Research Paper

Analyzing the Alterations in Middle Ear Wideband Energy Absorption Following Cleft Palate Corrective Surgery

Atefeh Kazemi[1], Mohsen Ahadi[1*], Malihe Mazaher Yazdi[1], Mohamad Maarefvand[1], Abbas Kazemi Ashtiani[2]

1. Department of Audiology, Rehabilitation Research Center, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran.
2. Department of Plastic and Reconstructive Surgery, School of Medicine, Iran University of Medical Sciences, Tehran, Iran.

Use your device to scan and read the article online

Citation Kazemi A, Ahadi M, Mazaher Yazdi M, Maarefvand M, Kazemi Ashtiani A. Analyzing the Alterations in Middle Ear Wideband Energy Absorption Following Cleft Palate Corrective Surgery. Iranian Rehabilitation Journal. 2024; 22(3):405-410. http://dx.doi.org/10.32598/irj.22.3.1411.2

http://dx.doi.org/10.32598/irj.22.3.1411.2

Article info:
Received: 25 Jun 2023
Accepted: 25 Jul 2023
Available Online: 01 Sep 2024

Keywords:
Wideband tympanometry, Cleft palate, Middle ear absorbance, Tympanometry

ABSTRACT

Objectives: Children with cleft palate may experience hearing problems, including middle ear disorders, which require careful monitoring to ensure successful treatment. To diagnose these hearing disorders, appropriate tools are necessary. While traditional single-frequency tympanometry has been commonly used as a practical tool for diagnosing middle ear problems, the effectiveness of this method has been questioned in some cases. Recently, newer tests of wideband tympanometry have been developed and may be able to provide a more comprehensive assessment of middle ear conditions in children with cleft palate.

Methods: To evaluate the effectiveness of wideband tympanometry, this study analyzed 14 young children who were scheduled to undergo cleft palate repair surgery. The children's ages ranged from 4 to 24 months. The study involved two evaluations, one before the surgery and another one month after the surgery. Different wideband absorption parameters were analyzed using the paired t test and the Wilcoxon test.

Results: The analysis of statistical data regarding tympanometric parameters before and after cleft palate surgery indicated a general enhancement in the condition of the middle ear. The study found that the middle ear pressure decreased, the absorption percentage increased, and admittance increased across all five frequencies, which is consistent with our initial assumptions.

Discussion: The results confirm that wideband tympanometry can be an effective approach to detecting changes in the middle ear after cleft palate repair surgery in children. The use of more sophisticated parameters and evaluations at various frequencies provides a more complete picture of the child's middle ear condition, potentially replacing single-frequency tympanometry assessments in the future.

*** Corresponding Author:**
Mohsen Ahadi, Associate Professor.
Address: *Department of Audiology, Rehabilitation Research Center, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran.*
Tel: *+98 (21) 22250541*
E-mail: *ahadi.m@iums.ac.ir*

Highlights

• Middle ear disorders are so common in children with cleft palate.

• Wideband tympanometry shows promise as a valuable tool for monitoring middle ear function in children undergoing cleft palate surgery.

• Wideband tympanometry provides enhanced diagnostic capabilities compared to conventional methods.

Plain Language Summary

Middle ear wideband energy absorption changes were analyzed before and after cleft palate corrective surgery in children. Wideband tympanometry was used to assess 14 children aged 4 to 24 months pre and one-month post-surgery. Results showed improvements in middle ear pressure, absorption percentage, and admittance across all frequencies post-operation. This study indicates that wideband tympanometry is more effective than traditional single-frequency tympanometry in evaluating middle ear conditions after cleft palate surgery. The findings emphasize the significance of timely surgical intervention to enhance middle ear function in children with cleft and lip palate.

Introduction

Cleft lip and palate are a common facial deformity that may involve cleft lip, lip and palate, or palate only [1]. A cleft palate specifically is a congenital abnormality affecting the secondary palate, which may be unilateral, bilateral, complete, or incomplete [2, 3]. Children with cleft palate frequently experience hearing problems, including otitis media, which is characterized by fluid accumulation in the middle ear leading to an ear infection. This occurs due to abnormal functioning of the tensor veli palatini and levator veli muscles, which causes a lack of ventilation in the middle ear cavity and subsequent fluid buildup. These conditions usually manifest within the first six months of life in children with cleft palate [4, 5]. The objective of treating children with cleft lip and palate is to achieve normal speech, eating, teeth, aesthetic appearance, psychological function, and hearing [5, 6]. Cleft lip surgery is typically conducted at approximately three months of age, while cleft palate surgery is performed around six months of age [5, 6].

Tympanometry is the most reliable method for assessing middle ear conditions in children with cleft palate, as confirmed by exploratory surgery. Tympanometry has a sensitivity of 95.6% and specificity of 59.6% in diagnosing middle ear diseases in these children [7]. Single-frequency tympanometry using a 226 Hz tone probe is more effective at identifying injuries related to middle ear stiffness, whereas a high-frequency tone probe, such as 1000 Hz or 678 Hz is more effective at identifying injuries related to mass [8]. Broadband reflectance can be used for infants with small ears and narrow canals because it has fewer probe-sealing problems. Compared to high-frequency tympanometry, it is also more sensitive to middle ear disorders [9]. Wideband tympanometry is a novel method for assessing impedance, admittance, absorption, and reflectance of the middle ear. It provides more diagnostic information than conventional methods without requiring additional measures and takes the same amount of time as conventional tympanometry. This technique involves recording several tympanograms over a wide frequency range from 250 Hz to 8000 Hz using a wideband click stimulus. In addition to the information available in conventional methods, this technique also provides additional information, such as a graph of sound energy absorption, resonance frequency (RF), and average tympanogram. Studies have revealed that the amount of middle ear energy absorbance is lower at frequencies below 1000 Hz and above 4000 Hz [9]. Since conventional tympanometry findings have low sensitivity and do not exhibit significant changes after surgery [10, 11]; accordingly, this study investigates the middle ear condition of individuals with cleft palate before and after surgery using the wideband tympanometry.

Materials and Methods

The research utilized a longitudinal approach with repeated assessments, employing a descriptive-analytical design. The study participants included individuals with cleft lips who sought medical care at Ali-Asghar Hospital and Hazrat-e-Fatemeh Hospital in Tehran City, Iran.

The study employed a non-random sampling technique to select participants based on the availability and willingness of their parents to participate. The sample size was established using G*Power software and data from a previous study conducted by Hunter et al. (2008) [12]. A total of 14 participants (8 boys and 6 girls) were determined to be necessary with a power of 0.8 and a significance level of 0.05.

The inclusion criteria were confirmation of cleft palate by an ear, nose, and throat doctor or plastic surgeon expert, scheduling of cleft palate repair surgery for the child, and an age range of 4 months to 2 years. Meanwhile, the exclusion criteria were parental unwillingness to continue cooperation and the presence of acute otitis media identified after the initial evaluation.

The Titan Wideband Tympanometry device (Interacoustics, Denmark) was used to record wideband tympanometric responses. Additionally, a questionnaire was administered to gather personal and contextual information. The first assessment was conducted before the cleft palate surgery, while the second evaluation took place approximately one month after the surgery to evaluate changes in wideband tympanometry findings.

The study evaluated various variables, including middle ear pressure, middle ear absorption percentage, external ear canal volume, admittance at five frequencies (226 Hz, 678 Hz, 800 Hz, 1000 Hz, and resonance frequency), tympanogram width at five frequencies, and middle ear pressure at five frequencies [13, 14]. Non-parametric Wilcoxon tests were used to compare the variables due to the small sample size and non-normal distribution of the data. The SPSS software, version 23 was used for data analysis.

Results

To investigate the impact of surgery on middle ear function, the study utilized the Wilcoxon signed-rank test. The results, as presented in Table 1, demonstrated significant differences between pre- and post-surgery values for middle ear pressure, resonance frequency, and absorption percentage. The study found that middle ear pressure significantly decreased after surgery, with a mean difference of -89.50 (w=231917.50, P<0.001). Resonance frequency also showed a significant increase, with a mean difference of 887.46 (w=0.00, P<0.001). Similarly, the absorption percentage significantly increased after surgery, with a mean difference of 38.14 (w=1773.00, P<0.001). However, no significant difference was observed in ear canal volume before and after surgery (mean difference=0.00, w=154047.00, P=0.73). These findings highlight the substantial impact of surgery on middle ear function, specifically changes in middle ear pressure, resonance frequency, and absorption percentage.

Table 2 presents a detailed comparison of admittance, tympanogram width, and middle ear pressure before and after cleft palate repair at five different frequencies. The results provide a clear understanding of the impact of surgical intervention on middle ear function. The study found a significant improvement in admittance at all frequencies after cleft palate repair. The mean admittance values notably increased, ranging from 0.32 to 0.36, compared to the preoperative values (P<0.001). Similarly, resonance frequency demonstrated a significant increase in admittance, indicating improved middle ear compliance and resonance characteristics (P<0.001). Also, a significant reduction in tympanogram width at all evaluated frequencies after cleft palate repair was observed. The mean differences ranged from -151.03 to -185.60, indicating a narrower range of pressure variation in the middle ear post-surgery (P<0.001). This reduction suggests improved middle ear stability and a more precise pressure regulation system. Cleft palate repair surgery also resulted in a meaningful increase in middle ear pressure across all frequencies, with mean differences ranging from 45.74 to 103.10 (P<0.001). This suggests that the surgery led to improved middle ear function and better regulation of pressure between ambient and middle ear pressure.

Discussion

This study examines middle ear function in pediatric patients with cleft palate and lip before and after surgical intervention, using wideband tympanometry. The results showed significant impairment in middle ear function before surgery, as indicated by all measured parameters. Wideband tympanometry demonstrated higher sensitivity for identifying middle ear pathology at lower frequencies (226 Hz) compared to conventional tympanometry. This was due to its more comprehensive analysis of the middle ear, which covers a wider range of frequencies, distinguishing it from the limited low-frequency measurement of traditional tympanometry. Overall, these findings underscore the efficacy of wideband tympanometry in evaluating middle ear function in children with cleft palate and lip, both before and after surgical intervention. Moreover, the study identified a postoperative increase in resonant frequency, denoting improved energy transmission, particularly at higher frequencies. These observations concur with previous research, such

Table 1. Comparison of middle ear pressure, middle ear absorption percentage, and external ear canal volume before and after cleft palate repair

Parameter	Mean±SE			Test Statistic (w)	P
	Before Surgery	After Surgery	Difference		
Middle ear pressure	54.40±141.10	-35.10±128.70	-89.50±178.38	231917.50	<0.001
Resonance frequency	296.64±37.19	1184.10±155.60	887.46±179.08	0.00	<0.001
Absorption percentage	31.79±13.35	69.93±12.40	38.14±22.13	1773.00	<0.001
Ear canal volume	0.62±0.17	0.62±0.15	0.0	154047.00	0.73

P<0.05 statistically significant.

Iranian Rehabilitation Journal

as the work by Wimmer et al. (2010), emphasizing the diagnostic relevance of high-frequency tympanometry for accurate assessment of increased energy transmission or resonance [8].

Additionally, average acoustic admittance at frequencies of 226 Hz, 678 Hz, 800 Hz, and 1000 Hz, along with resonance frequency and pre-and post-operative resonant frequencies, were examined. The results showed an overall increase in acoustic admittance at all five frequencies following surgery, indicating improved

Table 2. Comparison of admittance, tympanogram width, and middle ear pressure before and after cleft palate repair in five evaluated frequencies

Parameters	No.	Mean±SE			Wilcoxon Test (w)	P
		Before Surgery	After Surgery	Difference		
Admittance	226	0.04±0.04	0.36±0.10	0.32±0.04	4.50	<0.001
	678	0.05±0.03	0.32±0.11	0.27±0.05	0.00	<0.001
	800	0.05±0.02	0.35±0.12	0.30±0.05	0.00	<0.001
	1000	0.08±0.03	0.30±0.08	0.22±0.04	0.00	<0.001
RF		0.05±0.04	0.32±0.10	0.27±0.107	20.00	<0.001
Tympanic width	226	268.10±80.40	93.79±22.22	-174.31±87.65	307717.00	<0.001
	678	275.30±97.70	89.70±16.26	-185.60±92.80	307720.00	<0.001
	800	255.60±77.60	104.57±25.04	-151.03±76.11	307719.00	<0.001
	1000	272.10±88.70	88.50±25.44	-183.60±92.05	307290.00	<0.001
RF		219.80±57.50	94.36±19.88	-25.44±61.22	307537.00	<0.001
Middle ear pressure	226	-120.20±88.40	-17.10±54.90	103.10±18.18	21680.50	<0.001
	678	-63.70±59.00	-17.96±43.72	45.74±10.18	56193.50	<0.001
	800	-50.70±90.50	-2.71±4010	48.99±8.71	80278.50	<0.001
	1000	-55.90±59.10	-1.07±48.19	54.83±9.60	45778.00	<0.001
RF		-67.60±69.50	-1.57±34.88	68.03±77.51	32197.50	<0.001

P<0.05 statistically significant.

Iranian Rehabilitation Journal

RF: Resonance frequency.

middle ear function. These findings are consistent with a previous study by Tunçbilek et al. (2003) on a group of 50 children with cleft palate, which observed a reduction in middle ear pathologies, including type B and C tympanograms, accompanied by decreased acoustic admittance [15]. The study suggests that regular postoperative evaluations of middle ear function and auditory status are important for individuals with cleft palate.

Furthermore, tympanogram width at frequencies of 226 Hz, 678 Hz, 800 Hz, and 1000 Hz, and resonance frequency along with pre-and post-operative resonant frequencies, were compared. Tympanogram width represents the interval between two pressure points at which the tympanogram reaches 50% of its peak admittance. The results indicated a reduced tympanogram width at all five frequencies following surgery, suggesting a sharper peak and improved middle ear conditions. This finding supports the significance of early management in children with cleft palate, as emphasized by Robinson et al. (1992), which includes the timely insertion of ventilation tubes to ensure adequate hearing and contribute to a narrower peak and diminished tympanogram width [10].

Moreover, the average peak pressure in the middle ear at frequencies of 226 Hz, 678 Hz, 800 Hz, and 1000 Hz, and resonance frequency were compared before and after surgery. The results showed a negative reduction in peak pressure at all five frequencies, indicating improved middle ear function post-surgery. These findings are consistent with previous research by Keefe et al. (2012) which demonstrated that wideband tympanometry is more sensitive than 226 Hz tympanometry in predicting negative middle ear pressure and subsequent hearing loss [16]. Additionally, cleft palate closure through surgery can result in a reduction in middle ear pathologies, negative middle ear pressure, and auditory disorders, thereby mitigating the detrimental effects associated with the condition [17]. Overall, these findings underscore the importance of timely and effective surgical intervention for individuals with cleft palate to improve middle ear function and reduce related complications.

Conclusion

The current study utilized wideband tympanometry to evaluate middle ear function in children with cleft palate and lip before and after surgery. The results highlighted compromised pre-operative middle ear function, with wideband tympanometry showing superior diagnostic capacity compared to conventional techniques and offering enhanced precision in evaluating middle ear function in this patient population. Furthermore, wideband tympanometry was found to be a feasible option for newborns with narrow and small ear canals and demonstrated higher sensitivity in diagnosing middle ear pathologies compared to high-frequency tympanometry. As such, this study suggests that wideband tympanometry has significant potential as an alternative tool in clinical practice for assessing middle ear function.

Study limitations and future research recommendations

This study encountered several limitations that may impact the generalizability of its findings. Firstly, the emergence of the COVID-19 pandemic restricted access to potential patients. The ban on intercity travel, the quarantine of cities, and the reluctance of individuals to leave their homes resulted in a smaller sample size than originally intended. This smaller sample size may impact the generalizability of the findings. Another limitation was that the hearing evaluations used in the study required a significant amount of time and effort from participants, which may have led to fatigue and decreased compliance. This limited the feasibility of examining other hearing evaluations.

Future studies could be conducted on a larger scale with a larger sample size and the inclusion of additional hearing tests that can provide further insights into the auditory system's functioning. Additionally, periodic follow-up assessments of patients could be conducted to evaluate the success of the surgery and assess the function of the middle ear over time. This would provide a more comprehensive understanding of the long-term outcomes of the intervention and help identify any potential complications or issues that may arise with time.

Ethical Considerations

Compliance with ethical guidelines

The study received ethical approval from the Ethics Committee of Iran University of Medical Sciences (Code: IR.IUMS.REC.1399.779).

Funding

This study was extracted from the master's thesis of Atefeh Kazemi, approved by the Department of Department of Audiology, School of Rehabilitation Sciences, Iran University of Medical Sciences, and was supported by Iran University of Medical Sciences (No.: 0-1-6-19855).

Authors' contributions

Conceptualization: All authors; Data collection, writing the original draft: Atefeh Kazemi; Statistical analysis: Malihe Mazaher Yazdi; Project administration: Mohsen Ahadi and Abbas Kazemi Ashtiani; Study design, review and editing: Mohsen Ahadi: Malihe Mazaher Yazdi and Abbas Kazemi Ashtiani; Supervision: Mohsen Ahadi.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgments

The authors thank Nahid Jalilehvand, for her support and contribution in referring the patients. Her involvement was essential in allowing us to gather the required data. The authors express our gratitude to all those families who participated in the study.

References

[1] Kati F. Cleft lip and palate: Review article. World Journal of Pharmaceutical and Medical Research. 2018; 4(7):155-63. [Link]

[2] Goodacre T, Swan MC. Cleft lip and palate: Current management. Pediatrics and Child Health. 2012; 22(4):160-8. [DOI:10.1016/j.paed.2011.11.010]

[3] Shkoukani MA, Chen M, Vong A. Cleft lip-a comprehensive review. Frontiers in Pediatrics. 2013; 1:53. [DOI:10.3389/fped.2013.00053] [PMID]

[4] Mossey PA, Little J, Munger RG, Dixon MJ, Shaw WC. Cleft lip and palate. The Lancet. 2009; 374(9703):1773-85. [DOI:10.1016/S0140-6736(09)60695-4] [PMID]

[5] Beumer J 3rd, Roumanas E, Nishimura R. Advances in osseointegrated implants for dental and facial rehabilitation following major head and neck surgery. Seminars in Surgical Oncology. 1995; 11(3):200-7. [DOI:10.1002/ssu.2980110305] [PMID]

[6] Duarte GA, Ramos RB, Cardoso MC. Feeding methods for children with cleft lip and/or palate: A systematic review. Brazilian Journal of Otorhinolaryngology. 2016; 82(5):602-9. [DOI:10.1016/j.bjorl.2015.10.020] [PMID]

[7] Chen YW, Chen KT, Chang PH, Su JL, Huang CC, Lee TJ. Is otitis media with effusion almost always accompanying cleft palate in children?: The experience of 319 Asian patients. The Laryngoscope. 2012; 122(1):220-4. [DOI:10.1002/lary.22425] [PMID]

[8] Wimmer E, Toleti B, Berghaus A, Baumann U, Nejedlo I. Impedance audiometry in infants with a cleft palate: The standard 226-Hz probe tone has no predictive value for the middle ear condition. International Journal of Pediatric Otorhinolaryngology. 2010; 74(6):586-90. [DOI:10.1016/j.ijporl.2010.02.019] [PMID]

[9] Hunter LL, Shahnaz N. Acoustic immittance measures: Basic and advanced practice. California: Plural Publishing, Incorporated; 2013. [Link]

[10] Robinson PJ, Lodge S, Jones BM, Walker CG, Grant HR. The effect of palate repair on otitis media with effusion. Plastic and Reconstructive Surgery. 1992; 89(4):640-5. [DOI:10.1097/00006534-199204000-00007] [PMID]

[11] Tiwari R, Sharma RK, Panda NK, Munjal S, Makkar S. Tensor tenopexy: A clinical study to assess its effectiveness in improving Eustachian tube function and preventing hearing loss in patients with cleft palate. Journal of Plastic, Reconstructive & Aesthetic Surgery. 2013; 66(9):e239-45. [DOI:10.1016/j.bjps.2013.05.001] [PMID]

[12] Hunter LL, Bagger-Sjöbäck D, Lundberg M. Wideband reflectance associated with otitis media in infants and children with cleft palate. International Journal of Audiology. 2008; 47(sup1):S57-61. [DOI:10.1080/14992020802294057] [PMID]

[13] Margolis RH, Saly GL, Keefe DH. Wideband reflectance tympanometry in normal adults. The Journal of the Acoustical Society of America. 1999; 106(1):265-80. [DOI:10.1121/1.427055] [PMID]

[14] Feeney MP, Keefe DH, Hunter LL, Fitzpatrick DF, Garinis AC, Putterman DB, et al. Normative wideband reflectance, equivalent admittance at the tympanic membrane, and acoustic stapedius reflex threshold in adults. Ear and Hearing. 2017; 38(3):e142-60. [DOI:10.1097/AUD.0000000000000399] [PMID]

[15] Tunçbilek G, Özgür F, Belgin E. Audiologic and tympanometric findings in children with cleft lip and palate. The Cleft Palate-Craniofacial Journal. 2003; 40(3):304-9. [DOI:10.1597/1545-1569_2003_040_0304_aatfic_2.0.co_2] [PMID]

[16] Keefe DH, Sanford CA, Ellison JC, Fitzpatrick DF, Gorga MP. Wideband aural acoustic absorbance predicts conductive hearing loss in children. International Journal of Audiology. 2012; 51(12):880-91. [DOI:10.3109/14992027.2012.721936] [PMID]

[17] Tasko SM, Deiters KK, Flamme GA, Smith MV, Murphy WJ, Jones HG, et al. Effects of unilateral eye closure on middle ear muscle contractions. Hearing Research. 2022; 424:108594. [DOI:10.1016/j.heares.2022.108594] [PMID]