impedance Measurement with Children," Chap. 8, p. 185 in *Acoustic Impedance and Admittance—The Measurement of Middle-Ear Function*. eds. A. S. Feldman and L. A. Wilbur; Williams and Wilkins, Baltimore, 1976.

vi. tympanometry vs traditional ear examination

the technique relies to a large extent. Careful otoscopy can often be time-consuming. This tends to restrict the use of the procedure where large populations of ears are to be examined or when the time to do so is limited. Automatic tympanometry provides some solutions to the problems associated with audiometric and otoscopic examination because it can be performed by supportive personnel with minimal training. The physician can then examine the permanent record at a convenient time. Tympanometry is the most sensitive measure of the middle-ear function. The closer to the drum the pathology is situated, the more sensitive the measure becomes because the accumulation of fluid in the middle-ear space reduces the mobility of the drum by reduction of the air volume within the middle-ear space. The ability of tympanometry to identify and monitor eustachian tube dysfunction by measuring the middle-ear pressure can be of tremendous help to the physician. The procedure is fast and efficient and produces a permanent record to examine and compare. Thus the patient's progress between visits can be readily established.

In the practice of allergy, tympanometry can be particularly useful in monitoring eustachian-tube function because the physician has reliable information to assist in the decision and selection of appropriate medication. Tympanometry also provides the most simple verification of the proper functioning of pressure-equalization tubes. When the tympanogram reveals an exceptionally large ear-canal volume (i.e., ear-canal volume plus middle-ear cavity) along with a flat tympanogram, the physician is assured of tubal patency. Ossicular disruption can be easily ascertained by tympanometry when the ear presents an extremely high tympanogram. Conversely, shallow-peaked tympanograms are indicative of adhesions or fixations of the ossicular chain.

In summary, automatic tympanometry as provided by the 1722 offers a simple diagnostic method that can assist the physician in the diagnosis and management of middle-ear disease. The procedure can be done by supportive personnel, leaving the physician more time to spend in other aspects of the practice. The tympanometric record, clearly presented on a 5" x 8" easy-to-read card, can be conveniently inspected

and filed with the patient's records. The test requires less than 30-seconds-per-ear, and the cost-per-patient is minimal.