EUSTACHIAN TUBE FUNCTION MANOEUVRE IN INDIVIDUAL WITH INTACT TYMPANIC MEMBRANE

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May, 2013

CERTIFICATE

This is to certify that this dissertation entitled **"Eustachian Tube Function Manoeuvre in Individual with Intact Tympanic Membrane"**is a bonafied work in part fulfillment for the degree of Master of Science (Audiology) of the student with Registration No. 11AUD014. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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This is to certify that this dissertation entitled **"Eustachian Tube Function Manoeuvre in Individual with Intact Tympanic Membrane"**has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in other University for the award of any other Diploma or Degree.

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DECLARATION

This dissertation entitled **"Eustachian Tube Function Manoeuvre in Individual with Intact Tympanic Membrane"**is the result of my own study under the guidance of Mr Prawin Kumar, Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore, **Register No:** 11AUD014

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Dedicated to

My Beloved Parents and Nandani

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"Teachers lead a person from darkness to light"

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Introduction

Eustachian tube is a complex structure in the human body that connects middle ear to nasopharynx. The anterior two third portions are cartilaginous and the posterior one-third portion is bony. The junction of the bony and cartilage portions is known as isthmus (Rood & Doyle, 1985). In infants, the Eustachian tube is about half of the adult size. The Eustachian tube lengthens rapidly during childhood and reaches adult size by 7 years of age (Siegel, Cantekin, Todhunter&Sadler-Kimes, 1988). Further, the direction of the tube varies from horizontal to an angle of about 10^0 horizontal in infants (Graves & Edwards, 1944). However in adults, the tube is at an angle of approximately 45^0 to the horizontal plane (Proctor, 1967). The cartilaginous portions of Eustachian tube is having mucosal lining which is similar to the nasopharynx lining and contain mucous glands(Sadler, Siegel &Todhunter, 1989; Sudo, Sando&Ikui, 1997).

The major function of Eustachian tube is the regulation of middle ear ventilation that is important for proper middle ear function and sound transmission. The Eustachian tube is closed during rest and open only when activated through swallowing, coughing, and yawning. This mechanism protects the ear from rapid pressure changes, keeps the mucosa preserved and allows the tympano-ossicular unit to vibrate without interferences. The Eustachian tube helps in regulation of middle ear pressure, protecting middle ear from foreign pathogens anddrainage of fluid from the middle ear (Doyle, 1985; Honjo, 1985; Bluestone, Charles &Jerome, 2001).

The Eustachian tube dysfunction is one of the reasonof middle ear infection (Cele, et al., 1999). Otitis media is the most commonly diagnosed childhood middle ear disease that affects thousands of children every year (Bondy, Berman, Glazner&Lezotte, 2000). Otitis media with effusion is a pathological condition in which fluid and mucus gets trapped in the ear after infection. Poor Eustachian tube function plays a major role in the pathogenesis of otitis media and further may leads to serous otitis media and adhesive otitis media (Tos, 1998; Dominguez, Abenia, Ingalature, Varela &Lazaro (1998). The above condition may lead to conductive hearing loss and if it persistsfor longer duration, might causes delays in the development of speech, language and cognitive abilities (Klein, 2000).

There are various tests to measure function of Eustachian tube. They measures directly and indirectly the status of the middle ear and theEustachian tube. The opening function of the Eustachian tube can be measured through radiographic, manometric, tympanometric, sonometric and photoelectric methods. Radiographic method can be used even in perforated tympanic membrane, while sonometry is a method to study Eustachian tube function in physiological condition (Holmquist&Olen, 1980; Morita &Matsunaga, 1993; Murti, Stern, Cantekin& Bluestone, 1980).

The tympanometric measures are non-invasive objective teststhat help in assessing Eustachian tube function with intact as well as perforated tympanic membrane. The procedures are Valsalva manoeuvre, Toynbee manoeuvre, Inflation and deflation test, and William swallow test. It require a short administration time with standard clinical acoustic admittance meter.

Blyander, Tjernstrom and Ivarsson (1983) did a comparative study between children and adult with intact tympanic membrane to measure the opening and closing function of Eustachian tube. There were 58 children in the age range of 3-12 years and 61 adults in the age range of 17-73 years participated in the study. The results revealed poorer function of the exhalation /inhalation test in children than adult. Further, theeffect of age in adults was not observed for opening and closing function of Eustachian tube.

In a similar line, Bunne, Falk, Magnuson and Hellstrom (2000) studied the tubal opening and closing function in 20 retracted ears and normal ears in the age range of 28 to 56 years. They administered Valsalva inflation, and forceful sniffing test. The results revealed that individuals with retracted ears vary more in comparison to normal ears. Further, they also observed that rate of positive response in equalization and Valsalva test were significantly lower in retracted ears compared to normal ears.

Need for the study

Several studies reported that Eustachian tube dysfunction is a precursor of middle ear effusion (Bluestone & Berry, 1976;Blustone&Cantekin, 1981; Cantekin, Berry&Blustone, 1977). Abnormal function of Eustachian tube can result from obstruction in the tube or abnormal patency(Blustone, 1980). Functional obstruction reflects persistent Eustachian tube collapse because of increased tubal compliance or an inadequate opening mechanism. The assessment of Eustachian tube function is important for an audiologist and otologist. In spite of not being used very frequently, these non-invasive tests have great importance in assessing children and adults with Eustachian tube dysfunction. It also helps in monitoring prognosis after middle ear infection and/or upper respiratory tract infection.

No attempts have been made to develop normative data for different Eustachian tube function maneuver in Indian population for different age groups with intact tympanic membrane. However, there are few studies in western literature which discuss about Eustachian tube function in individuals with intact tympanic membrane

(Bylander, Ivarsson&Tjernstrom, 1981; Riedel, Wiley & Block, 1987; Kumazawa et al., 1993). Hence, there is a need to develop normative for Eustachian tube function maneuver for individuals with intact tympanic membrane in Indian population.

Aim of the study

- To develop normative forEustachian tube function maneuver indifferent age group individuals with intact tympanic membrane.
- To check the test-retest reliability of Eustachian tube function maneuver in these individuals.

Chapter - 2

Review of Literature

Eustachian tube (ET) regulates pressure between middle ear and nasopharynx. Individuals with intact tympanic membrane maintain atmospheric or ambient pressure at 0 daPa within middle ear cavity by the periodic opening of Eustachian tube during swallowing, coughing and yawning. In individuals with intact tympanic membrane, the poor function of Eustachian tube can result in negative middle ear pressure (Tideholm, Carlborg, Jonsson&Bylander, 1998).Individuals with high negative pressure are more likely to develop middle ear effusion. Hence, such a condition should be monitored closely (Antonio, Don, Doyle&Alper2002). Several studies reported that the amount of negative peak pressure is not a good indicator to consider abnormal Eustachian tube patency (Brooks, 1980; Holquist& Miller, 1972; Peterson &Liden, 1972). Porter (1974) reported that normal middle ears peak pressures ranges between -50 daPa and +50 daPa in adults. Several studies consider the lower cut-off value for normal peak pressure is about -100 daPa (Jerger, 1970; Jerger, Jerger, Mauldin, &Segal, 1974; Silman, Silverman &Arick1992).

Renvall(1975) studied normal middle ear pressure function in school going children. They had tympanometric peak pressure exceeding -150 daPa which was considered as the lower limit for normal middle ear function. They found that 90% of school going children have normal middle ear.The presence of lower value of peak pressure in children than adults shows that children maintain relatively lower middle ear pressure than adults (Brooks, 1980). Further, Harford(1980) reported that greater than +50 daPa refers to positive tympanometric peak pressure. Tos, Stangerup, Holm-Jensen and Sorensen (1984) reported that persistent negative tympanometric peak pressure more than -200 daPa leads to retraction of the tympanic membrane. Hence, whenever middle ear pressure exceeds -200 daPa over an extended period of time should be consider significant.

Feldman (1976) reported positive peak pressure in individuals with acute otitis media. Ostergard and Carter (1981) also reported positive peak pressure greater than 50 daPa in 1.7% of individuals with acute otitis media. However, studies show marked positive tympanic peak pressure in ears with pinhole perforations of the tympanic membrane (Fowler & shanks, 2002; Kessler, MacDonald & Cox, 1998;Kobayashi &Okitsu, 1986; Kobayashi, Okitsu&Takasaka, 1987).

Eustachian tube function test

Eustachian tube function (ETF) test helps in identifying abnormal functioning of Eustachian tube. It differentiates between functional obstruction and mechanical obstruction of Eustachian tube. Eustachian tube function tests helps in monitoring Eustachian tube functioning in cleft-palate repair, adenoidectomy, and elimination of nasal and nasopharyngeal inflammation (Bluestone, Paradise, Beery&Writtel, 1972; Bluestone, Cantekin& Beery, 1975; Bluestone, Cantekin& Beery, 1977). It also helps in predicting the success of repairing tympanic membrane in individual with perforated tympanic membrane (Holmquist, 1968; Siedentop, Tardy & Hamilton, 1968).

There are several tests to measures Eustachian tube function in individuals with intact tympanic membrane. They are Tympanomety, Sonotubometry, Sniff test, Nasal endoscopy, Valsalva manoeuvre, Toynbee manoeuvre, and Inflation and deflation test. However, there are few tests to measures Eustachian tube function in individuals with perforated tympanic membrane which includes force response test, the inflation test and the deflation test.

Test for assessing Eustachian tube function.

Pneumatic Otoscopy.

Otoscopy using a pneumatic attachment to visually inspect the tympanic membrane is one of the simplest and oldest ways to assess the middle ear end of the Eustachian tube system. The appearance of a middle ear effusion, the presence of high negative middle ear pressure, or both can be determined by a pneumatic otoscope (Bluestone &Shurin, 1974). However, the type of impairment such as functional or mechanical obstruction and the degree of abnormality cannot be determined by this method. A reasonable assessment of middle ear pressure is possible by proper use of the pneumatic otoscope. However, a normal appearing tympanic membrane is not an evidence of a normally functioning Eustachian tube.

Nasopharyngoscopy and Endoscopy of the Eustachian Tube.

Indirect mirror examination of the nasopharyngeal end of theEustachian tube system is also an old technique but still important part of the clinical assessment for individual with middle-ear disease. The development of endoscopic instruments has greatly improved the accuracy of this type of examination. The flexible fibre optic telescope has been used to examine the Eustachian tube from the nasopharyngeal and middle-ear end of the tube. Certain aspects of the structure of the Eustachian tube can be determined with currently available instruments(Guindy 1998, Takahashi, Honjo,Kurata&Sugimaru1996; Poe, Pyykko,Valtonen&Silvola, 2000).Poe, Halawa&Razek(2001), assessed tubal function in 44 adults using slow-motion video endoscopy. They found inflammation of the Eustachian tube and patulous Eustachian tube through video endoscopy.

Tests of Pressure Regulation Function of the Eustachian Tube.

There are tests that can assess the pressure regulation function of the Eustachian tube system. Some of the tests are employed, when the tympanic membrane is intact (tympanometry)whereas others are used when there is a perforated eardrum. Still others can be used irrespective of the integrity of the tympanic membrane (sonotubometry), when the tympanic membrane is not intact, the forced-response test may be used (Cantekin, Saez, Bluestone & Bern, 1979).

Sonotubometry is currently in use in routine research studies but is not yet available for clinical use. A new measurement of Eustachian tube mechanical properties using a modified forced-response test is currently being tested in animals and humans (Ghadiali, Federspiel, Swarts& Doyle, 2001).

Valsalva Test.

This technique is named after Antonio Maria Valsalva during early seventeen century. This test shows the effect of high positive nasopharyngeal pressure on Eustachian tube function.

Valsalva manoeuvre procedure given by Riedel et al. (1987).

Step 1:- Baseline tympanogram to be obtained.

Step 2:- The subject is instructed to pinch the nares and inflate the cheeks through force expiration with the mouth closed until the ears feel fill. Afterward, the subject is asked to release the nares and not to swallow.

Step 3:-Another baseline is to be obtained.

The test is considered positive when the Eustachian tube and middle ear is inflated by force expiration when the mouth is closed and nose is held by thumb and forefinger. Positive Valsalva test result indicates a normal function of Eustachian tube.

Disoeck (1952) found that the pressure rises to 300 H_2O with Valsalva manoeuvre. According to Davison (1965) the opening pressure using Valsalva method is 600 mm H_2O and the pressure applied in the nasopharynx will reach up to 3,200 mm H_2O.

According to Elner, Ingelstedt and Ivarsson (1971), the Valsalva test is not a tubal function test in physiological sense because there is no active muscle work in order to open the tube. The positive pressure is forced into middle ear cavity via Eustachian tube, which is not a physiological function. Tubal resistance to Valsalva manoeuvre is increased in the prone position due to changes in the muscle tonus or venous distension (Perlman, 1967). They observed even repeated swallowing exercise reduces the tubal resistance to Valsalva manoeuvre. They found that 86% among101 adults with normal ears had positive results onValsalva test.

According to Bluestone (1980) Valsalva manoeuvre is not a reliable test of Eustachian tube function. However, Riedel, Wiley & Block (1987) reported that Valsalva procedure is the best for producing reliable and interpretable results in adults with normal middle ears. They also reported that in adults with normal middle ear function, the shift in tympanometric peak pressure 47 to 79 daPa in 94% of participants.

Bunne, Magnuson, Falk and Hellstrom (2000) examined Eustachian tube function over time in children with secretary otitis media. In this study they had considered (42 ears) among 21childrens (13 boys and 8 girls) in the age group of 4 to 8 years. The middle ear pressure was recorded during repeated passive forced openings, equalization of pressure (+100 daPa and -100 daPa) by swallowing, Valsalva inflation and forceful sniffing. All tests were performed twice during sessions in the interval of 30 min for 2 days.

Results revealed that in the equalization, the rates of responses that changed from positive to negative between sessions and test daysranged from 12% to 33% in Valsalva tests. Further, it also showed a similar trendand a lower occurrence of positive equalization in ear with serous effusion. It was concluded that Eustachian tube opening and closing functions are highly variable in ears with serous otitis media. Consequently, single tubal function tests have low value when used as a prognostic tool in individual ears**.**

Swarts, Alper, Mandel, Villardo and Doyle (2011) studied Eustachian tube function test in adults without middle ear diseases to develop normative value for 5 Eustachian tube function test protocols. They considered 20 adults in the age range of 19 to 48 years for the study. None of the participants had recent history of otitis media, but 5 participants had otitis media in childhood and had undergone unilateral myringotomy. They used the force response test, inflation, deflation, forcible "sniff "and Valsalva test to evaluate Eustachian tube function. Results revealed that 2 subjects did not complete the task whereas, out of 18 subjects 5 subject failed to develop middle ear pressure and 7 subjects failed to maintain a residual middle ear pressure after completion of the manoeuvre. The average nasopharyngeal pressure was 707 daPa. The peak pressure was 449 daPa and residual pressure was 54 daPa. Similar results were obtained in second session where out of 14 subjects 2 subjects fail to develop positive middle ear pressure and 4 subjects failed to maintain a residual middle ear pressure after completion of the manoeuvre. The average nasopharyngeal pressure was 702 daPa. The peak pressure was 485 daPa and residual pressure was 68 daPa. For combined set of session correlation was statistically significant ($p<0.01$).

Politzer'sTest.

This test was developed by Politzer (1903).This method of politzerization was recommended to restore middle-ear pressure. Politzer test is performed by compressing one naris into which the end of a rubber tube attached to an air bag has been inserted while compressing the opposite naris with finger pressure. The subject is asked to repeat the letter K or is asked to swallow to close the velopharyngeal port. If there is a Eustachian tube block, the patient will not hear or feels anything in the ear. If the tube opens, entrance of air into tympanic cavity can be perceived. When the test result is positive, the overpressure that develops in the nasopharynx is transmitted to the middle ear, thus creating positive middle-ear pressure. Assessment of the middle-ear pressure and the significance of the test results are the same as with Valsalva's test in that a normal result indicates only tubal patency. However, both Valsalva and Politzer methods can be of benefit as a treatment when effusion or high negative pressure is present within the middle ear. During politzerization, the maximum nasopharyngeal pressure obtained will be 1600 mmH_2O for velopharyngeal closer and cannot be maintained above this level (Donaldson, 1973).

But a positive pressure of 1100 mmH_2O and more is necessary for this manoeuvre (Siedentop, Loewy, Corrigan&Osenar, 1978). Since the politzerization requires an over pressure in the nasopharynx which is transmitted through the Eustachian tube, if it opens during deglutition, it does not reproduce physiological function (Miller, 1965). It is difficult to quantify the various degree of Eustachian tube hypofunction by this technique.

Toynbee Test.

Toynbee test was developed by Toynbee (1860). Toynbee manoeuvre creates a positive pressure within the nasopharynx, followed by a negative pressure phase (Perlman, 1951).

Toynbee procedure given by Riedel et al (1987).

Step1:- Baseline tympanogram to be obtained.

Step2:- The subject is asked to swallow while pinching the nares. Later, the subject releases the nares and does not swallow.

Step3:-Another baseline is to be obtained.

A positive result is considered if there are alterations in middle ear pressure. If a negative middle ear pressure develops during closed nose swallowing, the Eustachian tube function most likely normal.

Change in middle-ear pressure in the Toynbee testis assessed in the same way as that it is assessed in Valsalva test. Negative pressure is created in the nasopharynx after the process of deglutition and the tube opens (Perlman, 1967; Cohn, 1977). The finding of negative middle ear pressure during this test usually shows normal tubal function. However, it has been reported that the Eustachian tube that are patulous or have very low resistance transfers gas from the middle ear into the nasopharynx during this manoeuvre as well as with sniffing (Bluestone, 1980). Thomsen (1958) confirmed the results of Toynbee test by impedance measurements i.e. a negative middle ear pressure from this manoeuvre (Shallop, 1976). Thomsen (1958) reported that30% of normal adults exhibited negative Toynbee test finding.

Elner, Ingelstedt and Ivarsson (1971) studied Eustachian tube function in 102 individuals with intact tympanic membrane. A total of 66 men and 36 women in age range of 21 - 60 years, were divided into 4 groups based on their age. The result of the

Toynbee test was positive in 74 out of 94 subjects whereas rest of the subjects were unable to build up negative pressure. The Eustachian tube opens and closes during negative phase in 47 subjects, resulting in middle ear pressure being negative. Further, in 18 subjects there was an alternately positive and negative middle ear pressure. However, 9 individuals showed constantly a positive middle ear pressure.

Bluestone, Casselbrant and Cantekin (1982) investigated normal children with traumatic perforations. Six out of seven children could change the middle-ear pressure, but none of the 21ears who had a retraction pocket or a cholesteatoma showed pressure change. The test is still of considerable value because the negative pressure that develops in the middle ear during or following the test indicates normal functioning of the Eustachian tube regardless of age. If positive pressure isnoted or no change in pressure occurs, the function of theEustachian tube may still be normal, and other tests ofEustachian tube function should be performed.

Riedel el al (1987) concluded that although the Toynbee procedure could be used to establish tubal function (opening) reliably, it was an unreliable measure for inducing middle ear pressure in order to equilibrate abnormal middle ear pressure. They also reported smaller amount of middle ear pressure shift in Toynbee manoeuvre compared to that of Valsalva manoeuvre. The results revealed that 67% had tympanometric peak pressures shift towards negative direction for Toynbee maneuver and out of which 96% of participants had a shift greater than 2 daPa.

Inflation-deflation test.

Inflation-deflation test is a method of measuring Eustachian tube function developed by Bluestone (1975). This test is currently used in clinical assessment of Eustachian tube function, when tympanic membrane is intact. The test is simple to perform and can give useful information regarding Eustachian tube function. In general, most normal adults can perform all or some parts of this test, but some normal children have difficulty in performing it. However, if any patient passes in some or all of the steps, Eustachian tube function is considered to be normal. This test followsnine step tympanometry procedures as follows;

Step I: - The tympanogram records resting middle-ear pressure.

Step II:-Ear canal pressure is increased to +200 mm H_2O with medial deflection of the tympanic membrane and a corresponding increase in middle-ear pressure. The subject swallows to equilibrate middle-ear overpressure.

Step III:-While the subject refrains from swallowing, ear canal pressure is returned to normal, thus establishing a slight negative middle-ear pressure (as the tympanic membrane moves outward). The tympanogram documents the established middle-ear under pressure.

Step IV:-The subject swallows in an attempt to equilibrate negative middle-ear pressure. If equilibration is successful, airflow is from the nasopharynx to the middle ear.

StepV:-The tympanogram records the extent of equilibration.

Step VI:-Ear canal pressure is decreased to -200 mm H_2O, causing lateral deflection of the tympanic membrane and a corresponding decrease in middle-ear pressure. The subject swallows to equilibrate negative middle-ear pressure; airflow is from the nasopharynx to the middle ear.

Step VII:-The subject refrains from swallowing while external ear canal pressure is returned to normal, thus establishing a light positive pressure in the middle ear as the tympanic membrane. The tympanogram records the overpressure established.

Step VIII:-The subject swallows to reduce overpressure. If equilibration is successful, airflow is from the middle ear to thenasopharynx.

Step IX:-The final tympanogram documents the extent of equilibration.

Riedel et al. (1987) concluded that the inflation procedure least useful as a test of Eustachian tube functions. They also found that in this procedure expected negative direction was obtained in 83% of the subject with a shift greater than 2 daPa in tympanometric peak pressure. McBride, Derkay, Cunningham and Doyle (1988) assessed Eustachian tube function in an normal population of 107 college-age subjects using two non-invasivemethods, Bluestone nine-step inflation-deflation test and sonotubometry.The results showed a 78% agreement between the two methods. The nine-step inflation-deflation test showed a 52% repeatability rate on three sequential test sessions while the sonotubometry test showed a 34% repeatability rate. The combined tests showed a 34% agreement for the three sequential tests. The findings reveal that the combination of the two tests identifies 96% of normal subjects as having at least some tubal function present. Although both tests provide similar information regarding the presence of tubal opening, the sonotubometry method was considered physiologically more accurate. Additional information shows that the average category of the nine-step test in the normal population was in second category. The mean duration of tubal dilation was 0.40 seconds, and the mean middle-ear pressure was -12 mm H_2O.

A Valsalva technique generates only a positive pressure in the middle ear, and often shows equalization after swallowing. Toynbee manoeuvre may generate either a positive or a negative pressure in the middle ear. The anatomical structure of Eustachian tube is such that equalization of positive pressure is easier than of negative pressure (Williams, 1975) however, finding from positive induced pressures alone do not fully describe Eustachian tube function.

Inability to develop negative middle-ear pressure after the Toynbee test or positiveintra-tympanic pressure after the Valsalva test does not differentiate between normal and abnormal tubal function. One disadvantage of these tests is that it is impossible to control the relative amounts of overpressure and under pressure generated in each individual. Some individuals even fail to generate negative pressure during the Toynbee maneuver. To overcome this difficulty, the following tests were developed.

Holmquist's method.

A test developed principally byHolmquist (1969). It measures the ability of the Eustachian tube to equilibrate induced negative middle-ear pressures. The test procedure involves five steps:

1. A baseline tympanogram is recorded to determine the initial middle-ear pressure.
2. A negative pressure is created in the nasopharynx by a pressure device connected to the nose, and the subject is asked to swallow to establish a negative pressure of about-200 mm H_2O in the middle ear.
3. A second tympanogram is recorded to evaluate the exact negative middle-ear pressure achieved.
4. The patient is told to swallow repeatedly (if the tube opens, the pressure is equalized).
5. A third tympanogram is recorded to register the final middle-ear pressure.

Siedentop, Lowey and Osenar (1978) studied Eustachian tube functioning in 15 normal ears and 14 pathological ears of adults with intact tympanic membranes;Eustachian tube function was measured by using tympanometry in an effort to reproduce the results published by Holmquist. In contrast to Holmquist's results, 60% of normal ears were unable to attain achieved negative middle ear pressures of -100 mm to -250 mm H_2O. Normal ears, as well as pathological ears, required repeated swallows to normalize negative pressure. Tests in both of this study groups were not always repeatable even though applied nasopharyngeal pressure was identical. Therefore, these study findings do not substantiate this procedure as a useful, reliable clinical tool for measuring Eustachian tube function in ears with intact tympanic membranes. They described the difficulties that may be encountered in this method and concluded that many subjects could not be tested by this method even though they had normal tympanic membranes and negative otologic histories.

Patulous Eustachian tube test.

A patulous Eustachian tube can be suspected and diagnosis confirmed by otoscopy or objectively by tympanometry when the tympanic membrane is intact (Bluestone, 1980). A baseline tympanogram is obtained while the patient is breathing normally and a second recording is obtained while the patient is holding breath. Fluctuation of the tympanometrictrace that coincides with breathing confirms the diagnosis of a patulous tube. Fluctuation can be exaggerated by asking the patient to occlude one nostril with the mouth closed during forced inspiration and expiration or by performing the Toynbeemanoeuvre.

When the tympanic membrane is not intact, a patulous Eustachian tube can be identified by the free flow of air into and out of the Eustachian tube by using the pump-manometer portion of the electro acoustic -Impedance Bridge. These tests should not be performed while the patient is in a reclining position because the patulous Eustachian tube will remain closed (Bluestone, 1998).

Manometry.

Manometry is simplest techniques involve the placement of an ear canal catheter with an airtight connection between a pressure-monitoring device and the middle-ear cavity. If the tympanic membrane is not intact, the middle-ear pressure is measured directly (intra-tympanicmanometry), butmanometry has been used when the tympanic membrane is intact. The middle-ear pressure must be inferred from the pressure change in the ear canal (extra-tympanicmanometry).

In cases where tympanic membrane is intact or non- intact, it is a closed pneumatic system. Recordings obtained by this method when the tympanic membrane is intact are of little value for assessing tubal function because atmospheric pressure changes the system volume, and the effects of temperature on the system are much more significant than are the small volume displaced by the tympanic membrane with changes in middle-ear pressure. On the other hand, this technique is a valuable tool for intra-tympanic applications when thetympanic membrane is not intact.

In such cases, a middle-ear pressure application device, such as a syringe or an air pump is connected to the ear canal through a valve. These devices help in measuring different levels of middle-ear pressure and the equilibration capacity of the Eustachian tube can be recorded directly as pressure drops after the subject swallows. The first quantitative tubal function study performed byintra-tympanicmanometry was the systematically conducted inflation-deflation test (Ingelstedt&Ortegren ,1963)

Later, numerous investigators employed the same technique to determine tubal function (Holmquist, 1969; Miller, 1965).The next improvement in this technique was the addition of aflowmeter to the manometric system to involve pressure-flow relationships during Eustachian tube function testing(Flisberg, 1966). Bluestone, Cantekin, & Berry (1975) introduced a modified inflation-deflation test by which passive function could also be described by variables such as forced opening pressure and closing pressure of the tube. In addition, a device similar to the ear canal catheter was developed for use with the modified inflation-deflation test so that nasopharyngeal pressure could be measured (Cantekin, Bluestone & Parkin, 1976)

Forced response test.

The forced response test was first described by Cantekin, Saez, Bluestone and Bern (1979). It has been used to evaluate Eustachian tube function in children with ventilation tubes inserted for otitis media and in populations who are at risk for the disease (Bluestone, 2004; Cantekin et al., 1979). Originally this test was used to evaluate Eustachian tube function in the rhesus monkey animal model for normal and abnormal middle ear ventilation.

The current equipment and method of Eustachian tube function test in laboratories and clinics use forced response test. The tympanic membrane must be non-intact and middle ear should be without evidence of middle ear inflammation to perform forced response test.Cantekin et al. (1979) investigated two groups of adults with non-intact tympanic membranes. Six subjects had traumatic perforations of the tympanic membrane and a negative otologichistory while five subjects had perforations as a sequel of otitis media. All the subjects were tested with two methods, the middle ear inflation-deflation technique and forced-response technique. Comparison of both the groups revealed marked differences between normal subjects and patients with middle ear disease. The forced-response test appeared to be a better method to determine degree of actual tubal function.

Doyle,Mandel, Seroky, Swarts and Casselbrant (2013) studied reproducibility of the forced response test in children with chronic otitis media with effusion in 85 children with age range of 36 to 83 months. All the participants had undergone surgery for insertion of bilateral ventilation tubes within 6 weeks. Children with cleft palate or other syndromes, predisposing to otitis media (OM) a history of complications of OM or its treatment were excluded. They identified 39 subjects who had a minimum of three valuable bilateral forced response tests done at an approximate between-test interval of 3 to 4 months. They used bilateral Eustachian tube function modification of the forced response test in each test session, described by Cantekin, Saez, Bluestone and Bern (1979). Results revealed that each subject had 3 measures of the different parameters on 3-month intervals for opening pressure, closing pressure, and dilatory efficiency. For all test parameters, the between-session and between-ear correlation coefficients were significant but the shared variance in the parameters among test sessions and between ears at the same test session was relatively low.

Sniff test.

The sniff test was developed by Magnuson and Falk (1983). The sniff test is a measure of the capacity of the Eustachian tube to protect the middle ear cavity against extreme nasopharyngeal pressure variation. During sniff test procedure the subject is asked to sniff forcefully 3 to 5 times. Since the Eustachian tube should always remain closed to protect the middle ear against negative pressure created in nasopharynx. If the middle ear pressure decreases once or more after sniffing, this shows a poor protective Eustachian tube function.

Falk (1981) studied tympanometry on 100 subjects with healthy ears in order to evaluate their ability to evacuate the middle ear. Fourteen percentage of participants were able to evacuate the middle ear to stable negative pressure ranging from -1.0 to -3.5 kPa with a mean value -1.9 kPa (1 kpa corresponds approximately to 100 mm water). The findings indicated that a sniff-induced negative pressure is not pathological. A temporary negative middle ear pressure induced by sniffing can explain the presence of a type ‘C’ tympanogram in patients with healthy ears. This finding also emphasizes the difficulty in determining the borderline between normal and pathological tympanogram. Falk (1981) reported that the cause of otitis media with effusion in 70% of children is forcible sniffing.

Eustachian tube function test in intact tympanic membrane.

Thomsen (1955) reviewed the various test of Eustachian tube function. Pressure was created in the rhinophyrnx and measured by a manometer. When they increased pressure in 100 mm H_2O steps and at each stage measured the acoustic absorption with Metz Bridge (Shallop, 1976). They found that normally 30 to 100 mm H_2O pressure was needed to open Eustachian tube in normal individuals.

Holmquist (1969) describe a new testing procedure designed for clinical routine in ears with intact tympanic membrane assessed with tympanometry. They studied 11 men and 9 women with intact tympanic membrane in the age range of 23 to 68 years. Eleven pathological subjects were selected on the basis of the history of slight troubles with tubal function in rhinitis, allergy, infection, flying, and diving. They have used the basic instrument for tympanometry or intra- aural reflex indicator. Twenty ears were tested twice with middle ear pressure established through nose range between -100 to -250 mm H_2O. Repeated tests also replicated the negative pressure as that of the initial test. The difference between the two tests for the pressure level recorded after swallowing was below 10 mm H_2O in 18 cases and 40 mm H_2O in two cases. In pathological cases, middle ear pressure was established in the range of -90 to -200 mm H_2O.

Siedentop, Loewy, Corrigan and Osenar (1978) formulated a tympanometric method of assessing Eustachian tube function in individuals with intact tympanic membrane. This method was similar to Holmquist's(1969) procedure. Studies have identified several class such as A, B, C, D, As, Ad, Add, and E (Jerger, 1970; Liden, Harford&Hallen, 1974). Type C is an indication of negative middle ear pressure. Feldman (1976) has suggested that deviation of pressure peak towards negative side is an indication of negative middle ear pressure.

Williams (1975) proposed a tympanometric pressure swallow test to assess Eustachian tube function behind an intact tympanic membrane. Same procedure has been utilised with children (Seidemann& Givens, 1977) as well as in a normal young adult population (Seifert, Seidemann& Givens, 1979). The above authors have demonstrated the validity and sensitivity of William's tympanometric pressure swallow test procedure and support the use of the measurement techniques in evaluating Eustachian tube ventilating efficiency.

Ingelstedt, Ivarson and Jonson (1967) performed an experiment in pressure chamber method. It was shown that tube did not open upon swallowing until chamber pressure reached 450 mm of H_2O relative to the ambient pressure. They also demonstrated the effects of step by step increases of negative pressure in the middle ear. They found that, it was easier to equalize a pressure of -150 mm H_2O than of -100 mm of H_2O. Seidemann and Givens (1977) gave a two parameter analysis of tympanometric Eustachian tube testing in children. The middle ear measurements involve the assessment of the two parameters of pressure and function (Seidemann, Byers &Sisterhen, 1976). The finding obtained in their study were analysed with respect to pressure change and change in middle function. Only slightly greater than one fifth of ears tested (89 ears) in their study demonstrated a pressure change $\geq$ 20 mm H_2O. Thirty four percent of the ears tested did not exhibit change in middle ear pressure following the test procedure while 79% of their population demonstrated function change of ≥ 5%. Only 8% of the ears tested demonstrated no function change.

Seidemann and Givens (1977) examined the variables involved in tympanometric assessment of Eustachian tube function in adults. They made use of Williams (1995) technique. They considered a pressure change of 20 mm H_20 or more and a function change of ≥ 5% as evidence of adequate Eustachian tube function.

Bylander, Tjernstrom, and Ivarsson (1981) compared Eustachian tube function in children and adults with normal ears to measures middle ear pressure and muscular opening function by tympanometry method in a pressure chamber. There were 85 children (44 girls and 41 boys) in the age range of 3-12 years and 92 adults (58 women and 34 men) in the age range of 17-73 years participated in the study. All participants had otologically healthy ears.

Results revealed that middle ear pressure ventilation by muscular opening of Eustachian tube (exhalation/inhalation test) in 61% of children could not equilibrate a relative under pressure in the middle ear of 100 mm H_2O compared with 10% of the adults during deglutition. One third (33%) of the children and one seventh (15%) of the adults showed improved tubal function results with deglutition. Twenty nine children (34%) were unable to open the tube by deglutition alone but 14 out of 29 children were able to opens the tube and improved their results with deglutition. Six children were completely unable to equilibrate the pressure by deglutition. Fourty three percent of the children could not equilibrate any under pressure when compared to 4% of normal adults and 15 children could not even equilibrate any positive pressure. This shows that the muscular opening function in normal children is significantly poorer than normal adults. Middle ear pressure which was recorded before the exhalation/inhalation test showed more negative value in a wider range in children which ranged between +80 to -200 mm H_2O with mean value -29.5mm H_20 in the range of +80 to+200H_20. In adults with mean value -4.2mm H_2O in range of +30 to -80 mm H_2O, while in adults the pressure ranged from +30 to -80 mm H_2O with a mean value of -4.2mm H_2O.

Bylander, Tjernstrom, and Ivarsson (1983) did a comparative study between children and adult with normal ears to measure the pressure opening and closing function. There were 58 children in the age range of 3-12 years (mean age of 7.0 years) and 61 adults in the age range of 17-73 years (mean age of 29.8 years) participated in the study. All individuals were presented with otologically healthy ears. The results revealed poorer function of the exhalation /inhalation test in children than in adult and poorest in youngest children. The pressure opening and closing function which include the passive pressure equilibration function reflects tubal closing forces. However, they did not observe any differences between normal children and adults as well as between different age groups of children.

Groth, Ivarsson and Tjernstrom (1982) examined reliability of the impedance method and a pressure chamber of Eustachian tube function test in 20 individuals with normal healthy ears with age range between 19 -24 years (mean age of 21 years). Results revealed good test retest reliability with better tubal function for all the parameters than in ears with poor tubal functions.

In similar study by Holmquist (1969), it was observed that 85 ears with dry chronic otitis media showed 80% reproducibility within ±1.5 cmH_2O after equilibration of+20cmH_2O and in 101 ears, 65% reproducibility after equilibration of-20cmH_2O.Virtanen (1977) calculated test retest reliability measures in 72 normal ears using sonotubometry. They found 80% reproducibility in sound transmission within 5 dB.Ingelstedt et al. (1974) tested the passive opening function of the Eustachian tube in 18 normal ears. They used the micro flow method in a pressure chamber. Results revealed that of pressure opening level in repeated measurement in single ear was 3.6cmH_2O within a session and between sessions 4.4 cmH_2O. Some authors reported that Eustachian tube function changes during repeated measurements, (Naunton&Galluser, 1967; Cantekin, Bluestone, &Saez, 1976; Groth et al, 1981).

From the review of literature, it is evident that there are several non-invasive techniques to check the function of Eustachian tube. However, the normative data and efficacy of different techniques is not described well. There is a dearth of information in this regard. Hence, present study was taken up to develop a normative for two techniques i.e. Valsalva and Toynbee manoeuvre in Indian population for different age group individuals.

Chapter 3

Method

The present study aimed at developing norms for Eustachian tube function manoeuvre using Valsalva and Toynbee manoeuvre for individuals with intact tympanic membrane. Toaccomplish the above mentioned aim, the following method was adopted.

Participants

A total of 80 individuals with intact tympanic membrane in the age range of 8 to 24 years participated in the study. They were further divided into four subgroups based on their age, group I included individuals in the age range of 8 to 12 years, group II in the age range of 12 to 16 years, group III in the age range of 16 to 20 years and group IV in the age range of 20 to 24 years. Each age group consisted of 20individuals with intact tympanic membrane. The demographic details of the participants are mentioned in Table 3.1

Table3. 1:*Demographic details of the participants*

Group	Gender		N	Mean age (Years)
	Male	Female		
I	16	04	20	10.0
II	10	10	20	14.6
III	07	13	20	18.1
IV	10	10	20	22.2

N: Total number of participants

Participant selection criteria.

All participants were having normal hearing sensitivity in both ears as defined by pure tone threshold ≤ 15dBHL from 250 Hz to 8000 Hz. All participants had 'A' type tympanogram binaurally with both ipsilateral and contralateral acoustic reflexes present at 500Hz, 1000 Hz, 2000 Hz and 4000 Hz. Those participants having any otologic or neurologic history were excluded from study based on a structured case history.

Instrumentation

The following equipments were used in this study:

- A calibrated double channel GSI-61 diagnostic audiometer with TDH-39 headphones was used for obtaining air conduction and bone conduction thresholds with Radioear (B-71) bone vibrator.
- A calibrated Immittance meter (GSI-Tympstar) was used for tympanometry, acoustic reflexes and Eustachian tube function (ETF) tests.

Test Environment

All the testing procedures were carried out in an acoustically treated air-conditioned room, where the noise levels were within permissible limits (ANSI S3.1, 1991).

Procedure

Pure tone thresholds were obtained between 250 Hz to 8000 Hz for air conduction and between 250 Hz to 4000 Hz for bone conduction thresholdsat octave frequency intervals using modified Hughson-Westlake procedure (Carhart&Jerger,

1959). Tympanometry was carried out using probe tone frequency of 226 Hz. Ipsilateral and contralateral acoustic reflexes were measured for 500, 1000, 2000, and 4000 Hz.

The Eustachian tube function manoeuvre was carried out through routine testing protocol with manual setting. The pressure was in the range from +200 daPa to -400 daPawith pressure rate 50 daPa/sec selected for the study. Each subject was made to sit comfortably on a chair. Prior to the testing, subject was instructed not to move, swallow, cough, clearing throat and/or sniff. A rubber probe tip was used to get tight seal, forming a close cavity bounded by the inner surface of the probe tip, the wall of the external ear and the tympanic membrane. Before performing maneuver, a baseline recording of tympanogram was obtained. Participants were asked to swallow only after or before the recording & to avoid while recording is going on. In order to study Eustachian tube function, the following manoeuvres were performed.

Valsalva manoeuvre procedure.

Step 1:-Baseline tympanogram was recorded using 226 Hz probe tone frequency.

Instruction to the participants "*Each individual was instructed to pinch the nares with mouth closed until the ears feel full and inflate the cheeks through forced expiration. Then individual was asked to release the nose and to refrain from swallowing"*.

Step 2:- 2nd recording of tympanogram was done.

Toynbee manoeuvre procedure.

Step 1:-Baseline tympanogram were recordedusing 226 Hz probe tone frequency.

Instruction to the participants "*Each individualwas instructed to swallow twice while pinching the nares. Afterward, the individual was asked to release the nares and not swallow".*

Step 2:- 2^{nd} recording of tympanogram was done.

Both manoeuvres were performed one after the other. For half of the individuals, first Valsalva manoeuvre was performed followed by Toynbee manoeuvre. While for the other half of the participants Toynbee manoeuvre was performed initially and Valsalva manoeuvre later. It was done to minimize the effect of one test on other test order effect. Similarly half of the participant's left ears were tested first and for the remaining half first right earswas tested to minimize ear effect for both the manoeuvres. In order to check the test-retest reliability, Eustachian tube function manoeuvre wasrepeated for 10 percent of the population after a month.

Statistical Analysis

Descriptive statistics, non-parametric tests (Kruskal Wallis tests, Mann Whitney U tests and Wilcoxon sign rank test) and Cronbach's alpha test was used to analyse the data using SPSS (version 20). Further, Cronbach's alpha test was done to check test-retest reliability of the Valsalva and Toynbee manoeuvre.

Chapter 4

Result and Discussion

This study was done to develop normative for Eustachian tube function manoeuver (Valsalva & Toynbee) in individuals belongs to different age group having intact tympanic membrane. The data obtained from 80 participants were analysed using SPSS software. The analysis was done to obtain

i) Normative for Valsalva and Toynbee manoeuvre technique

ii) Test-retest reliability of the Valsalva and Toynbee manoeuvre

To accomplish the above results, the following statistical tests administered which include descriptive statistics, non-parametric tests (Kruskal Wallis tests, Mann Whitney U tests and Wilcoxon sign rank test) and Cronbach's alpha test. Non-parametric tests were chosen because of higher standard deviation observed in the descriptive statistics. Further, Cronbach's alpha test was done to check test-retest reliability of the Valsalva and Toynbee manoeuvre.

Valsalva manoeuvre

The mean, median and standard deviation of Valsalva manoeuvre obtained from four different age groups (Group I, II, III, & IV) are included in Table 4.1. For baseline recording, the mean (SD) values are in the range of -2.00 (20.20) daPa to 6.75 (6.54) daPa including both ears across the different age groups. Further, it is noticed that SD is very high even for baseline measurements which show high variability among each age group. However, for Valsalva manoeuvre the mean (SD) values are in the range of -1.25 (15.12) daPa to 22.50 (25.46) daPa including both right and left ear across different age groups. The above finding indicates the positive shift of peak pressure from the baseline during Valsalva manoeuvre.

Table 4.1: Mean, median and standard deviation (SD) for Valsalva manoeuvre

Group	Ear	N	Baseline (daPa)			Valsalva(daPa)		
			Mean	SD	Median	Mean	SD	Median
8-12 years	RE	20	-2.00	20.22	7.50	5.25	22.50	10.00
	LE	20	1.50	15.73	15.73	13.00	23.86	20.00
12-16 years	RE	20	3.75	9.01	7.50	22.50	16.97	17.50
	LE	20	0.25	24.99	-2.50	22.25	29.13	27.50
16-20 years	RE	20	6.75	6.54	5.00	7.75	8.50	10.00
	LE	20	-1.75	15.58	0.00	-1.25	15.12	0.00
20-24 years	RE	20	3.00	8.64	2.50	22.50	25.46	15.00
	LE	20	3.75	21.69	5.00	19.25	35.80	12.50

N=Number of ears; RE= right ear; LE: left ear; SD= standard deviation

In the present study, the difference in peak pressure shift from baseline to Valsalva manoeuvre is in the range of 0.50 daPa to 22.00 daPa. Table 4.2 shows the peak pressure shift from baseline for both right and left ear after performing Valsalva manoeuvre. The peak pressure shift for Valsalva manoeuvre is highest for group II (12-16 years) followed by group IV (20-24 years) in comparison to group I (8-12 years), and III (16-20 years).

Table 4.2: Peak pressure shift from baseline for different age groups

Age Groups	N	EAR	Baseline (daPa)	Peak pressure shift (Baseline-Valsalva)
8-12 years	20	RE	-2.00	7.25
	20	LE	1.50	11.50
12-16 years	20	RE	3.75	18.75
	20	LE	0.25	22.00
16-20 years	20	RE	6.75	1.00
	20	LE	-1.75	0.50
20-24 years	20	RE	3.00	19.50
	20	LE	3.75	15.50

N=Number of ears; RE= Right ear; LE: Left ear

The finding of the present study is in agreement with study done by Riedel et al. (1987). They obtained mean peak pressure shift for the Valsalva procedure 63 daPa. The maximum peak pressure shift recorded was 284 daPa. However, the maximum pressure shift is quite higher side in comparison to the present study.

Table 4.3: Number of ears peak pressure shift in different directions for Valsalva manoeuvre

Group	N	Ear	Expected	Direction of shift opposite	No shift
I	20	RE	11	01	08
		LE	15	02	03
II	20	RE	19	00	01
		LE	17	02	01
III	20	RE	09	06	05
		LE	06	06	08
IV	20	RE	19	00	01
		LE	17	02	01

N=Number of ears; RE= Right ear; LE: Left ear

The results of the present study showed peak pressure shift towards positive pressure direction as expected during Valsalva manoeuvre. However, there are few ears in which shift is seen in opposite direction or no shift. Table 4.3 shows shift in peak pressure towards expected (positive) direction for 70.6% of ears and for 11.8% of ears opposite (negative) to the expected direction. However, there was no shift in peak pressure observed for 17.5% of ears for Valsalva manoeuvre.

Riedel et al. (1987) also obtained similar pattern of the ears for which a pressure shift was produced in the expected (positive) direction, in the opposite direction and no shift. Out of 48 ears, they found that 94% of ears in the expected direction, 4% in the opposite direction and 2% with no shift. They considered no shift if the difference between baseline and Valsalva manoeuvre was less than 2 daPa. The percentage of ears in the present study for opposite pressure shift and no shift was a little higher in comparison to the Riedel et al. (1987) study. The causes for difference in percentage are not known but may be because of differences in methodology between the two studies.

In another study done by Makibara, Fukunaga and Gil (2010), the mean range for baseline was observed at -15.67 daPa and -9.71 daPa for right and left ear.

Similarly, for Valsalva manoeuvre the mean range was 48.33 daPa and 41.81 daPa for right and left ear. They also showed positive (expected) shift on Valsalva manoeuvre for most of the individuals with intact tympanic membrane.

Kruskal-Wallis test was performed to analyse any significant difference in pressure between any groups. This was carried out separately in right and left ear as well as three conditions (baseline, Valsalva and Toynbee).

Table 4.4: Kruskal-Wallis test outcomes across age groups for Valsalva manoeuvre

Parameters	Ear	χ^2	df	p-value
Baseline	RE	2.62	3	0.453#
	LE	1.38	3	0.709#
Valsalva	RE	11.15	3	0.011*
	LE	11.80	3	0.008**

RE= Right ear; LE= Left ear; χ^2= Chi-square; *p<0.05; **p<0.01; #p>0.05

Table 4.4 represents the outcomes of Kruskal Wallis test across different age groups, there were no statistical significant difference observed for baseline recording for both right and left ear. However, there were statistically significant differences noticed in both ears for Valsalva manoeuvre at 0.05 levels.

Table 4.5: Mann Whitney U test outcome in Valsalva for different age groups

Age groups	Ears	Group II (12-16 yrs)		Group III (16-20 yrs)		Group IV (20-24 yrs)	
		RE	LE	RE	LE	RE	LE
Group I (8-12 yrs)	RE	S*		NS		NS	
	LE		NS		S*		NS
Group II	RE			S**		NS	
	LE				S**		NS
Group III	RE					S*	
	LE						NS

RE= Right ear; LE= Left ear; S= significant; NS= not significant; *p<0.05; **p<0.01

Further, Mann Whitney U test was done to check the difference between different age groups. The results revealed that for Valsalva manoeuvre, there were statistically significant differences observed for both ears in group II versus III only. However, no statistically significant differences noticed for both ears in group I versus IV and group II versus IV. For other groups, either right ear or left ear showed significant differences.

Wilcoxon signed rank test was done to check the pair wise compassion for both ears for each age groups separately. The results revealed that there is a statistically significant difference between baseline and Valsalva test for both right and left ear for group I, II and IV at 0.05 levels. However, significant differences were not observed for group III at 0.05 levels. The reason for non-significance is not known at one particular group. When raw data was visually seen, it was noticed that there is heterogeneity in group III data among individuals. The statistical outcome for each age group is shown in table 4.6.

Table 4.6: Wilcoxon sign rank test for pair wise comparison in each age group

Age groups	Pair wise comparisons	Z-value	p-value
Group I	Baseline RE-Valsalva RE	-2.886	0.004**
	Baseline LE-Valsalva LE	-2.807	0.005**
Group II	Baseline RE-Valsalva RE	-3.840	0.000***
	Baseline LE-Valsalva LE	-2.784	0.005**
Group III	Baseline RE-Valsalva RE	-0.544	0.586#
	Baseline LE-Valsalva LE	-0.535	0.593#
Group IV	Baseline RE-Valsalva RE	-3.083	0.002**
	Baseline LE-Valsalva LE	-2.108	0.035*

RE= Right ear; LE= Left ear; *p<0.05; **p<0.01; ***p<0.001; #p>0.05

Toynbee manoeuvre

Toynbee manoeuvre is a technique used to develop negative pressure in middle ear to check the patency of Eustachian tube in individuals with intact tympanic membrane. Table 4.7 includes mean, median and standard deviation (SD) for thefor baseline and Toynbee manoeuvre four different age groups (8-24 years).

Table 4.7: Mean, median and standard deviation (SD) for Toynbee manoeuvre

Group	Ear	N	Baseline (daPa)			Toynbee (daPa)		
			Mean	SD	Median	Mean	SD	Median
8-12 years	RE	20	-2.00	20.22	20.22	-14.00	18.95	-12.50
	LE	20	1.50	15.73	15.73	-1.50	20.46	-2.50
12-16 years	RE	20	3.75	9.01	9.01	-21.75	25.14	17.50
	LE	20	0.25	24.99	24.99	-26.25	26.60	-22.50
16-20 years	RE	20	6.75	6.54	6.54	-4.50	20.70	-5.00
	LE	20	-1.75	15.58	15.58	-7.75	23.81	-7.50
20-24 years	RE	20	3.00	8.64	8.64	-40.25	42.22	-40.00
	LE	20	3.75	21.69	21.69	-31.75	32.89	-40.00

N=Number of ears; RE=right ear; LE: left ear;

The mean (SD) value for baseline in right ear is from -2.00 (20.22) to 6.75 (6.54) and for left ear is from -1.75 (15.58) to 3.75 (21.69) across different age groups. Similarly after Toynbee manoeuvre, the mean (SD) value in right ear is from -4.50 (20.70) to -40.25 (42.22) and for left ear is from -1.50 (20.46) to -31.75 (32.89) across different age groups. Similar finding was obtained in earlier studies (Riedel et al., 1987; Makibara et al., 2010).

Table 4.8: Peak pressure shift from baseline to Toynbee manoeuvre

Group	N	EAR	Baseline (daPa)	Peak pressure shift (Baseline-Toynbee)
8-12years	20	RE	-2.00	12.00
	20	LE	1.50	3.00
12-16 years	20	RE	3.75	25.50
	20	LE	0.25	26.50
16-20 years	20	RE	6.75	11.25
	20	LE	-1.75	6.00
20-24 years	20	RE	3.00	43.25
	20	LE	3.75	35.50

N=Number of ears; RE= right ear; LE: left ear;

Table 4.8 shows that the peak pressure shifts from baseline for both right and left ear after performing Toynbee manoeuvre. The peak pressure shift for Toynbee manoeuvre is highest for group IV (20-24 years) followed by group II (12-16 years) in comparison to group I (8-12 years), and III (16-20 years).

Riedel et al. (1987) found that the mean for baseline 9 daPa and mean for 2nd recording after manoeuvre was at -6 daPa. The confidence interval ranges for baseline was 7 to 11 and for after manoeuvre -17 to 5. Hence, the overall shift was reported to be -15 daPa for Toynbee manoeuvre in individuals with intact tympanic membrane. In another study done by Makibara et al. (2010) obtained mean (SD) value for right and left ear in the range of -26.05 (9.65) and -23.90 (17.67) for Toynbee procedure respectively.

Table 4.9: Peak pressure shift in different directions for Toynbee manoeuvre

Group	N	EAR	Expected	Direction of shift opposite	No shift
I	20	RE	15	01	04
		LE	12	06	02
II	20	RE	15	04	01
		LE	16	02	02
III	20	RE	10	07	03
		LE	09	07	04
IV	20	RE	15	04	01
		LE	16	02	02

N=Number of ears; RE= Right ear; LE: Left ear

Table 4.9 represents the peak pressure shift for Toynbee manoeuvre for all the age groups. It can be found that there are 67.5% of ears show shift in peak pressure towards expected (negative) direction for Toynbee manoeuvre. However, 20.6% of ears show shift in peak pressure in opposite (positive) direction and 11.8% of ears show no shift. Study done by Riedel et al. (1987) obtained similar finding. They showed 67% of ears towards the expected (negative) direction and 29% of ears opposite (positive) to the expected direction and 4% showed no shift for Toynbee procedure. In another study done by Elner et al. (1971), the results revealed negative pressure shift in 47 individuals and positive shift in 9 individuals out of 74 individualswith intact tympanic membrane.

Table 4.10: Mann Whitney U test for different age groups comparisons in Toynbee manoeuvre

Age groups	Ears	Group II (12-16 years)		Group III (16-20 years)		Group IV (20-24 years)	
		RE	LE	RE	LE	RE	LE
Group I (8-12 years)	RE	NS		NS		S*	
	LE		S*		NS		S*
Group II	RE			S*		NS	
	LE				S*		NS
Group III	RE					S**	
	LE						S*

RE= Right ear; LE= Left ear; *p<0.05; **p<0.01; ***p<0.001; #p>0.05

Further, Mann Whitney U test was done to check difference between different age groups (table 4.10). The results revealed that for Toynbee manoeuvre, there were statistically significant differences observed for both ears in group I versus IV and group III versus IV at 0.05 levels. However, no statistically significant differences noticed for both ears in group I versus III and group II versus IV at 0.05 levels. For other groups, either right ear or left ear showed significant differences.

Table 4.11: Kruskal-Wallis test outcomes across age groups for Toynbee manoeuvre

Parameters	Ear	χ^2	df	p-value
Baseline	RE	2.62	3	0.453#
	LE	1.38	3	0.709#
Toynbee	RE	11.46	3	0.009**
	LE	15.76	3	0.001***

RE= Right ear; LE= Left ear; χ^2= Chi-square; **p<0.01; #p>0.05

Table 4.11 represents the outcomes of Kruskal-Wallis test across different age groups. The results showed there were no statistical significant difference observed for baseline recording in right and left ear. However, there were statistically significant differences noticed in both ears for Toynbee manoeuvre at 0.05 levels.

Table 4.12: Wilcoxon signed rank test for pair wise comparison in each age group

Age groups	Pair wise comparisons	Z-value	p-value
Group I	Baseline RE-Toynbee RE	-3.361	0.001**
	Baseline LE- Toynbee LE	-746	0.456#
Group II	Baseline RE- Toynbee RE	-3.471	0.001**
	Baseline LE- Toynbee LE	-3.634	0.000***
Group III	Baseline RE- Toynbee RE	-2.430	0.015**
	Baseline LE- Toynbee LE	-1.427	0.154#
Group IV	Baseline RE- Toynbee RE	-3.529	0.000***
	Baseline LE- Toynbee LE	-3.505	0.000***

RE= Right ear; LE= Left ear; *p<0.05; **p<0.01; ***p<0.001; #p>0.05

Wilcoxon signed rank test was done to check the pair wise comparison for both ears for each age groups separately (table 4.12). The results revealed that there is a statistically significant difference between baseline and Toynbee test for both right and left ear for group II and IV at 0.05 levels. However, significant differences were not observed for group I and III left ear at 0.05 levels.

Effect of aging on Valsalva and Toynbee manoeuvre

Kruskal Wallis test was done to see the comparison across different age groups for both Valsalva and Toynbee manoeuvre. The results revealed that for Valsalva manoeuvre there were statistically significant differences observed for both left (χ^2= 11.80, df=3, p<0.008) and right (χ^2= 11.15, df=3, p<0.011) ear. Similarly for Toynbee manoeuvre there were statistically significant differences noticed for both left (χ^2= 15.76, df=3, p<0.001) and right (χ^2= 11.46, df=3, p<0.009) ear.

Study done Bylander et al. (1983) showed that pressure equilibrium capacity differs in children and adults. They found that younger children (3-5 years) are having poorer equilibrium capacity than older (6-12 years) children. However, older children performance was similar to adults (17-73 years). They presume that differences in finding could be because of immature neuromuscular function which improves with age. As per Holborow (1970, 1975) finding, the tubal and peritubal anatomy changes throughout childhood and that may be influencing the efficiency of the tubal muscular mechanism. The above finding is also supported by Bylander and Tjernstrom (1983). They revealed that a change in Eustachian tube function in young children (3-12 years) is not only because of anatomical changes rather immaturity of the neuromuscular system during childhood.

Figure 4.1, 4.2, 4.3 and 4.4 show the median peak pressure for baseline, Valsalva and Toynbee manoeuvre in both ears for intact tympanic membrane in different age groups. Figure 4.1 to 4.4, it can be very clearly observed that the median peak pressure is higher for Valsalva and Toynbee in comparison to baseline measurement. However, the median value is in positive direction for Valsalva and in negative direction for Toynbee manoeuvre.

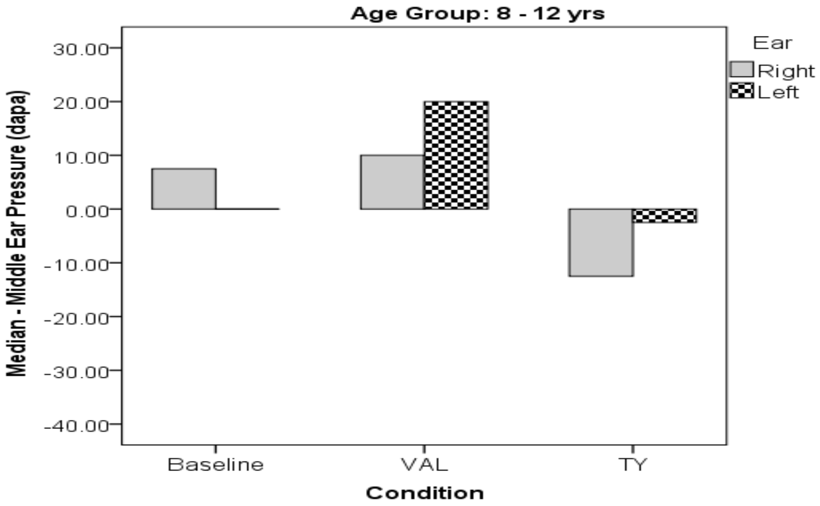

Figure 4.1: Median middle ear pressure for group I (8-12 years) for Valsalva and Toynbee manoeuvre (VAL: Valsalva; TY: Toynbee)

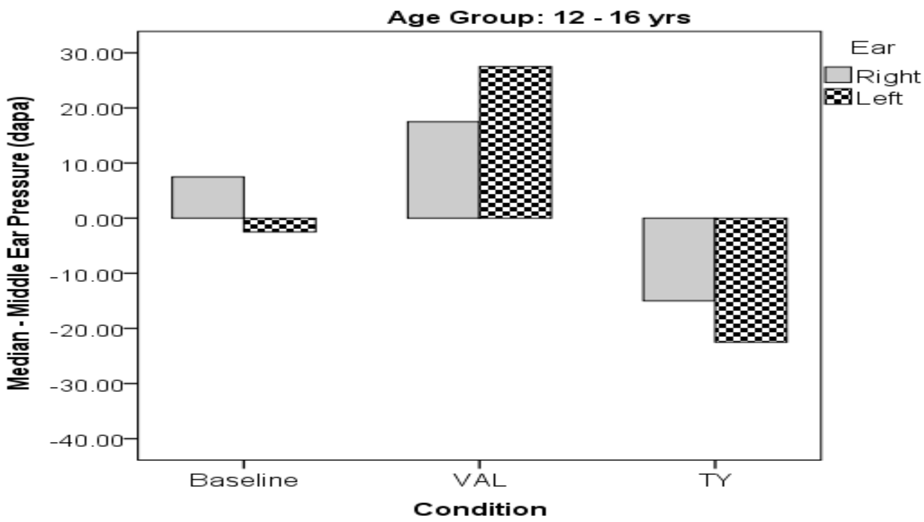

Figure 4.2: Median middle ear pressure for group II (12-16 years) for Valsalva and Toynbee manoeuvre (VAL: Valsalva; TY: Toynbee)

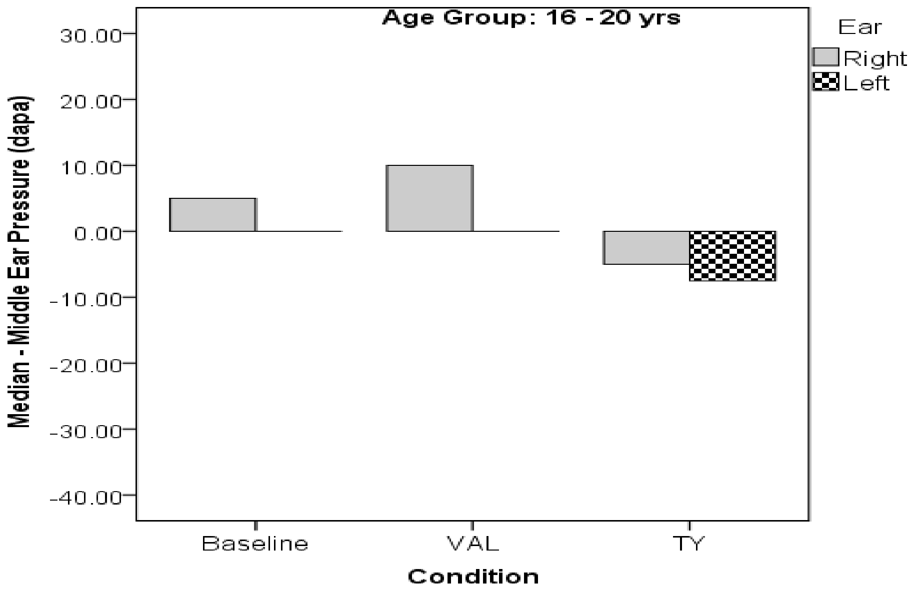

Figure 4.3: Median middle ear pressure for group III (16 -20 years) for Valsalva and Toynbee manoeuvre (VAL: Valsalva; TY: Toynbee)

Figure 4.4: Median middle ear pressure for group IV (20 -24 years) for Valsalva and Toynbee manoeuvre (VAL: Valsalva; TY: Toynbee)

Test-retest reliability of Valsalva and Toynbee manoeuvre

Test retest analysis of Valsalva and Toynbee test was done for 10 % population of total data collected. The Cronbach's alpha was a statistical tool used to check test retest reliability of both the manoeuvre. The results of the study revealed that there is excellent test retest reliability for both Valsalva and Toynbee manoeuvre.

Table 4.13: Cronbach's alpha value of Valsalva and Toynbee manoeuvre

	Ear	α
Baseline	RE	0.91
	LE	0.92
Valsalva	RE	0.91
	LE	0.87
Toynbee	RE	0.97
	LE	0.92

RE; Right ear; LE: Left ear; α: Cronbach's alpha

Table 4.13 show that Cronbach's alpha value greater than 0.87 for right and left ear for baseline, Valsalva and Toynbee manoeuvre. As per classification described by Versino, Colnaghi&Callieco (2001), Cronbach's alpha value greater than or equal to 0.7 is considered as excellent reliability. Hence, present study revealed excellent reliability for both the tests.

Study done to check reliability in tests of the Eustachian tube function by Groth et al. (1982) is in support of present finding. They also observed good test-retest reliability in individuals with intact tympanic membrane. They checked different parameters such as pressures opening levels, pressure difference and static pressure equilibrium capacity. Further, they also found that those ears with perfect tubal function had better test retest reliability in comparison to ears with poor tubal function.

Chapter - 5

Summary and Conclusion

The abnormal function of Eustachian tube in individuals with intact tympanic membrane leads to negative middle ear pressure. Eustachian tube dysfunctions are mostly seen young children than adults. Otitis media is one of the most common problems seen in children and adults due to abnormal function of Eustachian tube. Individual with intact tympanic membrane maintain atmospheric pressure or ambient pressure at 0 daPa within middle ear cavity by the periodic opening of Eustachian tube during swallowing, yawing, coughing etc.

Eustachian tube function test helps to identifying abnormal functioning of Eustachian tube. There are non-invasive test to measures Eustachian tube function in individuals with intact tympanic membrane such asTympanometry, Valsalva manoeuvre, Toynbee manoeuvre, and Inflation and deflation test. Hence, present study was conducted with the aim of developing normative data for Eustachian tube function tests using Valsalva and Toynbee manoeuvre in individuals with intact tympanic membrane. Both the technique was used on 80 individuals age ranged from 8 to 24 years. They were further divided into four different age groups (8-12 years, 12-16 years, 16-20 years, & 20-24 years) to see effect of aging on Eustachian tube function tests. Further, test-retest reliability of above tests on ten percent of total individuals was also checked.

The results revealed that there was no statistical significant difference observed for baseline recording between right and left ear across different age groups. However, there were statistical significant differences seen across different age groups for Valsalva and Toynbee manoeuvre for both or either right and left ear at 0.05 levels.

For Valsalva manoeuvre, in the present study the difference in peak pressure shift from baseline is in the range of 0.50 daPa to 22.00 daPa. The pressure shift observed in expected (positive) direction for 70.6% of total individuals participated in the study. Similarly, for Toynbee manoeuvre, the difference in peak pressure shift from baseline is in the range of 3.00 daPa to 43.25 daPa. The pressure shift observed in expected (negative) direction for 67.5% of the total individuals participated in the study. However, the standard deviation for both the tests was found to be higher for all the age groups in spite of expected direction of shift in peak pressure. Hence, while using for clinical population professional needs to be careful taking consideration of norms for different age groups. Present study recommends focusing on direction of shift for both the manoeuvre rather than the amount of shift. Since there is wide range in terms of amount of shift either for Valsalva or Toynbee manoeuvre.

Test-retest analysis test were done using Cronbach's alpha statistical tool. The results showed scores greater than 0.87 for right and left ear for baseline, Valsalva and Toynbee manoeuvre. The above scores indicate high test-retest reliability for individual with intact tympanic membrane.

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