High Frequency Tympanometry in Neonates with Normal Otoacoustic Emissions: Measurements and Interpretations

Arvinder Singh Sood · Charanjit Singh Bons ·
Gursharan Singh Narang

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Abstract Tympanometry is used in evaluating middle ear functional conditions. Before 6 months of age its results may be misleading. High-frequency studies aim to provide more valid procedures. In this study, 236 healthy newborns (127 male, 109 female; 73 % rural, 27 % urban) with age between 0 and 42 days (mean 27 days) no risk for hearing impairment; were analyzed for DPOAE. 209 babies who passed DPOAE were further analyzed for high-frequency tympanometry using Interacoustic AT235h tympanometer, which was possible for 399 ears. The success rate for HFT was 95.3 %. Descriptive statistics for six parameters TPP, Y 200, Y peak, Y tail, YpC-200 and Ypc-tail were analyzed and compared with previous studies. All the parameters except the Ypc-tail were in the range of previous studies.

Keywords High-frequency tympanometry (HFT) · DPOAE · Peak pressure · Admittance

Introduction

Universal newborn hearing screening (UNHS) has led to the early identification of hearing loss. Audiologists are now faced with the goal of diagnosing the type and severity of an infant's hearing loss by 3 months of age [2]. The most common cause of referral on UNHS is conductive hearing loss, the majority of which is secondary to otitis media or middle ear effusion [7, 8]. Assessing middle ear status is difficult in young infants for both the audiologist and otolaryngologist [6, 28]. The audiologist has bone conduction auditory brainstem response (ABR) and high-frequency otoscopy and/or otomicroscopy to determine presence or absence of middle ear effusion. None of these tools is perfect and it is reassuring to both the physician and the audiologist when audio logic results and otologic findings are in agreement.

Tympanometry is an objective test of middle ear function that has been routinely used in audiology practice for the identification of middle ear dysfunction. Conventional tympanometry with a low probe tone frequency of 226 Hz has been acknowledged as a reliable and effective method for detecting middle ear dysfunction for children and adults, with sensitivity and specificity values ranging from 80 to 90 % and 71 to 100 %, respectively [9, 12, 21]. Despite its successful application to children and adults, the use of conventional 226 Hz tympanometry has been proven to be inaccurate in diagnosing middle ear problems in infants younger than 7 months of age [5, 20, 23, 27]. The inability of conventional 226 Hz tympanometry to function accurately in young infants has been attributed to the special acoustic and anatomical properties of the infants' external and middle ear system. Studies have shown that, unlike adults, young infants have soft external ear canal wall [14, 16] and reduced stiffness of the middle ear system

A. S. Sood (✉) · C. S. Bons
Department of ENT, Sri Guru Ram Das Institute of Medical
Sciences & Research (SGRDIMS), Mehta Road, Amritsar,
India
e-mail: drarvindsinghsood@gmail.com

C. S. Bons
e-mail: csbons@gmail.com

G. S. Narang
Department of Pediatrics, Sri Guru Ram Das Institute of Medical
Sciences & Research (SGRDIMS), Mehta Road, Amritsar,
India

[11, 13]. Fortunately, encouraging findings, to date, have supported the application of high-frequency tympanometry (HFT) with a probe tone of 1,000 Hz to detect middle ear problems in neonates [4, 25, 29]. Although HFT with young infants was introduced thirty years ago [23, 27], clinical application of HFT did not evolve until the 1990's with implementation of UNHS. Both the Joint Committee on Infant Hearing (2007) and the American Speech-Language Hearing Association (2004) recommend HFT for infants from birth to 6 months of age. Several high-frequency probe tones have been studied (e.g. 660, 880, and 1,000 Hz).

Recently, research has centered on a 1 kHz probe tone which is currently the highest frequency available on commercial clinical tympanometers [24].

This stimulus has been shown to be more valid than other high-frequency probe tones (e.g. 660 and 678 Hz) in studies by Baldwin [4, 25, 29], Rhodes et al. [25], and Williams et al. [29].

Purpose

The present study was designed to evaluate the benefit of HFT (1 kHz probe tone) in the middle ear assessment of infants, birth to 3 months of age. The goals of the current study were as follows:

1. Collect additional normative data for infants in the birth to three months age range.
2. Based on normative data collected in the current study and from the literature, ascertain whether there is a significant correlation between high-frequency tympanometric results and otologic findings.

Material and Methods

Research Design

This was a prospective clinical study which included 236 healthy neonates who were attending the out patient at Speech and Hearing Unit, ENT department of Sri Guru Ramdas Institute of Medical Sciences and Research, Amritsar during October 2010 to December 2010 and were referred from the Department of Pediatrics for hearing assessment.

Sample Population

The study comprised of 236 healthy neonates of either sex from rural (73 %) and urban (27 %) background. Out of

these 236, 127 were males and 109 were females. Participants were between 1 to 42 days of age (mean 27 days) The following exclusion and inclusion criteria were observed for the selection of the sample of the present study:

Inclusion Criteria

- (1) Age range 0–3 months.
- (2) Children with healthy ears on clinical examination.
- (3) Children whose parents gave their consent to the request of the investigator for the assessments.
- (4) All participants were full term babies (38–42 weeks gestation period) with uneventful birth histories.
- (5) They were free from any congenital anomalies or pre existing conditions or histories predispose to hearing loss.
- (6) Their birth weight was well within normal range (ranging from 2,000–3,500 grams; mean 2,700 grams).

Exclusion Criteria

- (1) Participants were not included in the final statistical analysis if they had any congenital defect.
- (2) Demonstrated one or more of the 'at risk' factors for hearing loss listed in the Joint Committee on Infant hearing (JCIH 2000).
- (3) Those who showed signs of any external or middle ear pathology on otoscopic examination.

Evaluation

The assessments included in the study were as follows:

- (1) Clinical assessment
- (2) Otoscope examination
- (3) DPOAE assessment
- (4) High-frequency 1,000 Hz tympanometry

Procedure

All the neonates who met all inclusion and exclusion criteria were clinically assessed by pediatrics department, case histories and records were noted down and referred to ENT department. They were otoscopically examined by an ENT specialist of the rank of Associate professor with vast experience. Screening distortion product otoacoustic emission (DPOAE) test were performed by a senior audiologist of 20 years experience using Intelligent Hearing system IHS USB Lite machine. OAEs are non-invasive and technically simple to record, usually requiring only a few minutes for both ears. Sedation is not indicated for OAE measurement, even in children. No behavioral response is

required for participating in the testing, so the procedure is not affected by a patient's motivation, attention, or cognitive status.

In the first stage screening DPOAE tests were performed on all the 236 neonates. All OAE tests were carried out in non sound treated rooms in the presence of their mothers. Ambient noise levels of room were kept below 50 dB. Majority of participants were tested in their mother's lap. Neonates were fed, dry, comfortable and were in asleep or in a restful state. The ear that was most easily accessible was tested first. Great care was taken to optimize probe seal. Probe fit was checked before the DPOAE test commenced, when good probe fit was indicated, testing began. The pass criteria for the DPOAE screening were the presence of a DPOAE spectrum at least 3 dB above the noise floor and at least halfway across the test frequencies bands of 2–3 and 3–4 kHz. Neonates whose result were REFER for DPOAE, were not included for the study and were referred for diagnostic ABR.

As a result for data exclusion, the data for 27 neonates who either failed screening DPOAE in one or both the ears or did not complete the DPOAE tests were excluded from the final statistical analysis. 418 ears of these 209 neonates (107 males and 102 females) were eligible for the second stage of the study, in which they were tested for high-Frequency 1,000 Hz tympanometry using Interacoustic AT235h equipment. All tests were carried while the babies were at rest in the arms of their mothers and were quiet. The equipment used was calibrated as per the manufacturer's specifications. All tympanometry tests were carried out by same audiologist. The applied pressure varied +300 to −300 daPa. 1,000 Hz tympanograms were recorded twice to confirm reliability.

Results

Repeatable 1,000 Hz. tympanometry findings were obtained 399 ears of 209 babies. In three babies test could not be completed for both the ears, while in 13 babies, test could not be completed in one ear. For 19 ears proper seals could not be established. As compared with the original sample size that was 472 ears, success rate for the 1 kHz tympanometry was 84.53 %. Considering the pass criteria for DPOAE, the success rate for 1 kHz tympanometry was 95.4 %.Based on the shapes of tympanograms, were thus obtained were classified as Type I, II, III and IV.

As shown in Fig. 1.

Type I tympanograms consists of single peak with maximum admittance value occurring at a pressure of 0 daPa or around it. This type resembles the standard Type A classification of Liden/Jerger classification [17].

Fig. 1 Type I tympanogram obtained with a probe tone of 1,000 Hz, exhibiting single peak obtained for left ear of a normal female baby of 2 days of age who passed DPOAE test with Y peak = 1.35 mmho

Those tympanograms which has no identifiable admittance peak (Fig. 2) and more or less flat, admittance being constant from +200 to −200 daPa are classified as Type II. They resembles Type B of Liden/Jerger classification [17].

Type III tympanograms displays a double peaked configuration (Fig. 3). The admittance attains maximum +ve values at two different +ve values at two different ear canal pressures level.

Type IV tympanograms consists of shapes which does not seem to belong to above three classified types (see Fig. 4).

Descriptive statistics were calculated for parameters.

1. TPP Tympanometry peak pressure which is the ear canal pressure corresponding to uncompensated peak admittance
2. Y +200 uncompensated admittance measured at 200 daPa
3. Y peak refers to the maximum uncompensated admittance measured during the pressure sweep.
4. Y tail refers to the uncompensated admittance measured under negative air pressure at the end of the pressure sweep.
5. Ypc-200 refers to peak compensated admittance, with compensation occurring at the admittance value measured at −200 daPa ear canal pressure.
6. Ypc-tail refers to peak compensated admittance, with compensation occurring at the admittance value measured at approximately −400 daPa ear canal pressure.

Fig. 2 showing Type II tympanograms for a 1 day old baby boy who passed DPOAE screening with Y +200 and Y peak more or less similar

Fig. 3 Type III tympanograms exhibiting double peaks for a baby boy of 41 days of age

Descriptive statistics include mean, standard deviation, range, minimum, maximum, N, 5th percentile, 50th percentile, and 95th percentile. Tympanogram terminology

Fig. 4 Type IV tympanograms with no identifiable classification

used in this article refers to compensated and uncompensated tympanograms, also known as base lined and un base lined tympanograms, respectively. These normative data were obtained only from those newborn babies who passed the DPOAE test and had a single-peaked tympanogram. Single-peaked tympanograms are selected because recent studies indicate that they are consistent with normal middle ear function in young infants [1, 4, 15].

A factorial model that included two factors ear (left/right) and gender (male/female) and all interactions was fitted to the data to investigate the effects of these variables on each of the six tympanometric parameters (TPP, Y +200, Y peak, Y tail, Ypc-200 and Ypc-tail). The significance of any term was assessed using the analysis of variance (ANOVA) at 0.05 significance level. Results from the ANOVA revealed no significant main effects for gender and ear, and no significant interactions for any of the test parameters

Discussion

The success rate of 1 kHz tympanometry was 95.4 % in this study, which is better than the results of [15] who obtained a success rate of 87.9 %. Only those babies which are at rest and not crying are considered for 1,000 Hz. Tympanometry. Success rate was defined differently between the current study and [15]. Success in the current study referred to the ability to complete a tympanogram that had limited artefact which could interfere with interpretation. Kei et al. [15] defined success as the ability to maintain a hermetic seal during tympanometry. Other

Table 1 The mean, median, standard deviation, sample variance, range, minimum and maximum and 95th percentiles for each of the above described tympanometric measures (TPP, Y 200, Y peak, Y tail, Ypc-200 and Ypc-tail)

Variable	TPP	Y +200	Y peak	Y tail	Ypc-200	Ypc-tail
Mean	3.37	1.48	2.08	1.03	0.58	1.03
Median	−24	1.49	1.95	1.0	0.54	1.18
SD	38.2	0.42	0.74	0.30	0.42	0.59
Range	139	1.2	2.5	0.7	1.4	1.8
Minimum	−81	0.9	0.9	0.8	0	0.1
Maximum	58	2.1	3.4	1.6	1.4	1.9
5 % percentile	−127	1.10	1.18	0.34	0.27	0.71
50 % percentile	−19	1.16	2.3	0.93	0.94	1.34
95 % percentile	41	2.13	3.83	1.56	2.6	3.02

All the values are calculated manually except the TPP and Y peak

normative studies did not discuss the success rate of HFT. Margolis et al. [18] collected data via retrospective analysis; therefore, only subjects with completed tests were reviewed. Mazlan et al. [19] and Swanepoel et al. [26] did not specify the number of ears excluded based solely on inability to complete HFT. Results of the current study indicate that HFT has a success rate similar to conventional (226 Hz) tympanometry, with a 89–87 % success rate in infants from birth to 3 months of age (Tables 1, 4, 5, 6).

Tables 2, 3, 4, 5, 6, and 7 provide a comparison of this study's normative data to other published norms for the following values: Y +200, Y peak, Y tail, Ypc-200 Ypc-tail, and peak pressure. The published norms include Kei et al. [15], Margolis et al. [18], Mazlan et al. [19], and Swanepoel et al. [26]. None of the published norms used a tympanometry protocol identical to the current study. Differences in subject selection, instrumentation parameters and validation criteria were present among all of the studies reported.

The published norms used TEOAE aid in middle ear assessment, whereas in this study, the otologic examination in combination with DPOAE was used to validate normal

Table 2 Comparison table for TPP peak pressure

1 kHz study	Kei et al. [15]	Margolis et al. [18]	Mazlan et al. [19]	Current study
N (ears)	212	43	40	418
Infant age	Neonates	2–4 weeks	6–7 weeks	0–6 weeks
Mean	18.3	−10	−2.08	3.7
SD	41.6	68	67.99	38.2
Minimum	n/a	−200	−254	−81
Maximum	n/a	200	80	58
5th percentile	−58	−133	n/a	−127
50th percentile	n/a	1.4	n/a	−19
95th percentile	5.09 left ear 5.01 right ear	2.2	n/a	41

middle ear status. The age range of the test subjects differed among the studies as well. This could affect the admittance values, which have been demonstrated to increase with age during infancy [13, 19]. The mean Ypc-200 was smaller than mean Ypc-tail (0.58 vs 1.03 mmho) and a paired *t* test showed that the difference between these two test parameters was significant.

This study used a interacoustic 235 h tympanometers, whereas Swanepoel et al. [26] used the GSI ympStar Version 2; the other studies used different equipment. Research indicates equipment differences can affect measured values, specifically peak pressure [10]. Kei et al. [15] used a +200 to −200 daPa pressure sweep, while our study and other published norms used a +200 to −300 daPa pressure sweep.

Despite all the discrepancies noted above, this study's values for Y +200, Y peak, and Y tail, Ypc-200 and Ypc-tail are in the same range as values from other published normative Norms for Ypc +200 were compared to Kei et al. [15], Margolis et al. [18], and Mazlan et al. [19]. Margolis et al. [18] has the most similar tympanometric parameters to this study; therefore, their data were used for the main comparison. The Ypc +200 norms for mean, 5th

Table 3 Comparison table for Y 200

1 kHz study	Kei et al. [15]	Margolis et al. [18]	Mazlan et al. [19]	Current study
N (ears)	212	43	40	418
Infant age	Neonates	2–4 weeks	6–7 weeks	0–6 weeks
Mean	3.20 left ear 3.06 right ear	1.4	1.33	1.48
SD	1.11 left ear 1.07 right ear	0.4	0.41	0.42
Minimum	n/a	0.7	0.62	0.91
Maximum	n/a	2.3	2.78	2.1
5th percentile	1.54 left ear 1.40 right ear	0.8	n/a	1.10
50th percentile	n/a	1.4	n/a	1.6
95th percentile	5.09 left ear 5.01 right ear	2.2	n/a	2.13

Table 4 Comparison table for Y peak

1 kHz study	Margolis et al. [18]	Mazlan et al. [19]	Swanepoel et al. [26]	Current study
N (ears)	43	40	177	418
Infant age (weeks)	2–4	6–7	1–4	0–6
Mean	2.7	2.35	2.4	2.08
SD	1.2	0.71	0.7	0.74
Minimum	0.8	1.16	1.2	1.0
Maximum	7.0	4.5	5.1	3.4
5th percentile	1.2	n/a	1.5	1.8
50th percentile	2.5	n/a	2.3	2.3
95th percentile	4.8	n/a	3.8	3.83

Table 5 Comparison table for Y tail

1 kHz study	Margolis et al. [18]	Current study
N (ears)	43	418
Infant age (weeks)	2–4	0–6
Mean	0.8	1.3
SD	0.4	0.3
Minimum	0	0.9
Maximum	1.7	1.6
5th percentile	0.3	0.34
50th percentile	0.8	0.93
95th percentile	1.4	1.56

percentile, and 95th percentile are similar: 1.1, 0.27, and 2.6 mmho, respectively for this study and 1.3, 0.1, and 3.5 mmho, respectively for Margolis et al. [18] (see Table 3).

This study's normative mean for Ypc-tail compared to Margolis et al. [18] is 0.87 mmho less (see Table 7). This could be due to the difference between no. of participant sample ears (418 vs 43 ears).

Compared to the mean peak pressure of Kei et al. [15], Margolis et al. [18], Mazlan et al. [19], and Swanepoel et al. [26], this study's mean peak pressure was the most near to zero. This study's peak pressure values may have been influenced by the large no. of sample size and/or procedural parameters (e.g., pump rate).

Peak pressure in conventional 226 Hz tympanometry is the least diagnostic tympanometric value. Whether this is true for 1 kHz tympanometry is yet to be established. However, peak pressure is still clinically applicable due to the need to identify and monitor high negative middle ear pressure in infants (ASHA) [3]. It can add information about the status of middle ear effusion or infection, whether it is developing or resolving. Also, children with recurrent otitis media exhibit a higher prevalence of

Table 6 Comparison table for Ypc 200

1 kHz study	Kei et al. [15]	Margolis et al. [18]	Mazlan et al. [19]	Current study
N (ears)	212	43	40	418
Infant age	Neonates	2–4 weeks	6–7 weeks	0–6 weeks
Mean	1.04 left ear 1.16 right ear	1.3	1.01	1.1
SD	0.51 left ear 0.58 right ear	1.0	0.52	0.62
Minimum	n/a	0	0.35	0.2
Maximum	n/a	5.0	2.58	2.4
5th percentile	0.39 left ear 0.39 right ear	0.1	n/a	0.27
50th percentile	n/a	1.0	n/a	0.94
95th percentile	1.95 left ear 2.28 right ear	3.5	n/a	2.6

Table 7 Comparison table for Ypc-tail

1 kHz study	Margolis et al. [18]	Current study
N (ears)	43	418
Infant age (weeks)	2–4	0–6
Mean	1.9	1.03
SD	1.3	0.59
Minimum	0.1	0.1
Maximum	6.0	1.9
5th percentile	0.6	0.71
50th percentile	1.7	1.34
95th percentile	4.3	3.02

negative middle ear pressure, even during periods of resolution, than children.

Summary

Despite a number of methodological differences, preliminary evidence with a large no. of sample group suggests that this study's norms are similar to those of previous investigators. Comparing the three rating methods used for 1 kHz tympanograms, preliminary results indicate similarity among the current study's norms, the norms of Margolis et al. [18], and the professional judgment of experienced audiologists. The rate of completion for 1 kHz tympanometry in infants ranging from one to 3 months of age in a clinical setting was 95.4 %.

Both ASHA [3] and JCIH [2] recommend the addition of 1 kHz into the middle ear assessment battery. Determining the exact benefit of 1 kHz tympanometry in regard

to its ability to refer infants with middle ear pathology is still needed. If 1 kHz tympanometry is sufficiently sensitive to middle ear pathology, standard protocols for administration and guidelines for interpretation will be needed to promote its widespread application in the clinical pediatric without recurrent otitis media [22].

References

1. Alaerts J, Luts H, Wouters J (2007) Evaluation of middle ear function in young children: clinical guidelines for the use of 226- and 1,000-Hz tympanometry. *Otol Neuro Otol* 28:727–732
2. American Speech-Language-Hearing Association (2007) Executive summary for Joint Committee on Infant Hearing (JCIH) year 2007 position statement: principles and guidelines for early hearing detection and intervention programs. <http://www.asha.org/NR/rdonlyres/2CCB66CC-63AF-47AF-9988CCF1438EC1F/0/JCIHExecutiveSummary.pdf>. Assessed 8 July 2011
3. American Speech-Language-Hearing Association (2004) Guidelines for the audiologic assessment of children from birth to 5 years of age. <http://www.asha.org/members/deskref-journals/deskref/default>. Assessed 28 July 2011
4. Baldwin M (2006) Choice of probe tone and classification of trace patterns in tympanometry undertaken in early infancy. *Int J Audiol* 45:417–427
5. Beery Q, Andrus W, Bluestone C, Cantekin E (1975) Tympanometric pattern classification in relation to middle ear effusion. *Ann Otol Rhinol Laryngol* 84:56–64
6. Bluestone C, Klein J (2007) Otitis media in infants and children, 4th edn. BC Decker, Inc, Hamilton
7. Boone R, Bowers C, Martin P (2005) Failed newborn hearing screens as presentation for otitis media with effusion in the newborn population. *Int J Pediatr Otorhinolaryngol* 69:393–397
8. Doyle K, Burggraaff B, Fujikawa S, Macarthur C (1997) Neonatal hearing screening with otoscopy, auditory brain stem response, and otoacoustic emissions. *Otolaryngol Head Neck Surg* 116:597–603
9. Finitzo T, Friel-Patti S, Chinn K, Brown O (1992) Tympanometry and otoscopy prior to myringotomy: issues in diagnosis of otitis media. *Int J Pediatr Otorhinolaryngol* 24:101–110
10. Gaihede M, Marker F (1998) Agreement between two tympanometers: a methodological study of instrument comparison. *Scand Audiol* 27(2):113–119
11. Himelfarb MZ, Popelka GR, Shanon E (1979) Tympanometry in normal neonates. *J Speech Hear Res* 22:179–191
12. Harris PK, Hutchison KM, Moravec J (2005) The use of tympanometry and pneumatic otoscopy for predicting middle ear disease. *Am J Audiol* 14:3–13
13. Holte L, Margolis RH, Cavanaugh R (1991) Developmental changes in multifrequency tympanograms. *Audiology* 30:1–24
14. Keefe DH, Bulen JC, Arehart KH, Burns EM (1993) Ear-canal impedance and reflection coefficient in human infants and adults. *J Acoust Soc Am* 94:2617–2638
15. Kei J, Allison-Levick J, Dockray J, Harrys R, Kirkegard C, Wong J, Maurer M, Hegarty J, Young J, Tudehope D (2003) High-frequency (1000 Hz) tympanometry in normal neonates. *J Am Acad Audiol* 14:20–28
16. Kenna MA (1990) Embryology and developmental anatomy of the ear. In: Bluestone CD, Stool SE, Sheetz MD (eds) *Pediatric otolaryngology*, 2nd edn. Saunders, Philadelphia
17. Lyra e Silva Kde A, Novaes Bde A, Lewis DR, Carvalho RM (2007) Tympanometry in neonates with normal otoacoustic emissions: measurements and interpretation. *Rev Bras Otorrinolaringol* 73(5):633–639
18. Margolis RH, Bass-Ringdahl S, Hanks WD, Holte L, Zapala DA (2003) Tympanometry in newborn infants: 1 kHz norms. *J Am Acad Audiol* 14:383–392
19. Mazlan R, Kei J, Hickson L, Stapleton C, Grant S, Lim S, Linning R, Gavranich J (2007) High-frequency immittance findings: newborn versus six-week-old infants. *Int J Audiol* 46:711–717
20. McKinley AM, Grose JH, Roush J (1997) Multi-frequency tympanometry and evoked otoacoustic emissions in neonates during the first 24 hours of life. *J Am Acad Audiol* 8(218):23
21. Mills RP (1987) Persistent middle ear effusions in children with recurrent acute otitis media. *Clin Otolaryngol* 12:97–101
22. Moody S, Alper C, Doyle W (1998) Daily tympanometry in children during the cold season: association of otitis media with upper respiratory tract infections. *Int J Pediatr Otorhinolaryngol* 45(2):143–150
23. Paradise JL, Smith CG, Bluestone CD (1976) Tympanometric detection of middle ear effusion in infants and young children. *Pediatrics* 58:198–210
24. Purdy SC, Williams MJ (2000) High frequency tympanometry: A valid and reliable immittance test protocol for young infants? *New Z Audiol Soc Bull* 10:9–24
25. Rhodes MC, Margolis RH, Hirsch JE, Napp AP (1999) Hearing screening in the newborn intensive care nursery: comparison of methods. *Otolaryngol Head Neck Surg* 120:799–808
26. Swanepoel DW, Werner S, Hugo R, Louw B, Owen R, Swanepoel A (2007) High frequency immittance for neonates: a normative study. *Acta Otolaryngol* 127:49–56
27. Shurin PA, Pelton SI, Finkelstein J (1977) Tympanometry in the diagnosis of middle-ear effusion. *N Engl J Med* 296:412–417
28. Watkin P, Baldwin M (1999) Confirmation of deafness in infancy. *Arch Dis Child* 81:380–389
29. Williams MJ, Purdy SC, Barber C (1995) High frequency probe tone tympanometry in infants with middle ear effusion. *Aust J Otolaryngol* 2:169–173