TYMPANOMETRY AND MIDDLE EAR EFFUSION

THESIS

Presented to the Graduate Council of the North Texas State University in Partial Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

By

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Research was conducted on twenty-seven preoperative myringotomy patients to clarify the correlation between tympanometry type and the presence of middle ear effusion.

Test results indicate that the relationship between tympanometry and middle ear effusion is dependent on the amount of fluid present. In impacted ears primarily Type B tympanograms were obtained whereas for less than impacted ears all tympanogram types were seen. Also suggested was that a combination of height of the tympanogram and the amount of negative pressure may be diagnostically more important than negative pressure alone as an indicator of effusion.

It was recommended that other measures in addition to tympanometry be employed in the diagnosis of middle ear effusion and that further research is needed to achieve optimal use of impedance audiometry.
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CHAPTER I
INTRODUCTION

The early identification of middle ear disease in children has received increased attention in recent years (Brooks, 1968; Harker and Van Wagoner, 1974). The concern is not only over the medical implications but also for the possible educational ramifications of the hearing loss that often accompanies the middle ear problem.

Otitis media is an inflammation of the middle ear caused by a malfunctioning eustachian tube. Closing of the tube results in stoppage of the flow of oxygen to the middle ear spaces. Any remaining oxygen is absorbed by the mucosa of the middle ear and a negative pressure is produced. This results in a secretion of fluid by the mucosa. This fluid decreases the action of the middle ear system and if not treated sufficiently may cause a severe and permanent hearing loss.

The high incidence of middle ear disorders and otitis media in school age children has been demonstrated in several investigations. Of 1,191 children in a five year study in Pittsburgh, Pennsylvania, twenty-nine and six tenths per cent had some type of ear disease. Sixteen and three tenths per cent of those having ear disease had some type of otitis media (Eagles, 1972).
In a National Health Survey a sample of 7,119 children age six to eleven years were examined for hearing abnormalities. Of these, sixteen percent or an estimated 3.8 million non-institutionalized children had at least one abnormal tympanic membrane, indicative of present or past middle ear problems (Roberts, 1972).

The high incidence of middle ear disease in children has led to attempts in developing methods for early detection and prevention of disease progression.

Conventional methods for detection of any middle ear disorder include pure tone audiometry, otoscopic examination and case history information. However complete the above measures may be they "cannot identify all children who have physical abnormalities which may have predictive value or who may need medical treatment" (Eagles, 1972). The need for more sensitive methods of examination led to the use of impedance audiometry as a screening device.

Impedance audiometry is an objective measure of the functional state of the tympanic membrane and the middle ear. The test is a battery of three measurements: tympanometry, static compliance and acoustic reflex threshold.

Tympanometry is a measurement of the relative compliance change of the ear drum as air pressure is altered positively and negatively in the external auditory canal. The compliance changes can provide an indirect measure of existing air pressure in the middle ear. In addition, tympanogram shape
has been suggested as a means of providing information regarding the presence of fluid in the middle ear. However, research data have shown conflicting results as to when negative middle ear pressure is significant enough to use as a diagnostic clue. Also, disagreement exists as to just how strong a relationship exists between tympanogram shape and the presence or absence of middle ear fluid (Northern and Downs, 1974, Bluestone, 1973, Jerger, 1974). At the same time impedance audiometry is being recommended and used as the primary tool in public school hearing conservation programs as a screening device for middle ear disease. The preceding issues are undecided (Orchik and Herdman, 1975).

This study proposed to utilize pre-operative myringotomy patients, with suspected middle ear effusion, and examine the relationship of tympanometry to the presence or absence of middle ear effusion. Special attention was given to the amount of negative pressure present as well as tympanogram shape with the hope of further clarifying tympanometry as a differential diagnostic tool. It was felt that the only objective measure of the above mentioned relationship was the use of impedance measurement immediately prior to surgery.
CHAPTER II

REVIEW OF LITERATURE

In this chapter the etiology, incidence and age of onset of otitis media are discussed. Following is a general overview of impedance audiometry and a specific review of research dealing with tympanometry as a differential diagnostic test for otitis media and middle ear effusion.

Otitis Media: Etiology, Incidence and Age of Onset

Etiology of Otitis Media

Otitis media is an inflammation of the middle ear. There are three basic theories regarding the pathogenesis of the disease: the allergic, inflammatory and metaplastic theories (Fernandez and McGovern, 1965).

Proponents of the allergic theory believe that the mucous membranes of the middle ear, eustachian tube, nasopharynx, paranasal sinuses and the nasal cavity are associated because of their anatomic continuity. Thus an allergic stimulus of the upper respiratory tract would involve any and all of the above mentioned structures. For example the allergic reaction of edema leads to a blocking of the eustachian tube. Air is then prevented from entering the tympanic cavity. The air remaining in the tympanum is absorbed by the tissue with a resultant fluid secretion (Solow, 1958).
The second theory proposes that the fluid of otitis media is of an inflammatory origin with an infectious base. During the process of an upper respiratory infection it is believed that the infection extends from the nasopharynx to the eustachian tube and into the middle ear (Senturia, et. al., 1960). It is postulated that various types of effusion seen are "expressions of the same pathologic process observed or arrested at different stages of development" (Fernandez and McGovern, 1965).

The third proposed theory is that following inflammation the mucosa of the tympanic cavity undergoes metaplasia or tissue change. Histopathologic reports by Friedman, (1963), suggest that the altered mucosa of the middle ear is the source for the mucoid secretion of otitis media.

**Incidence of Otitis Media**

Literature regarding the incidence of otitis media in children is sparse. In early reporting Jordan (1949) stated that the apparent increase in the incidence of the disease was due only to routine hearing exams in the public schools and increased public interest.

In general review of otolaryngology patients Hoople (1950) states that between three and four per cent of all patients visiting a general otolaryngologist will suffer from otitis media.
Reporting in 1952 Seuhs cited three major reasons for the increased incidence of the disease:

1) Increased vigilance by otolaryngologist
2) Viral infection
3) Hypovirulent infections due to increased usage of antibiotics and chemotherapy.

Theobald (1958) feels there is an increase in incidence related to enlarged or infected adenoid tissue and also to the "frequent and often indiscriminate use of antibiotics."

Among his own patient load twenty-four per cent of fifty young patients, who were referred for tonsil and adenoid evaluation, had otitis media. Of an additional twenty-five cases studied, fourteen years old and younger, all were shown to have otitis media.

**Age of Onset of Otitis Media**

The age of onset of middle ear infections is substantially documented. Although a discrepancy exists as to the age of highest risk it is consistently reported that the "onset of middle ear disease...commonly occurs in childhood, with highest incident rates found among children under ten years of age" (Glorig and Gerwin, 1972).

In early independent studies of patients both Armstrong (1957) and Lemon (1962) found that over fifty per cent of general practice cases of otitis media were in children under
ten years of age. Davison (1966) supports this in a study of one hundred children with otitis media. Sixty-five per cent of his patients were also less than ten years old.

Several studies show disagreement as to the exact age of onset. Of four hundred patients with serious otitis media Lemon (1962) found the onset of symptoms was between the ages of four and seven for over seventy per cent of his patients with the highest incidence evidenced at six years of age.

Fernandez and McGovern (1965) in a study of one hundred thirteen infants and children found the onset in each child was before the age of eight. In seventy-four per cent of these cases the onset began before four years of age. Sixty-eight per cent of those seen were between the ages of five and eight years with over a one year history of medical treatment for ear complaints.

In a six year study by Eagles, et. al. (1967) of 3,059 pre-school and elementary school age children in Pittsburgh, Pennsylvania, it was concluded that pre-school as well as early school years are high risk ages for middle ear disease onset. Fewer children in the youngest age group were shown to have abnormal findings. However, ear disease was discovered in forty-two per cent of the children at first observation, that is the youngest age of the child during the total years of study.
Impedance Audiometry

The inadequacy of conventional methods (otoscopic examination, case history information, and pure tone audiometry) in detecting middle ear disease has led to the use of impedance audiometry as a major component of the diagnostic battery. An understanding of the concept of impedance should precede discussion of impedance as a diagnostic tool.

Impedance is a measure of the opposition by a system to a flow of energy. Acoustic impedance is used to measure the opposition at the lateral surface of the tympanic membrane, created by an acoustic wave. The technique of impedance "is based on the principle that sound pressure level (SPL) is a function of closed cavity volume" (Northern and Downs, 1972). Sound waves reflected from the tympanic membrane yield information regarding the integrity of the middle ear system. Objective measures, such as electroacoustic impedance, may be used to assess this middle ear status.

One electroacoustic impedance bridge commonly utilized today is the Madsen Type ZO-70 coupled with a pure tone audiometer. A diagram of the components of the impedance bridge is seen in Figure 1.

An air-tight seal of the external auditory meatus is obtained with a probe tip containing three tubes encased in a rubber tip. One tube is connected to a loudspeaker which
Figure 1. IMPEDANCE BRIDGE CIRCUIT

[Diagram of the impedance bridge circuit with labeled components: microphone, amplifier, bridge circuit, reference voltage, potentiometer, air pump, oscillator, loudspeaker, and balance meter.]
emits a tone, generated by a 220 Hertz oscillator, into the sealed cavity. A second tube is connected to a tiny probe microphone which measures the sound pressure level of the reflected 220 Hertz tone via a bridge circuit and balance meter. The sound pressure level may be varied, utilizing a potentiometer, over a range corresponding to an equivalent volume of 0.2 - 5.0 cubic centimeters. The third tube is connected to an air pump and manometer capable of varying air pressure in the sealed cavity from $+400 \, \text{mm/H}_2\text{O}$ to $-400 \, \text{mm/H}_2\text{O}$.

Small rubber hoses connect the receiver and probe microphone to the probe tip. Air is delivered to the probe tip via a third rubber hose. These are then mounted at the end of a headband. Affixed at the opposite end of the headband is a conventional earphone. When connected to an appropriate sound source and the impedance bridge accurate measurements of middle ear function may be obtained. Prior to obtaining any measurements the headset must be properly positioned on the patient, with the probe tip sealing one ear and the earphone placed over the opposite ear.

The assessment of acoustic impedance consists of a battery of three measurements: tympanometry, acoustic reflex threshold, and static compliance.
Tympanometry is a measure of the compliance changes of the tympanic membrane as air pressure is varied in the external auditory canal. The changes at various pressure levels are then plotted graphically on a tympanogram.

In a study by Jerger (1970) utilizing an electroacoustic impedance bridge (Madsen Type ZO-70) and a pure tone audiometer (Beltone, Type 10D) the basic tympanogram patterns were classified and related to conditions of the middle ear in four hundred patients. Seen in Figure 2 are the classic tympanogram patterns.

A Type A pattern is represented by a sharp rise to a point of maximum compliance, somewhere around atmospheric pressure, followed by a drop as negative pressure is applied. This curve is seen with normal functioning middle ears. A Type B curve associated with rigid middle ear systems is marked by a rather slow change in compliance as air pressure is varied without any real peak of maximum compliance (Northern, 1974). The Type C tympanogram is characterized by a displacement of maximum compliance to the left of 0mm/H$_2$O of pressure because of negative pressure in the middle ear. The maximum compliance point is then seen at -100mm/H$_2$O or more.

For acoustic reflex threshold measures the electroacoustic bridge is used to show relative changes in the impedance of the middle ear system. With the balance meter nulled to zero
Figure 2. CLASSIS TYMPANOGRAM CURVES
an acoustic signal is delivered to the non-probe ear at various intensities. If sufficiently loud, a bilateral con-
traction of the stapedius muscle will occur, causing an impedence change at the tympanic membrane. This will result in an upward deflection of the balance meter. The lowest signal level capable of eliciting this deflection is the acoustic reflex threshold.

The third portion of the test battery, static compliance, is a measure of the compliant volume of air in the middle ear spaces. Static compliance is obtained from two volume measures. The first, $Z_1$, is obtained with $+200\text{mm/H}_2\text{O}$ pressure applied to the ear drum. This creates a hard walled cavity and allows measurement of the volume of air in the external auditory canal. The volume measure is read in cubic centimeters from the bridge scale. The second measure, $Z_2$, is obtained with the drum at its most compliant point. This allows the middle ear system to be in its most efficient state. A volume reading of the sealed canal and the middle ear are then obtained. The two volumes are subtracted yielding a figure equalling the compliance of the middle ear.

Research has shown impedance as a useful tool in the diagnosis of middle ear disorders (Jerger, 1970). However, in using impedance as an aid in diagnosing otitis media disagreement is found in interpretation of impedance data as the following review demonstrates.
Tympanometry and Middle Ear Effusion

In a study of one hundred children, fifty with fluid found in both ears and fifty with normal middle ears, Brooks (1968) established three criteria involving the impedance meter as indicative of fluid filled middle ears. These are:

1) A pressure greater than -200mm/H$_2$O
2) Reduced compliance less than 0.22 cubic centimeters
3) A flat compliance curve on which the peak value is less than 0.03 cubic centimeters above the value 50mm/H$_2$O on either side of the maximum compliance point.

Of these it was felt the flattening of the tympanogram curve was the greatest indicator since it is possible to have reduced compliance from other causes.

In a later study by Brooks (1969) 697 of 1,053 children were reported to have normal functioning middle ears. Stapedial reflex presence was accepted as basis of normal function. Ninety-five per cent of these children had middle ear air pressures varying in a range from zero to -170mm/H$_2$O. This was then established as the value for normal middle ear pressure.

Northern and Downs in a 1972 report felt that middle ear air pressure of -200mm/H$_2$O was indicative of fluid. They report a Type C tympanogram in over eighty per cent of children studied who had fluid at myringotomy. No further statistics were given as to the number of children in the study, the age of the children or testing procedure.
A later investigation of fifty-two children (eighty-seven ears) tested prior to myringotomy revealed the majority of ears (fifty-nine) had a Type B tympanogram showing either high negative (greater than -200mm/H$_2$O), high positive (greater than +200mm/H$_2$O) or indeterminate middle ear air pressure. In forty-nine of these fifty-nine ears (eighty-three per cent) effusion was present at operation (Bluestone, 1973). Only two of the eighty-seven ears were shown to have a Type C tympanogram (negative pressure between -100mm/H$_2$O and -200/H$_2$O). No effusion was reported present at myringotomy in these ears.

In a further effort to classify significant negative air pressure and tympanometry type for diagnostic value of otitis media Rock (1974) reports a variance of +50mm/H$_2$O to -50mm/H$_2$O in one hundred fifty-three normal ears. No further negative pressure was found in any of these ears.

Rock defines secretory otitis media as a pathological state of the middle ear containing fluid behind an intact tympanic membrane with an abnormal negative middle ear air pressure. For ears containing fluid he found a predominance of Type B tympanogram curves. However, of thirty-nine ears with a Type C curve, fifteen per cent were also shown to have secretory otitis media at myringotomy. A Type C curve was defined as any ear showing negative pressure greater than -50mm/H$_2$O. Of these thirty-nine ears forty-six per
cent showed acoustic reflex absence. In the presence of these two criteria a watch for secretory otitis media is recommended by Rock with the aid of subsequent testing or diagnostic myringotomy.

In a three part report (Jerger, et. al., 1974) the application of impedance audiometry to clinical diagnosis was studied. The final report of the series details impedance results of middle ear disorders in 454 patients. Of these, sixty-two, in an age range of six to seventy-nine years, were diagnosed as otitis media patients by otolaryngologic examination or surgical findings. No information was given as to time lapse between impedance testing and myringotomy. In one hundred eighteen ears Type B tympanograms were reported in forty-three per cent of the ears, Type C in forty-seven per cent and Type A in ten per cent. Fluid was present in eighty-eight per cent of the one hundred eighteen ears. In this subgroup with fluid forty-four per cent yielded Type B curves, forty-five per cent revealed Type C curves and eleven per cent showed Type A curves. In another subgroup with out fluid (twelve per cent of the entire group) Type B curves were obtained in thirty-eight per cent of the ears while sixty per cent showed Type C curves. The study group concluded that tympanogram shape cannot be strongly associated with presence or absence of fluid in the middle ear.
Summary

The preceding review suggests there is disagreement as to what constitutes an abnormal tympanogram as well as the relationship of tympanometry to the presence or absence of middle ear effusion. The discrepancies may be explained by a number of factors including how an abnormal tympanogram was defined, time lapse between impedance measurement and myringotomy or the failure to confirm otoscopic impression through myringotomy.

The present investigation was designed as an attempt to further clarify the relationship between tympanometry and the presence of fluid in the middle ear (otitis media). Specifically subjects scheduled to undergo myringotomy were examined using the electroacoustic impedance bridge within thirty minutes of surgery and the following questions asked:

1. Is there a relationship between the type of tympanogram obtained and the presence or absence of middle ear fluid?

2. Is tympanogram type dependent upon the amount of fluid?

3. In tympanograms showing a definite point of maximum compliance (Type C) is the presence or absence of fluid related to the amount of negative pressure?

4. Is a flattened tympanogram (Type C) a definite indication of the presence of fluid?
CHAPTER III

EXPERIMENTAL PROCEDURES

Information concerning subjects, instrumentation, calibration and experimental procedures utilized are presented in this chapter.

Subjects

The subjects consisted of twenty-seven patients undergoing myringotomy for suspected middle ear effusion at Westgate Hospital in Denton, Texas. They ranged in age from 2 1/2 years of age to eighty-one years of age. For this study the ears of each patient were considered separately and the total sample amounted to fifty-two ears.

Instrumentation

A Madsen ZO-72 impedance bridge was employed for impedance measurement. This bridge is one of a series of electroacoustic instruments that enable measurement of middle ear functions.

A small metal case containing a receiver and two microphones are attached to a ZO-72 headband. The receiver and microphones are connected by rubber tubing to a loudspeaker which emits a 220 Hertz tone, a tiny probe microphone which
measures the sound pressure level of the reflected 200 Hertz tone and an air pump and manometer enabling variance of the air pressure in the sealed cavity from +400mm/H$_2$O to -400mm/H$_2$O. Soft eartips placed at the end of this casing are inserted in the ear canal to form an air tight seal. Once this seal is attained accurate measurements of middle ear function may be obtained.

Test Environment

Testing was conducted in the holding area of the operating rooms at Westgate Hospital, Denton, Texas. Seen in Figure 3 is a block diagram of the area. The testing environment was relatively quiet and only authorized personnel were permitted in the test area.

The impedance bridge was placed on a hospital cart in an area away from general traffic flow. The subject was rolled in on a hospital transport bed within a foot of the bridge to enable ease of testing.

Procedure

Each subject was brought in thirty minutes prior to undergoing myringotomy. The subjects were partially anesthetized and placed in a supine position on a hospital transport bed. If awake the patient was informed of the test procedure.
Figure 3. Block Diagram of Test Environment, Westgate Hospital, Denton, Texas.

4. SuptICAL Secretary
3. Transport beds
2. Parking
1. Impedance Bridge
Testing was conducted with the probe tip in the test ear and the earphone positioned on the patient's chest or on the non-test ear. After placement of the tip a tympanogram was recorded graphically from $+200\text{mm/H}_2\text{O}$ to $-400\text{mm/H}_2\text{O}$ in $100\text{mm/H}_2\text{O}$ steps. Also plotted was $+40\text{mm/H}_2\text{O}$ and $-40\text{mm/H}_2\text{O}$ in reference to the point of maximum compliance.

Tympanograms were classified as either A, B or C on the basis of the criteria previously mentioned (Jerger, 1970). In addition, two further types were defined on the basis of the height of the point of maximum compliance. If either A or C tympanograms had a maximum point of greater than six on the compliance scale it was classified as an $A_s$ (shallow) or $C_s$. These types are seen in Figure 4. Bluestone (1973) found a seventy-five per cent probability of effusion with $A_s$ tympanograms. A $C_s$ curve has not been described previously but indicates simply a shallow tympanogram with negative pressure.

The testing procedure took no more than five minutes per child. This included the testing of both ears and the graphic recording of the tympanogram.

The child was then taken to the operating room where the myringotomy was performed. Immediately following the myringotomy, the operating physician dictated the post-operative findings as to presence or absence of effusion.
Type $A_S$

Type $C_S$

Figure 4. TYPES $A_S$ AND TYPE $C_S$ TYMPANOGRAMS
and the amount of effusion. The surgeon had no prior knowledge of the impedance results. If no fluid was present the post-operative report read no effusion. If fluid was present it was rated on a scale of one to three. A rating of one suggested minimal fluid (i.e., a hypotympanic strip of fluid). A rating of two implied a moderate amount of fluid; that is, significant effusion but the middle ear was not impacted. The third rating indicated the middle ear was impacted with fluid.

Approximately one week later the impedance results and operative findings were compared and analyzed.
CHAPTER IV

RESULTS AND DISCUSSION

Of the fifty-two ears examined forty were found to have fluid. Of these twenty ears were impacted while seven ears were found to have minimal fluid. The remaining thirteen were judged to be moderate in terms of amount of fluid in the middle ear. Table 1 displays the ears according to tympanogram type and the status of the middle ear.

TABLE I
TYMPANOGRAM TYPE AND ITS RELATION TO MIDDLE EAR STATUS

<table>
<thead>
<tr>
<th>Type</th>
<th>No Fluid</th>
<th>Minimal Fluid</th>
<th>Moderate Fluid</th>
<th>Impaction Of Fluid</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>7</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>16</td>
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<tr>
<td>B</td>
<td></td>
<td></td>
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<td></td>
<td>13</td>
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<tr>
<td>C</td>
<td>5</td>
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<td>6</td>
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<td>AS</td>
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</tr>
<tr>
<td>CS</td>
<td></td>
<td>2</td>
<td></td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>TOTAL</td>
<td>12</td>
<td>7</td>
<td>13</td>
<td>20</td>
<td>52</td>
</tr>
</tbody>
</table>
The sections to follow describe in detail the relationship between tympanogram type and the presence or absence and amount of fluid in the middle ear.

Impacted Middle Ear

Twenty ears were found to be impacted with fluid. Of these, thirteen ears exhibited type B tympanograms. Of the remaining ears, three showed type C\textsubscript{g} curves, one was an A curve, one ear demonstrated a type A\textsubscript{s} curve, one ear exhibited a type C and one ear showed an atypical C tympanogram. These eight tympanograms are seen in Figures 5a and 5b. Figure 6 presents a composite of the type B tympanograms.

Minimal Middle Ear Effusion

Of seven ears revealing only a minimal amount of effusion three were type A curves, two demonstrated type A\textsubscript{s} curves and two revealed type C tympanograms. Negative pressure seen in the type C curves was \(-100\text{mm/H}_2\text{O}\) for both ears.

Ears Without Effusion

Effusion was not found in twelve of the ears studied. Of these, seven demonstrated type A curves while the remaining five were type C curves. The amount of negative pressure seen in the type C curves is shown in Table 2. It will be noted that the range of negative pressures in those ears without fluid ranged from \(-100\text{mm/H}_2\text{O}\) to \(-160\text{mm/H}_2\text{O}\).
Figure 5a. Shallow temperature seen in impacted bars.
TABLE II
NEGATIVE PRESSURE IN EARS WITHOUT EFFUSION

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<th>Ear #</th>
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<tr>
<td>#1</td>
<td>-100mm/H$_2$O</td>
</tr>
<tr>
<td>#2</td>
<td>-100mm/H$_2$O</td>
</tr>
<tr>
<td>#3</td>
<td>-100mm/H$_2$O</td>
</tr>
<tr>
<td>#4</td>
<td>-120mm/H$_2$O</td>
</tr>
<tr>
<td>#5</td>
<td>-160mm/H$_2$O</td>
</tr>
</tbody>
</table>

Moderate Amount of Fluid

Of the thirteen ears containing a moderate amount of fluid five revealed type A curves, six showed type C curves and two ears exhibited a type Cs tympanogram. The amount of negative pressure for the type C tympanograms is shown in Table 3. Negative pressure ranged from -100mm/H$_2$O to -260mm/H$_2$O in these type C tympanograms.

TABLE III
NEGATIVE PRESSURE IN EARS WITH A MODERATE AMOUNT OF FLUID

<table>
<thead>
<tr>
<th>Ear #</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>-100mm/H$_2$O</td>
</tr>
<tr>
<td>#2</td>
<td>-140mm/H$_2$O</td>
</tr>
<tr>
<td>#3</td>
<td>-200mm/H$_2$O</td>
</tr>
<tr>
<td>#4</td>
<td>-200mm/H$_2$O</td>
</tr>
<tr>
<td>#5</td>
<td>-220mm/H$_2$O</td>
</tr>
<tr>
<td>#6</td>
<td>-260mm/H$_2$O</td>
</tr>
</tbody>
</table>

Negative Pressure and Middle Ear Effusion

Table 4 illustrates the presence or absence of effusion as a function of amount of negative pressure in fifteen ears showing type C tympanograms and middle ear fluid.
TABLE IV
NEGATIVE PRESSURE AS A FUNCTION OF FLUID PRESENCE OR ABSENCE

<table>
<thead>
<tr>
<th>Legend</th>
<th>$\leq -100$</th>
<th>$-150 \leq -200$</th>
<th>$\geq -200$</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Fluid</td>
<td>****</td>
<td>*</td>
<td>****</td>
</tr>
<tr>
<td>+No Fluid</td>
<td>++++</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

Based upon these findings there appears to be an approximate fifty per cent probability of fluid in the middle ear for pressures less than $-200\text{mm/H}_2\text{O}$. To the contrary, effusion was found in all type C tympanograms with negative pressure greater than $-200\text{mm/H}_2\text{O}$.

Type B Tympanograms and Effusion

Thirteen ears of the fifty-two tested showed type B tympanograms. All thirteen ears were impacted with fluid. Thus the type B pattern was the most consistent indicator of the status of the middle ear.

Effect of Anesthesia on Tympanogram

Recent research with animals (Northern, 1975) has indicated a positive pressure change in the middle ear with nitrous oxide sedation. To examine what effect sedation might have on the present study, ten ears were tested the evening prior to as well as the morning of surgery. The evening prior to surgery, patients were in an upright position.
and were not sedated. Prior to surgery, however, all patients had been injected with ennovar and atropine. Both medications are routinely used as preoperative anesthetics.

In seven of the ten ears there was essentially no change in the tympanogram. In the remaining three ears pressure changes of 60mm/H₂O to 120mm/H₂O were seen. The pressure changes were in both positive and negative directions, however. It was concluded, therefore, that the two anesthetics employed did not affect the tympanograms obtained in this investigation.

Two ears showed some reductions in the height of the tympanogram. However, the shallow tympanogram may better reflect the status of the middle ear at surgery (approximately fifteen hours after initial testing). Further research is needed to clarify this issue.

Discussion

The relation between tympanogram type and the presence of fluid appears dependent upon the amount of fluid in the middle ear.

The clearest indications of abnormal tympanograms were seen in impacted ears. Recall that twenty ears were impacted and nineteen of these showed clearly abnormal tympanograms. Thirteen type B, three type C₃ and one A₃ curves were found. In addition one C tympanogram and one atypical type C were demonstrated. The remaining ear revealed a type A tympanogram.
Interestingly type B curves were not found in any other ears. In impacted ears a type B tympanogram might be expected based upon previous research (Bluestone, 1973; Jerger, 1970). A type C\textsubscript{S} tympanogram has not been described previously. However, the present study suggests it is a reliable indicator of middle ear abnormality. Five C\textsubscript{S} tympanograms were identified in this population and each corresponded with either moderate fluid or an impacted middle ear.

In ears showing amounts of fluid less than impaction, it appears one may see any type of tympanogram except perhaps a type B. Of twenty ears having minimal or moderate amounts of fluid, eight revealed type A tympanograms, eight were type C, two showed type A\textsubscript{S} curves and two exhibited type C\textsubscript{S} tympanograms.

This is a somewhat surprising finding. Jerger (1974) has suggested that tympanogram type is not a reliable indicator of middle ear effusion. However, Jerger's conclusion is not based entirely on surgically confirmed middle ear fluid. Also he gives no indication as to whether amount of fluid is considered.

The present research would qualify Jerger's (1974) statement to suggest that in impacted ears tympanogram shape is likely to be abnormal. However, for ears with fluid less than impaction, tympanometry is not a reliable indicator of middle ear status.
The inability to correlate tympanogram shape with less than impacted ears creates a problem for the clinical application of impedance audiometry especially in public school hearing screening programs. It would appear that establishing a criterion for otologic referral based upon tympanometric data alone may be untenable. The exception would be in the case of the type B and type C tympanogram, where medical examination would obviously be indicated.

However, even in ears impacted with fluid one type A tympanograms was seen with one type C and one atypical C. These findings suggest a need for further research to look to other measures in combination with tympanometry for a clearer indication of middle ear status.

Of those ears not demonstrating effusion either type A (seven ears) or type C (five ears) curves were seen. Type A tympanograms are typically associated with dry ears. The type C tympanogram has been suggested as a possible indicator of Eustachian tube malfunction (Jerger, 1970; Bluestone, 1973) however, question has been raised as to what constitutes significant negative pressure (Orchik and Herdman, 1975).

In this investigation, the relationship between degree of negative pressure (type C) and effusion is not clear. Of the ears examined fifteen demonstrated type C tympanograms as shown in Table 4. Based upon this data it would appear that
effusion might be found with negative pressure anywhere from 
-100mm/H\textsubscript{2}O to -260mm/H\textsubscript{2}O. The probability of effusion appears 
higher for pressures greater than -200mm/H\textsubscript{2}O, however, further 
research is needed. Continuing investigation of type C 
tympanograms in a manner similar to the present study may 
define what relationship, if any, exists.

A clear relationship appears when height of tympanogram 
and negative pressure are viewed together. Such a comparison 
involves type A\textsubscript{S} and type C\textsubscript{S} curves. All shallow tympanograms 
showed effusion. However, two of the three A\textsubscript{S} curves showed 
only a minimal amount of fluid while the five C\textsubscript{S} curves re-
vealed a moderate amount of fluid or impacted middle ears. 
Apparently negative pressure equal to or greater than -100mm/H\textsubscript{2}O 
in combination with a shallow tympanogram is a better indicator 
of effusion than negative pressure alone. However, once again 
continuing research is needed to more clearly define this 
relationship.

Conclusions and Recommendations

The following conclusions seem warranted on the basis 
of the present data:

1. A type B tympanogram is a definite indicator of 
middle ear fluid. Further, when a type B tympano-
gram is demonstrated a high probability exists 
of an impacted middle ear.
2. For less than impacted middle ears any type of tympanogram, except perhaps for type B, may be observed.

3. The amount of negative pressure is less important in terms of predicting effusion than a combination of the height of the tympanogram and the amount of negative pressure.

Based upon the findings of this research the following recommendations are made:

1. In future research, the relationship between negative pressure and height of tympanogram be examined further as a means of improving the diagnostic capability of impedance audiometry in assessing middle ear status in otitis media.

2. That in clinical applications of impedance, tympanometry be combined with other measures, such as acoustic reflex, static compliance and pure tone audiometry. This would appear to be especially important in evaluation of middle ear function in suspected otitis media.

Further research is indicated to clarify the relationship between tympanometry and presence or absence of middle ear fluid. Only through continued research can optimal use of an already sensitive clinical tool be achieved.
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BOOKS

