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Comparison of Acoustic Immittance Measures Obtained With Different Commercial Instruments

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Abstract

Three acoustic admittance measurements (tympanometric peak pressure, peak compensated static acoustic admittance, and tympanometric width) were compared across seven commercially available acoustic immittance systems. Forty-nine adult subjects (45 females and 4 males), 16 to 50 years of age (mean = 27.7 years), with normal middle ear function participated in this investigation. Small but statistically significant differences were observed for each of the tympanometric variables for several of the instruments evaluated. In most instances, the differences were small enough that the same normative data could be applied across the instrumentation employed in this study; however, there were two measurement conditions, peak compensated static acoustic admittance and tympanometric width, where, for selected instruments, the range in values differed by an amount great enough to warrant consideration in clinical decision making.

Key Words Peak compensated static acoustic admittance, tympanometric peak pressure, tympanometric width, tympanometry

Tympanometry is an integral component in the assessment of peripheral auditory function. The usefulness of this measurement in the identification of middle ear disorders has been well documented in the literature for more than 20 years (Jerger, 1970; Jerger et al, 1974; Paradise et al, 1976; Orchik et al, 1978; Fiellau-Nikolajsen, 1983; Nozza et al, 1992, 1994). During that same period, changes have been made regarding the methodologies by which these measurements are obtained and, to some degree, the way the results are interpreted. Commercial instruments manufactured today differ from those used in the 1970s, in that acoustic admittance is measured in physical, rather than arbitrary, units. Furthermore, standards specifying the characteristics of these instruments have been available only since 1987 (ANSI, 1987).

In recent years, there have been a number of published articles reporting normative data on adults (de Jonge, 1986; Wiley et al, 1987), children (Koebsell and Margolis, 1986; Holte et al, 1990; Nozza et al, 1992), and both children and adults (Margolis and Heller, 1987) for the variety of tympanometric variables (ear canal volume, tympanometric peak pressure, peak compensated static acoustic admittance [henceforth, static acoustic admittance] and tympanometric width) typically included in measurements of this type. A variety of instruments, representing a number of different manufacturers, were used in those studies and, in some instances, the test protocols also varied. It has been shown that several test parameters can affect tympanometric responses including pump speed (Margolis and Heller, 1987), method of calculating the gradient (Koebsell and Margolis, 1986), direction of pressure change (Shanks and Wilson, 1986), and method of compensation for ear canal volume (Margolis and Shanks, 1991).

Test–retest reliability of acoustic immittance measurements was addressed recently by Wiley and Barrett (1991). In a group of 20 adults with normal hearing and normal middle ear function, these investigators examined the test–retest

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reliability of three acoustic admittance variables with respect to differing probe tone frequencies and direction of pressure change over five test sessions. They reported that static acoustic admittance yielded the highest test–retest correlations, regardless of the test condition. Tympanometric width was examined only with a low-frequency probe tone, and test–retest reliability for this variable was not found to be as high as static acoustic admittance or acoustic susceptance.

In addition to test–retest reliability across test sessions with the same instrument, consideration must also be given to the reliability of different instruments yielding similar immittance results for the same individual across clinics. That is to say, can the same normative data set be used across all instruments? The purpose of this investigation was to compare the aural acoustic immittance measurements obtained with seven acoustic immittance systems that are commercially available for clinical use. The immittance measurements included static acoustic admittance, tympanometric peak pressure, and tympanometric width.

METHOD

Forty-nine adults (45 females and 4 males), ranging in age from 16 to 50 years with a mean age of 27.7 years, volunteered to participate in this investigation. Most of these participants were students in the Communication Sciences and Disorders program at The University of Georgia; hence, the disproportionate number of females employed in the study. All of the subjects reported a negative history for any recent middle ear disease. Tympanometric measurements were obtained using seven different commercially available instruments. These included the Danplex Tymp 87 (Life-Tech, Inc., Drippling Springs, TX), Grason-Stadler model 1733 (GSI 33), Grason-Stadler model 1737 (GSI 37), Grason-Stadler model 1738 (GSI 38) (Grason-Stadler, Inc., Milford, NH), Madsen Zodiac 901 (Madsen Electronics, Inc., Minnetonka, MN), Maico model 630 (Maico Hearing Instruments, Inc., Minneapolis, MN), and the Virtual model 310 (Virtual Corp, Portland, OR) immittance systems. With the exception of the GSI 37, which is considered a screening device, all of the remaining instruments were considered diagnostic units. Each of the acoustic immittance systems was calibrated in accordance with the ANSI specifications (ANSI, 1987). Seven tympanograms, one from each instrument, were obtained using a low-frequency probe tone (226 Hz) on one ear of each of the participants, and the test ear was counterbalanced across subjects. The tympanometers were set to sweep pressure +200 to –400 daPa for all instruments except the Virtual 310, in which case the pressure sweep range was set for +250 to –300 daPa. The sweep rate was adjusted to be as equivalent as possible between instruments. The sweep rate for each of the systems under investigation was as follows: GSI 33, GSI 37, GSI 38 (600/200 daPa/sec), Maico 630 (550/200 daPa/sec), Zodiac 901 and Danplex Tymp 87 (200 daPa/sec), and Virtual 310 (125 daPa/sec). With the exception of the Virtual system, the sweep rate for all instruments slowed to 200 daPa/sec near the tympanometric peak. Ear canal volume was estimated at the most positive point in each of the respective sweeps. Test order was rotated so that each instrument appeared in each of seven possible test positions seven times. Each of the measured values (i.e., tympanometric peak pressure, static acoustic admittance, and tympanometric width) was obtained from the hard copy provided by the instrument, or, in one instance, read directly from the instrument monitor.

RESULTS

Means, standard deviations, and 90 percent ranges (5–95%) for each of the tympanometric variables examined in this study are shown in Table 1. For comparison purposes, normative data from one other adult study also is included in the table.

Tympanometric Peak Pressure

Tympanometric peak pressure differences across test instruments were small, yet, in several instances, were statistically significant. Paired comparison t-tests adjusted for Bonferonni Family Wise control of Type I error showed the mean tympanometric peak pressure for the GSI 33 to be statistically different ($p < .01$) from all of the remaining systems. The GSI 33 produced an interesting finding in that the mean tympanometric peak pressure was slightly positive, whereas all of the other immittance devices showed negative mean tympanometric peak pressures. In fact, as noted, the 90 percent range (5–95%) for the GSI 33 was from –5 to 25 daPa. A statistically significant difference ($p < .01$) also was found between the Madsen Zodiac 901 (mean = –6.84) and the GSI 37 (mean = –19.29). Smaller, yet statistically significant, differences ($p < .01$) also were found for the GSI 38 versus

Table 1 Group Admittance Values for Normal Adult Ears (n = 49) as Measured across Seven Commercial Acoustic Immittance Instruments

Tympanometry Variables		*Middle Ear Analyzers*							
		GSI 33	*Zodiac 901*	*GSI 37*	*GSI 38*	*Maico 630*	*Danplex 87*	*Virtual 310*	*Margolis/Heller**
Tympanometric peak pressure (daPa)	Mean	8.4	−6.8	−19.3	−14.8	−10.3	−6.3	−10.3	−16.2
	SD	10.1	10.0	10.1	10.5	17.7	8.0	10.4	21.5
	90% range	−5 to 25	−25 to 5	−40 to −5	−35 to 0	−31 to 7	−25 to 5	−23 to 14	−83 to 0
Peak compensated static acoustic immittance (mmho) compensation method (+200)	Mean	.66	.90	.69	.62	.67	.68	.61	.72
	SD	.26	.38	.35	.31	.31	.33	.27	.32
	90% range	.3 to 1.1	.4 to 1.6	.3 to 1.3	.3 to 1.3	.3 to 1.2	.3 to 1.3	.3 to 1.0	.27 to 1.38
Tympanometric width (daPa)	Mean	87.7	84.7	68.6	66.6	NA	NA	83.2	76.8
	SD	21.5	20.4	16.5	17.1	NA	NA	19.5	18.8
	90% range	55 to 125	58 to 113	45 to 100	45 to 100	NA	NA	56 to 118	51 to 114

*Margolis and Heller (1987).
NA = not applicable.

the GSI 37, the GSI 38 versus the Danplex 87, and the GSI 38 versus the Virtual 310.

Static Acoustic Admittance

Paired comparison t-tests showed the mean static acoustic admittance (.9 mmhos) observed for the Madsen Zodiac 901 to be statistically different ($p < .01$) from each of the other acoustic immittance systems. Compared to the other instruments, the mean static acoustic admittance for the Madsen instrument differed by more than .21 mmhos. Much smaller differences were found for the remaining systems, yet statistical significance was achieved for some of them. The static acoustic admittance for the GSI 38 was found to be less than that of the GSI 37 and the Danplex 87 by only .07 and .06 mmhos, respectively, but the difference was statistically significant. The static acoustic admittance for the GSI 37 also was found to be different statistically ($p < .01$) from the Virtual 310, even though the mean difference between the two was only .08 mmhos. The 90 percent range for the Zodiac 901 (.4–1.6 mmhos) also was found to be somewhat higher than the other test systems. For each of the other instruments, the 5th percentile was .3 mmhos and the 95th percentile ranged from 1.0 to 1.3.

Because of the size of the mean difference in static acoustic admittance between the Madsen Zodiac 901 and all of the other acoustic admittance systems, a second set of data was obtained on a smaller sample of ears (n =15). The purpose was to examine the possibility that a problem developed with the Zodiac 901 during the course of the investigation that may have affected the data. Tympanometric data were obtained on 15 young adults, some of whom also participated in the original data set, using a different Madsen Zodiac 901 and the same GSI 33 instrument described above.

The mean difference in the peak compensated static acoustic admittance data between the two instruments again reached statistical significance ($p < .01$), but the difference was smaller for the second data set as compared to the first (Table 2). At the same time, mean static acoustic admittance for the two sets of data did not differ significantly for the GSI 33, nor were differences obtained between the two Zodiac 901

Table 2. Peak Compensated Static Acoustic Admittance (Means and Standard Deviations) Comparing the Zodiac 901 and GSI 33 Middle Ear Analyzer

	*GSI 33**	*Zodiac 901†*
First data set (mmho) (n = 49)		
Mean	.66	.90‡
SD	.24	.38
Second data set (mmho) (n = 15)		
Mean	.68	.78‡
SD	.20	.22

*Same instrument used for both sets of data collection; †different instrument used for each data collection set; ‡mean difference between Zodiac 901 and GSI 33 reached statistical significance ($p < .01$).

instruments found to be significant. These findings lend support to the results obtained with the original data, which showed a difference between the Zodiac 901 and other instruments on measures of static acoustic admittance.

Tympanometric Width

Only five of the seven acoustic immittance systems measured tympanometric width. These included the GSI 33, GSI 37, GSI 38, Madsen Zodiac 901, and the Virtual 310 instruments. Paired comparison t-tests showed that the GSI 37 and the GSI 38 were statistically different ($p < .01$) from each of the remaining admittance meters, but were not significantly different from each other. The mean tympanometric widths for the GSI 37 and GSI 38, as shown in Table 2, were 68.6 and 66.8 daPa, respectively, while the other instruments showed a tympanometric width that ranged from 81.7 daPa for the GSI 33 to 84.7 daPa for the Zodiac 901.

DISCUSSION

This investigation examined the differences in acoustic immittance measurements for seven commercially available acoustic admittance meters to determine if the same normative data could be applied to each of these systems. Three response variables were compared across instruments for 49 adults with normal middle ear function. The results showed small yet statistically significant differences for several of the instruments for each of the three variables. It should be noted that, although statistical significance was reached for some of the measurements, in most instances, the same normative data set would be applicable across instruments. That is to say, while several of the tympanometric peak pressure comparisons and peak compensated static acoustic admittance comparisons were found to be statistically significant, in most cases, the magnitude of the difference was probably too small to affect clinical decisions. Furthermore, for six of the seven instruments, the means and 90 percent ranges compared favorably with previously published normative data. There were, however, two measurement conditions for which the differences possibly warrant clinical consideration. One condition occurred with respect to the measured static acoustic admittance and the other with respect to tympanometric width. In the former instance, the mean static acoustic admittance for the Zodiac 901 admittance meter ranged from .21 to .29 mmhos higher than any of the other instruments. These data also were slightly higher (.18 mmhos) than those reported by Margolis and Heller (1987). By comparison, the remaining instruments showed static acoustic admittance values that were very similar to the female normative data reported by Margolis and Heller (1987), which was not surprising, considering the large number of women included in the present study. In the latter instance, the mean tympanometric width for the GSI 37 and the GSI 38 was found to be significantly narrower than all of the remaining systems, and the differences ranged from 13.1 to 16.1 daPa and from 14.9 to 17.9 daPa for the two instruments, respectively. One possible explanation for the differences in tympanometric width may be due to the fact that the algorithm employed in the GSI 37 and GSI 38 instruments for slowing the pump speed from 600 to 200 daPa differs from that used in the GSI 33 (E. Klinger, personal communication, April 11, 1995). The differences noted for the static acoustic admittance measurement obtained with the Madsen Zodiac 901 and for the tympanometric width measurement obtained with the GSI 37 or GSI 38 instruments may warrant consideration in the clinical decision process.

Determining the significance of these differences in developing referral criteria or in the management of the patient is beyond the scope of this study. It is evident that there are differences in the measured responses of peak compensated static acoustic admittance, tympanometric width, and tympanometric peak pressure as measured by commercially available acoustic immittance systems. The clinical significance of these findings await further trials that examine the sensitivity and specificity of these measurements in a general clinical population.

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