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Interchangeability of three different methods of calculating Pure Tone Average in patients with vestibular schwannoma to assess the risk of surgery-related hearing loss

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

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ABSTRACT:

Background: Patients with vestibular schwannoma (VS) most commonly present with hearing threshold reduction for high frequencies and a falling type of audiometric curve. However, it is doubtful whether all Pure Tone Averages described in the literature characterize patients with VS correctly, as the type of PTA which comprises higher frequencies may be more appropriate for hearing status assessment in those patients.

Aim: The aim of this study was to analyze 3 common methods of calculating Pure Tone Averages (PTA1 – 500, 1000, 2000 and 3000 Hz; PTA2 – 500, 1000, 2000 and 4000 Hz; PTA3 – 500, 1000 and 2000 Hz) and to determine which of them is the most reliable for the assessment of VS patients

Material and Methods: The study group included 86 patients operated on due to vestibular schwannoma accessed via the middle cranial fossa.

Results: Regarding the method of calculating Pure Tone Averages (PTA1, PTA2 and PTA3) identical or similar correlations were found between the preoperative values of Pure Tone Averages (PTA1, PTA2 and PTA3) and surgery-related hearing loss, as well as individual parameters of audiologic tests.

Conclusions: Pure Tone Averages calculated according to 3 different methods (PTA1, PTA2, PTA3) may be used interchangeably in the assessment of hearing in VS patients.

KEYWORDS: acoustic neuroma, audiometry, hearing loss, vestibular schwannoma

ABBREVIATIONS

AAO-HNS – American Academy of Otolaryngology – Head and Neck Surgery
ABR – auditory brainstem response
IID – interaural interval difference
ILD – interaural latency difference
PTA – Pure Tone Average
SDS – speech discrimination score
SDT – Speech Detection Threshold
SRT – Speech Reception Threshold
VS – vestibular schwannoma

INTRODUCTION

Literature data concerning hearing assessment in patients with vestibular schwannoma (VS) are based on numerous scales proposed by authors, including AAO-HNS, Sanna classification and others. Almost all of the described classifications are based on Pure Tone Average (PTA) in pure-tone audiometry and/or speech discrimination score (SDS) in speech audiometry. However, the compatibility of test results is quite controversial. This is due to the fact that SDS may be viewed as a universal parameter, while Pure Tone Average is calculated in three different versions in scales used in professional literature. The use of scales depends on a tendency in a specific region of the world: PTA calculated from hearing thresholds for the frequencies of 500, 1000, 2000 and 3000 Hz is common in North America and partly in Europe, PTA for 500, 1000, 2000 and 4000 Hz is calculated mainly in Asia, but also in parts of Europe, while PTA for 500, 1000 and 2000 Hz is commonly used in European papers [1–4]. Despite the similarity of those methods, different findings may be obtained in groups of VS patients, including types of audiometric curves specific for this group of patients, which may cause differences in the results of further analyses [5–9].

AIM

The aim of the present study was to assess which one of 3 popular methods of calculating Pure Tone Averages is the most reliable for patients with vestibular schwannoma and to determine whether scientific research based on 3 different versions of Pure Tone Averages may be compared without limitations. To the best of our knowledge, no analyses regarding this issue in VS patients have been published so far.

MATERIAL AND METHODS

Retrospective analysis covered data obtained from audiologic tests and case histories of 86 patients operated on for vestibular schwannoma with the tumor removed via middle cranial fossa approach, which is a technique promoting hearing preservation. Every procedure was performed by the same experienced otosurgeon.

The remaining inclusion criteria for the study were: preoperative magnetic resonance imaging confirming the presence of the tumor in the region of the cerebellopontine angle, vestibular schwannoma confirmed in postoperative histopathological examination, the results of subjective (pure-tone audiometry, speech audiometry) and objective (impedance audiometry, ABR testing) audiologic tests performed preoperatively, the results of pure-tone audiometry performed within 3 postoperative months.

Each study group patient underwent diagnostic and medical procedures according to a standard protocol implemented in our Department concerning patients with a suspected tumor of the cerebellopontine angle. According to the protocol, each patient underwent a series of audiologic tests including pure-tone audiometry, speech audiometry, impedance audiometry with stapedial reflex testing and auditory brainstem response (ABR) within the preoperative month. Follow-up monitoring of patients included audiologic tests, including pure-tone audiometry performed 3 months postoperatively.

Both preoperative and postoperative Pure Tone Audiometry results constituted the basis for the correlation analysis of Pure Tone Averages (calculated in 3 versions) compared to parameters included in audiologic tests listed below.

Individual versions of Pure Tone Averages, later referred to as abbreviations:

- PTA1 – Pure Tone Averages calculated for the frequencies of 500, 1000, 2000 and 3000 Hz,
- PTA2 – Pure Tone Averages calculated for the frequencies of 500, 1000, 2000 and 4000 Hz,
- PTA3 – Pure Tone Averages calculated for the frequencies of 500, 1000, 2000 Hz.

Analyzed parameters

The following parameters were specified in pure-tone audiometry: the values of hearing thresholds at individual test frequencies, air- and bone-conduction, PTA calculated in 3 versions on the side affected with VS, interaural differences in the values of hearing thresholds for each of the test frequencies from 125 to 8000 Hz, for air-conduction (the value of hearing threshold in the operated ear minus the value of hearing threshold in the non-operated ear), and interaural differences between Pure Tone Average – PTA (the value of Pure Tone Average in the operated ear minus the value of Pure Tone Average in the non-operated ear).

The following parameters were analyzed in speech audiometry: speech discrimination (expressed as percentages) for individual sound volumes with particular attention paid to the value of 55–65 dB SPL as one which corresponds with typical speech intensity; interaural differences in speech discrimination (expressed as percentages) for individual values of sound volume – discrimination for the non-operated minus discrimination for the operated ear at a specific volume; Speech Detection Threshold (SDT) expressed in dB SPL; Speech Reception Threshold (SRT) – expressed in dB SPL; SDS – expressed as percentages; interaural difference between SDS (value for the non-operated ear minus value for the operated ear); achieving 100% of speech discrimination by the patient – with zero-one method.

Impedance audiometry was used to assess the presence or absence of the stapedial reflex and the value of sound intensity at which the stapedial reflex was obtained. However, if the reflex was absent, its value was recorded as 130 dB in order to facilitate the analyses.

Moreover, the patients were grouped based on normal or pathological stapedial reflex (with the pathological reflex described as test volume exceeding reference values – 100 dB SPL, positive Metz symptom and a complete lack of stapedial response). Type A tympanograms were obtained in each patient. Therefore, tympanogram curve shape was disregarded in the analysis.

ABR tests were conducted with Smart box platform integrated with Smart-EP software (Intelligent Hearing Systems, Corp., Miami, Florida, USA). A 90 dB nHL broadband click was used as the acoustic stimulus. The frequency of stimulus delivery was 31/s.

The following ABR parameters were assessed: waveform morphology – the presence of waves I, III and V; wave latency values – I, III and V; interval values – I–III, I–V, III–V; interaural latency difference (ILD) for waves I, III and V; interaural interval difference (IID) for I–III, I–V and III–V; amplitude values for waves I, III and V measured as an average of 3 measurements for each wave; interaural amplitude difference for waves I, III and V; interaural amplitude ratio for waves I, III, V – amplitude values measured on the side of the tumor compared with contralateral amplitudes for the respective wave; amplitude ratio for waves V and I – ARI_V; interaural ARI_V ratio – ipsilateral vs. contralateral to the tumor, the consistency of selected parameters with reference values according to Hall – 1997 [10].

The above-mentioned parameters of the assessment of the pre- and postoperative hearing status calculated on the basis of data obtained from pure-tone audiometry were used to evaluate surgery-related hearing loss by determining absolute hearing loss, which was defined as a difference between pre- and postoperative PTA for the operated ear. It was calculated in 3 versions – adequately for each type of PTA. All statistical calculations were performed with IBM SPSS Statistics software. Prior to the analyses all the quantitative variables had been examined in terms of data distribution with two measures of distribution: skewness and kurtosis.

The calculations were based mainly on Pearson's r coefficient and Spearman's rho coefficient. A result was considered statistically significant with the P value below 0.05 ($P < 0.05$).

Ethical consideration

The study was approved by the local Institutional Ethics Committee Review Board where the study was conducted. The project conforms to The Code of Ethics of the World Medical Association (Declaration of Helsinki).

RESULTS

Descriptive statistics of the study group demonstrated that the transformation of BIAP classification of hearing impairment presented in 3 different versions depending on Pure Tone Average PTA1, PTA2, PTA3 (traditionally calculated only for the parameter categorized as PTA2 in this study) led to a minimal discrepancy as regards classes obtained by the patients.

Normal results were found to be ranging from 36% for PTA1 to 44.2% for PTA3 (Tab. I.).

As regards the method of calculating Pure Tone Averages (PTA1, PTA2 and PTA3), we used Pearson's r coefficient to investigate the presence of a correlation between preoperative mean values of Pure Tone Averages (PTA1, PTA2 and PTA3) and surgery-related hearing loss (the respective pre- and postoperative differences in Pure Tone Averages PTA1, PTA2, or PTA3).

Each correlation proved to be negative which showed that surgery-related hearing loss decreased with an increase in the values of Pure Tone Averages. Detailed results are presented in Tab. II.

Speech audiometry showed that preoperative parameters which indicated a correlation regarding surgery-related hearing loss had similar values of Pearson's r correlation regardless of the variant of calculating absolute hearing loss (according to PTA1, PTA2, PTA3) – Tab. III.

They included: individual values of speech discrimination intensities: 45–120 dB SPL, SDT, SRT and the fact of achieving (or not) 100% of speech discrimination. The lowest correlation with surgery-related hearing loss was demonstrated for SDS parameter, which showed a statistically significant positive correlation only in case of hearing loss calculated according to PTA2.

However, surgery-related Pure Tone Average reductions calculated according to PTA1 and PTA3 remained at the limit of statistical significance.

Tab. I. Preoperative BIAP hearing impairment calculated for 3 variants of Pure Tone Averages PTA1, PTA2, and PTA3.

		PTA1	PTA2	PTA3
hearing impairment	normal	36.00%	37.20%	44.20%
	slight	29.10%	26.70%	31.40%
	moderate	32.60%	33.70%	20.90%
	severe	2.30%	2.30%	3.50%
total		100.00%	100.00%	100.00%

Tab. II. Correlation between surgery-related hearing loss (the respective pre- and postoperative differences of PTA1, PTA2, or PTA3) and preoperative mean values of Pure Tone Averages (PTA1, PTA2 and PTA3) [dB HL].

SURGERY-RELATED ABSOLUTE HEARING LOSS CALCULATED ACCORDING TO		PREOPERATIVE PTA1	PREOPERATIVE PTA2	PREOPERATIVE PTA3
PTA1	r	-0.331**	-0.322**	-0.357**
	p	0.002	0.002	0.001
PTA2	r	-0.331**	-0.328**	-0.361**
	p	0.002	0.002	0.001
PTA3	r	-0.307**	-0.302**	-0.357**
	p	0.004	0.005	0.001

** $p < 0.01$

ABR test showed that regardless of the method of calculating absolute hearing loss (according to PTA1, PTA2, PTA3) statistically significant similarity was observed between Pearson's r coefficient and the following values: deviation from the reference values of I–V interval, deviation from the reference values of III–V interval, normal amplitude ratio of waves V and I (Tab. III.).

Impedance audiometry revealed that a similar statistically significant correlation with absolute hearing loss calculated for each of the three PTAs was found for the intensity for obtaining the stapedial reflex [dB SPL] for: Ipsi 2000 Hz for the operated ear, Contra 500 Hz for the non-operated ear, Contra 1000 Hz for the non-operated ear [dB SPL], Contra 2000 Hz for the non-operated ear, Contra 4000 Hz for the non-operated ear, and the normality of the reflex for 500, 1000 and 2000 Hz in the operated ear (Tab. III.).

The above results proved to be very similar to individual PTA variants (Tab. III.) which may suggest that the variants of Pure Tone Averages may be used interchangeably in VS patients.

DISCUSSION

Professional literature presents a variety of hearing status classifications used in the assessment of patients with vestibular schwannoma. However, the comparison of research results between individual clinical centers may raise some doubts. Dugar et al. [11] and Lassaletta et al. [12] noted in their papers that depending on the scale of hearing assessment, serviceable hearing in the group of VS patients ranged from 0% to 56%.

Notably, the discrepancy is very wide. Commonly used scales of hearing capacity assessment are based on 3 differently calculated Pure Tone

Tab. III. Correlation between the indexes of speech audiometry, ABR test and impedance audiometry and surgery-related hearing loss calculated as Pure Tone Averages PTA1, PTA2 and PTA3 (post- and preoperative differences between Pure Tone Averages PTA1, PTA2 and PTA3) – Pearson's r coefficient values.

	SURGERY-RELATED ABSOLUTE HEARING LOSS CALCULATED ACCORDING TO		
PARAMETR	PTA1	PTA2	PTA3
SPEECH AUDIOMETRY			
SDT	-0.324**	-0.314**	-0.307**
SRT	-0.341**	-0.338**	-0.321**
SDS	0.22	0.226*	0.208
Did the patient achieve 100% of speech discrimination?	0.325**	0.341**	0.306**
45 dB SPL	0.252*	0.249*	0.227*
50 dB SPL	0.313**	0.311**	0.298**
55 dB SPL	0.361**	0.360**	0.350**
60 dB SPL	0.382**	0.382**	0.370**
65 dB SPL	0.373**	0.370**	0.355**
70 dB SPL	0.351**	0.346**	0.331**
75 dB SPL	0.333**	0.327**	0.313**
80 dB SPL	0.302**	0.297**	0.281*
85 dB SPL	0.274*	0.265*	0.246*
90 dB SPL	0.252*	0.239*	0.224*
95 dB SPL	0.254*	0.249*	0.231*
100 dB SPL	0.229*	0.234*	0.209
105 dB SPL	0.264*	0.269*	0.245*
110 dB SPL	0.285*	0.289*	0.267*
115 dB SPL	0.267*	0.271*	0.250*
120 dB SPL	0.251*	0.257*	0.236*
ABR			
deviation from the reference values of I–V interval	0.261*	0.280*	0.273*
deviation from the reference values of III–V interval	0.248*	0.244*	0.240*
normality of the amplitude ratio of waves V and I against reference values	0.277*	0.262*	0.251*
IMPEDANCE AUDIOMETRY			
Ipsi 2000 Hz for the operated ear [dB SPL]	-0.263*	-0.258*	-0.238*
Contra 500 Hz for the non-operated ear [dB SPL]	-0.258*	-0.250*	-0.233
Contra 1000 Hz for the non-operated ear [dB SPL]	-0.308**	-0.309**	-0.280*
Contra 2000 Hz for the non-operated ear [dB SPL]	-0.338**	-0.334**	-0.299*
Contra 4000 Hz for the non-operated ear [dB SPL]	-0.424**	-0.421**	-0.373**
reflex normality for 500 Hz in the operated ear	0.269*	0.271*	0.267*
reflex normality for 1000 Hz in the operated ear	0.334**	0.330**	0.325**
reflex normality for 2000 Hz in the operated ear	0.399**	0.388**	0.362**

* $p < 0.05$; ** $p < 0.01$

Averages, which leads to the conclusion of a possible resultant incoherence of classifications proposed by different centers [5–9].

VS patients frequently present with hearing threshold reduction for high frequencies and a falling type of audiometric curve [5–9]. Therefore, the type of Pure Tone Averages which comprises higher frequencies may be more appropriate for hearing assessment in those patients.

The majority of papers published in Europe and North America describe Pure Tone Averages calculated on the basis of 4 frequencies: 500; 1000; 2000 and 3000 Hz (Tab. IV.). This method of calculation is also recommended by AAO-HNS in the assessment of the hearing status [1, 13].

In some parts of Asia, with a marked predominance of Japanese centers, the recommended method of calculating Pure Tone Averages involves the classification of the hearing status with Pure Tone Averages for the frequencies of 500, 1000, 2000 and 4000 Hz [14]. This version of PTA for patients with vestibular schwannoma was proposed in Sanna classification presented during a symposium in Keio in 2003 (Tab. V.) [14], Nordstadt classification [2], and Hannover classification [3]. In some parts of Europe and according to BIAP recommendations Pure Tone Average is calculated for 3 frequencies: 500,

Tab. IV. AAO-HNS (American Academy of Otolaryngology – Head and Neck Surgery) hearing classification [1].

CLASS	PTA – PURE TONE AVERAGES CALCULATED FOR THE FREQUENCIES OF 500, 1000, 2000 AND 3000 HZ	SDS – SPEECH DISCRIMINATION SCORE
A	≤ 30.00 dB HL	≥ 70%
B	30.01–50.00 dB HL	≥ 50%
C	≥ 50.01 dB HL	≥ 50%
D	each level	< 50%

Tab. V. Sanna classification [14]. PTA – Pure Tone Averages calculated for the frequencies of 500, 1000, 2000 and 4000 Hz, SDS – speech discrimination score.

CLASS	PTA	SDS
A	≤ 20 dB HL	≥ 80%
B	21–30 dB HL	79–70%
C	31–40 dB HL	69–60%
D	41–60 dB HL	59–50%
E	61–80 dB HL	49–40%
F	≥ 81 dB HL	< 39%

1000 and 2000 Hz (Tab. VI.) [4]. The same type of Pure Tone Average calculation was proposed in Gardner-Robertson classification for the assessment of the hearing status in patients with vestibular schwannoma [15].

The present paper revealed that PTA1 and PTA2 variants are similar in the assessment of the hearing status in VS patients,

Tab. VI. BIAP hearing impairment classification. PTA – Pure Tone Averages calculated for the frequencies of 500, 1000 and 2000 Hz [4].

PTA3	HEARING IMPAIRMENT
< 20 dB HL	normal
21–40 dB HL	slight
41–70 dB HL	moderate
71–89 dB HL	severe
> 90 dB HL	profound

while PTA3 is slightly more liberal and more patients fall within normal reference ranges.

Correlation analysis showed that the values of preoperative Pure Tone Averages (PTA1, PTA2 and PTA3) and surgery-related hearing loss (the respective differences between pre- and postoperative Pure Tone Averages – PTA1, PTA2 and PTA3) are similar to individual PTA variants, which suggests that the above 3 variants of Pure Tone Averages may be used interchangeably in VS patients.

CONCLUSIONS

In conclusion, Pure Tone Averages calculated according to 3 different methods (for 500, 1000, 2000 and 3000 Hz; 500, 1000, 2000 and 4000 Hz; and for 500, 1000, 2000 Hz) constitute the basis for coherent assessment of the hearing status in VS patients and may be used interchangeably in the determination of hearing capacity in VS patients.

REFERENCES

1. Committee on Hearing and Equilibrium guidelines for the evaluation of hearing preservation in acoustic neuroma (vestibular schwannoma). American Academy of Otolaryngology-Head and Neck Surgery Foundation, INC. Otolaryngol Head Neck Surg, 1995; 113(3): 179–180.
2. Samii M., Matthies C.: Hearing preservation in acoustic tumour surgery. Adv Tech Stand Neurosurg, 1995; 22: 343–373.
3. Samii M., Matthies C.: Management of 1000 vestibular schwannomas (acoustic neuromas): the facial nerve-preservation and restitution of function. Neurosurgery, 1997; 40(4): 684–695.
4. BIAP Recommendation 02/1 bis – Audiometric classification of hearing impairments. biap.org. International Bureau Audiophonology 26 October 1996. Retrieved 18 June 2017.
5. Tutar H., Duzlu M., Göksu N., Üstün S., Bayazit Y.: Audiological correlates of tumor parameters in acoustic neuromas. Eur Arch Otorhinolaryngol, 2013; 270(2): 437–441.
6. Ochal-Choińska A., Lachowska M., Kurczak K., Niemczyk K.: Audiologic prognostic factors for hearing preservation following vestibular schwannoma surgery. Adv Clin Exp Med., 2019; 28(6): 747–757.
7. Hunt A.A., Cass N.D., Coughlin A., Gubbels S.P.: Time-based Assessment of Hearing Preservation Rates After Microsurgical Resection of Vestibular Schwannomas: A Systematic Review. Otol Neurotol., 2020; 41(5): 679–685.
8. Zanoletti E., Mazzoni A., Frigo A.C., Borsetto D., Cazzador D.: Hearing Preservation Outcomes and Prognostic Factors in Acoustic Neuroma Surgery: Predicting Cutoffs. Otol Neurotol., 2020; 41(5): 686–693.
9. Patel N.S., Huang A.E., Dowling E.M., Lees K.A., Tombers N.M. et al.: The Influence of Vestibular Schwannoma Tumor Volume and Growth on Hearing Loss. Otolaryngol Head Neck Surg., 2020; 162(4): 530–537.
10. Hall J.W., Mueller H.G.: Audiologists' Desk Reference: Volume I. Diagnostic Audiology Procedures, Procedures, and Practices: San Diego: Singular Publishing Group, 1997.
11. Dugar J., Nikolopoulos T.P., O'Donoghue G.M.: Hearing preservation in acoustic neuroma surgery: the impact of different patient selection criteria. Laryngoscope, 2002; 112(11): 2051–2053.
12. Lassaletta L., Fontes L., Melcon E., Sarria M.J., Gavilan J.: Hearing preservation with the retrosigmoid approach for vestibular schwannoma: myth or reality? Otolaryngol Head Neck Surg, 2003;129(4): 397–401.
13. Caye-Thomasen P., Dethloff T., Hansen S., Stangerup S.-E., Thomsen J.: Hearing in patients with intracanalicular vestibular schwannomas. Audiol Neurootol, 2007; 12(1): 1–12.
14. Kanzaki J. (ed.): Acoustic neuroma: Consensus on systems for reporting results. Keio University international symposia for life sciences and medicine, Vol 10. Tokyo, New York: Springer, 2003. 1 online resource (xvi, 194).
15. Gardner G., Robertson J.H.: Hearing preservation in unilateral acoustic neuroma surgery. Ann Otol Rhinol Laryngol, 1988; 97(1): 55–66.

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