Critical Review:
Which tympanic measures (multifrequency or standard) are effective for detecting otosclerosis in patients with middle ear disorders?

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This critical review examines whether multifrequency tympanometry is more effective than standard tympanometry for detecting otosclerosis in adults with middle ear disorders. Study designs included: one Non-randomized Clinical Trial- (between and within groups), four Non-randomized Clinical Trial- Mixed (between). Overall, the evidence indicates that multifrequency tympanometry provides a more efficient technique in detecting otosclerosis than standard tympanometry.

Introduction

Otosclerosis is a disease which affects the ossicles of the middle ear cavity leading to a gradual conductive hearing loss. The normally hard bone of the otic capsule and ossicles are replaced with a vascular spongy bone (Castillo & Roland, 2007) inhibiting the systems proper movement. Chen et al (2002) stated that "otosclerosis is the single most frequent cause of conductive hearing impairment among Caucasian adults, with an estimated prevalence of 2 to 10 per 1000 in a clinical population" (as cited in Shahnaz et al, 2009).

Currently, the audiometric measure used to diagnose otosclerosis is standard tympanometry using a frequency of 220Hz. As there are other sources of conductive hearing loss, it is difficult to diagnose otosclerosis using only this one frequency. For example, malleus/incus fixation, ossicular discontinuity, congenital ossicular malformation, otitis media, and cholesteatoma all have similar presentations for tympanometry. Therefore, according to Naumann et al (2005), it is very important for a clinician to be able to rule out these other sources of conductive hearing loss before diagnosing otosclerosis (as cited by Shahnaz et al, 2009).

When diagnosing otosclerosis, status of tympanic membrane and the presence of an air-bone gap is very important (Van Camp & Vogeleer 1986). If the tympanic membrane has a disorder that increases its mobility, otosclerosis could potentially be masked. Every study in this critical review monitored the status of the tympanic membrane and omitted participants in which the tympanic membrane was compromised.

In addition to standard tympanometry, another way in which otosclerosis can be diagnosed is through computed tomography. However, as stated by Naumann et al (2005) this technique is very expensive, exposes the individual to radiation and has poor sensitivity (as cited in Shahnaz et al, 2009). Therefore an approach that can effectively detect otosclerosis, that is cost effective and also noninvasive would benefit the health care system, patients and medical professionals treating these individuals. The specific measures focused on in this critical review compare standard tympanometry, multiple frequency, multicomponent tympanometry, and resonant frequency and F45 admittance phase angle.

Objectives

The primary objective of this paper is to critically evaluate existing literature regarding the specific measures used to effectively detect otosclerosis in patients with middle ear disorders. The secondary objective is to propose an evidence-based recommendation about specific measures for persons with otosclerosis.

Methods

Search Strategy

Computerized databases, including PUBMED and Ovid (Medline) were searched using the following search strategy: ((wideband reflectance and acoustic)) OR ((multifrequency and (immittance or admittance or tympanometry or tympanogram or impedance) and acoustic)) AND otosclerosis. The search was limited to articles written in English.

Selection Criteria

Studies included in this review were required to examine specific measures of middle ear dysfunction that are effective in detecting otosclerosis. The search was limited to the adult population and must include a population with otosclerosis. The search strategy resulted in a total of nine papers. Three papers were excluded because they do not include a population with otosclerosis. Another paper was a review article which did not include any data therefore; it will not be used in this critical review. Consequently, a total of five papers will be used in this systematic review of the literature.

Data Collection

Results of the literature search yielded 5 studies: Between Non Randomized Control Trial (4) and Between and Within Groups Non Randomized Control Trial (1).

Results

Study 1

The purpose of the study by Causse, Bel, Causse, Vernieres, Sermay and Desire (1977) was to investigate the benefit of multifrequency impedance testing in relation to stapedial fixation in otospongiosis (an early phase of otosclerosis) and other factors including Sensory Neural Hearing Loss, middle ear disorders other than otospongiosis and otospongiosis associated with other factors. The study design was a Non-randomized control Trial between and within groups which is an evidence Level 2a. According to Coletti (1975), the differences in tympanogram shape showed that changes occur when a frequency range of 200-2000Hz is used as cited by Causse et al. (1977).

Research was gathered using a Madsen ZO-70 impedance bridge; X-Y Hewlett-Packard, type 7010 A recorder; Tekelec sinusoidal generator, type TE500A; Tektronix two-channel oscilloscope, with a two-way sensitive control. All research was collected in sound-proof booths. Out of the 175 participants, 99 had pure otospongiosis giving a total of 158 ears which could be tested. The tympanograms were grouped according to their types. This was done to establish a correlation between the groups of tympanograms and the anatomical findings which were found during operations. (p. 343).

Causse et al. found that a peak inversion occurred at 1200Hz for normal hearing ears but did not occur for individuals with otospongiosis. Whereas at 1650Hz, the peak inversion is more marked in normal hearing ears than those with otospongiosis. In summary, the authors investigated how different techniques affect the tympanogram. The authors state that they were able to determine the limits of multifrequency testing.

Despite the large sample size and good study design, weaknesses in the analysis of this data limit interpretation of the evidence. Although there appears to be evidence to suggest that multifrequency tympanometry can be used to detect otosclerosis, this study failed to analyze the data in such a way as to allow for reliable conclusion.

Study 2

Van Camp and Vogeleer (1986) set out to measure the acoustic properties of individuals with otosclerosis and individuals with normal hearing. The purpose of the study was to assess acoustic resistance, reactance and phase angle for two discreet probe tone frequencies (220 and 660Hz). In a Non-Randomized Clinical Trial between subjects, an evidence Level 2a, the authors surveyed 29 otosclerotic ears and 30 individuals with normal hearing.

The data was collected with an Otoadmittance meter connected to a two-channel X-Y recorder (Houston Instruments model 2000) which was calibrated daily. This apparatus creates a phasor tympanogram which plots the susceptance and conductance simultaneously. Each ear was preconditioned for the testing. The ear canal pressure was lowered to -400daPa and released. This helped to reduce immitance shifts that can occur with repetitive testing.

The data which includes mean, median, standard deviation, 10 and 90% intervals, skewness g_1 and kurtosis g_2, is presented for the group with otosclerosis while the mean and standard deviation is presented for the normal hearing group. However, there is no statistical analysis done with this data; only descriptive analysis is reported. When comparing the mean and standard deviation in the two groups at 220Hz, there does not appear to be a significant difference. These results are what would be expected, as this frequency is not affective in detecting certain middle ear disorders such as otosclerosis. However, when 660Hz is compared between the two groups, the mean is quite different but the standard deviation is so great that no conclusions can be made from the data. It cannot be concluded whether these results are statistically significant. Another limitation is that no audiometric data was given for the otosclerotic group so it is unclear whether an air-bone gap was present in the participants as it is the air-bone gap that usually indicates otosclerosis. Therefore, this study is inconclusive as to whether tympanometry at 660Hz is more effective at detecting otosclerosis than tympanometry at 220Hz.

Study 3

In 1997, Shanaz and Polka conducted a Non-randomized Control Trial between groups (Evidence Level 2a) to determine which tympanometric parameter was most effective at detecting otosclerosis. This study included fourteen individuals who had been diagnosed with otosclerosis and were scheduled for surgery, and thirty-six normal hearing adults. Out of the fourteen individuals, ten participants had a purely conductive component while four had mixed hearing loss. A Grason-Stadler (GSI-16) was used for pure-tone audiometry and a Virtual System (model 310) was used to perform the high-frequency tympanometry.

There were nine tympanometric measures examined; static admittance (SA), tympanometric width (TW), resonant frequency (RF) at standard 226Hz. Four other measures of resonant frequency were taken from sweep pressure recordings (SP) and sweep frequency recordings (SF), and finally, two estimates of the frequency corresponding to 45° admittance phase angle (one from SP recordings, the other from SF recordings).

The researchers investigated nine various measurements to determine which one was best at detecting otosclerosis. Analysis of the data was done by evaluating two criteria which define normal function in the current literature. These include 1) values which fall within the 95% confidence interval around the mean and 2) values which fall within the 90% range. This classification data for each measure of test performance was computed and compared. According to Shahnaz and Polka, A' is a way of measuring the test performance in which the "HT rate is adjusted by the rate of false positives. To achieve a high A' score, a test must have both a high HT rate and low FA rate" (p.9). Of the nine tympanometric measures, F45° :SF was the best single tympanometric measure for differentiating normal and otosclerotic ears.

The clinical implications of this study are that resonant frequency and the frequency corresponding to 45° phase angle be used to detect otosclerosis.

<u>Study 4</u>

Miani, Bergamin, Barotti and Isola (2000) evaluated the acoustic admittance characteristics of three different groups; individuals with fenestral otosclerosis unilaterally, another group with bilateral otosclerosis, and individuals with normal hearing. The outcome measures of acoustic admittance characteristic studied include resonance frequency (RF), acoustic conductance value (G) at RF and the interaural differences for individuals with unilateral otosclerosis.

In a Non-randomized Control Trial between and within groups (Evidence Level 2a), Miani et al (2000) evaluated 70 ears of individuals with otosclerosis; 16 cases were unilateral (Cos ears) and 27 cases (54 ears) were bilateral (Os). The inclusion criterion for the Os group was the presence of a conductive gap in frequencies between 250 and 2000Hz greater than 10dB, and surgical confirmation. The 16 individuals with unilateral otosclerosis presented with a less than or equal to 10dB air-bone gap in their normal ear. The control group, which consisted of 24 normal hearing individuals, had pure-tone thresholds of greater than 10dB HL. After a normal tympanic membrane was verified in all of the participants, a multifrequency admittance evaluation with fast probe-tone frequency was performed.

Group comparisons were made between the normal hearing control group and individuals with unilateral otosclerosis being measured contralaterally. The means of the results were made with Student's two-tail t-test for independent samples. The statistical comparisons were also verified with a non-parametric test. Results indicate a statistically significant difference in RF between the otosclerotic ears and the normal hearing ears.

The authors concluded that multi-frequency multi-component tympanometry is an appropriate assessment in difficult to diagnose cases of otosclerosis.

<u>Study 5 Non-randomized Clinical Trial Mixed Between and Within Groups (2a)</u>

Shahanz, Bork, Polka, Longridge, Bell and Westerberg (2009) compared conventional and multifrequency tympanometry (MFT) in their ability to distinguish between otosclerotic ears and normal ears. The study included 62 normal hearing adults and 28 individuals with surgically confirmed otosclerosis. The population of the control group was solely Caucasian as otosclerosis occurs mostly within this population. However, one quarter of the otosclerotic group was non-Caucasian with 2 individuals being Chinese, 1 Hispanic, 4 East Indian and 1 Filipino. Otoscopy and pure tone audiometry was done for all participants along with a standard 226Hz tympanogram. Following that, high probe-tone frequency tympanograms were performed using sweep frequency and sweep pressure recording methods.

Tympanometric data such as static admittance and tympanometric width were measured using a 226Hz frequency. Multicomponent tympanometry was used to establish resonant frequency and frequency corresponding to admittance phase angle of 45 degree (F45°). A mixed-model ANOVA was conducted for the F45° using Condition (otosclerotic ears versus normal ears) and sex (male versus female). Shahnaz et al. found that the main effects of Condition were significant while the main effect of sex was not significant. A second mixed-model ANOVA was conducted for RF using Condition and sex. Similar to F45̊, there was a significant difference between condition and no significant difference between sexes. The authors used ROC plot analysis in order to compare F45̊ and Resonant Frequency using positive and negative compensation, and Conventional 226Hz tympanometric measures for determining optimal techniques for diagnosing otosclerosis.

In summary, the purpose of this study was to determine which of these measures is best able to detect otosclerosis. Otosclerosis was detected in all but one of the 28 subjects. However, 5 out of the 28 cases with otosclerosis were not identified with either RF, F45̊, or Static Admittance but they were all detected by looking at tympanic width alone. The authors indicate that "this pattern suggests that information provided by tympanic width is supplementary to the information provided by other tympanometric variables" (p.226). The validity and importance of this study is compelling as it indicates a significant difference between conventional tympanometry and multi-frequency tympanometric parameters.

Discussion

The first two studies do not include any statistical analysis of their data, therefore it is not possible to conclude whether or not their findings have clinical implications. Both studies would be dramatically improved if the data were analyzed so that a comparison could be made between the techniques studied. The third study done by Shahnaz et al (1997) used a statistical analysis of A' which supports the use of multifrequency tympanometry specifically resonant frequency and F45̊ to diagnose otosclerosis. Finally, Shahnaz & Polka provide compelling data and statistical analysis to support multifrequency tympanometric parameters being used to detect otosclerosis in adult groups.

Clinical Implications

Current clinical practice does not include multifrequency tympanometric parameters in the diagnosis of otosclerosis. However, the overall evidence provided by recent studies strongly suggests and supports the use of this technique to aid in the diagnosis of this disease in order to effectively treat these individuals. In summary, incorporating multifrequency tympanometric parameters such as F45̊ and Resonant Frequency into clinical practice could reduce diagnostic time, resulting in better patient outcome and decreasing health care costs.

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