Hearing Outcomes Reporting in Lateral Skull Base Surgery

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Abstract

Hearing outcomes reporting has evolved significantly and new standards for reporting now enable a more precise and comprehensive representation of hearing outcomes. Hearing is one of the critical sensory domains contained within the lateral skull base and temporal bone. For those patients with serviceable hearing, hearing preservation is a key treatment goal. Pre- and postoperative hearing assessment is fundamental to the diagnostic evaluation of patients preparing to undergo lateral skull base surgery. Standardization in reporting these hearing outcomes is critical to compare the efficacy of different treatment options for lateral skull base lesions. Over the time, reporting of hearing outcomes has evolved from broadly categorizing patients into large groups to comparing individual patients which requires more specific datasets to compare pre- and posttreatment hearing outcomes. Future research in lateral skull base surgery will benefit from precise, accurate, and easily understood reporting outcomes, all of which will allow for more efficient comparability between studies and pooling of data for meta-analysis.

Keywords

- lateral skull base surgery
- hearing
- audiology
- neurotology

Introduction

In the modern era of lateral skull base surgery, there is a strong emphasis on preserving function. As surgical techniques have advanced, mortality rates have fallen and a focus on minimizing morbidity has become paramount. Hearing is one of the critical sensory domains contained within the lateral skull base and temporal bone. For patients with serviceable hearing, hearing preservation is a key treatment goal in lateral skull base surgery. The importance of hearing preservation is elevated in younger patients who may have many years of potentially serviceable hearing or in those patients with benign tumors of the skull base. There are numerous surgical approaches to the lateral skull base which allow the surgeon to tailor the procedure and approach to a patient's pathologic and physical status. Functionally, preservation of the otic capsule, labyrinthine artery, and cochlear nerve are the major requirements for hearing preservation. Surgical approaches that traverse the otic capsule provide wider exposure and direct access to the

cerebellopontine angle; however, hearing will be lost. In contrast, there are numerous otic capsule-sparing approaches to the skull base, providing opportunities for hearing preservation with the trade-off of varying degrees of exposure.

Management of the lateral skull tumors in patients with serviceable hearing is quite complex. In addition to the various otic capsule-sparing surgical approaches, which can preserve inner ear structures and the integrity of the cochlear division of the eighth cranial nerve, nonsurgical management options, namely, active surveillance and radiotherapy, –also preserve the anatomic structures critical for hearing. However, even with these nonsurgical strategies, progressive hearing loss may ensue as a result of radiation effect or disease progression. Deciding which of the various strategies to apply to any given patient with functional hearing requires an understanding of the techniques and existing data on the hearing preservation rates of these therapeutic options. Unfortunately, the historical use of various inadequate pre- and posttreatment hearing measurements and classifications has made the comparison of

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hearing outcomes following these various treatments difficult and complicated.

For those patients deemed appropriate surgical candidates, pre- and postoperative hearing assessment is fundamental to the diagnostic evaluation of patients preparing to undergo lateral skull base surgery. Hearing is measured by trained clinicians, usually audiologists, and is graded according to published standards.^{1,2} Routine audiometry measures hearing thresholds using pure (single-frequency) tones at predetermined frequencies. The most important frequencies to hearing are then averaged together to provide the pure tone average (PTA) which represents the average volume threshold of sound detection. The 4-frequency PTA typically combines 0.5, 1, 2, and 3 kHz and was recommended by the 1979 American Medical Association (AMA) guidelines for calculating hearing handicap.³ This combination of frequencies continues to be recommended by the AMA as the gold standard and has been extensively evaluated against other combinations, none of which have demonstrated superiority.⁴

The other critical component of hearing evaluation is the word recognition (or speech discrimination) score (WRS or SDS) which is a measure of sound clarity at a volume well above the minimal threshold of hearing. The WRS provides information regarding the clarity of hearing and more specifically, the ability to discern words. Of the two basic metrics, PTA and WRS, the WRS offers more functional relevance for patients as WRS predicts whether hearing loss is amenable to amplification. While hearing aids can make sound louder, they do not make sound clearer. If patients experience decreased WRS as a result of disease or treatment, they will have functional hearing impairment that cannot be rectified by simply increasing volume with a hearing aid. Retrocochlear pathology will often affect WRS disproportionately when compared with changes in PTA. Moreover, retrocochlear-pattern hearing loss is classically associated with “rollover”—a phenomenon characterized by decay of the speech discrimination score with increased stimulus intensity.

Standardization in reporting hearing outcomes is critical to compare the efficacy of different treatment options. For example, an omission of either PTA or WRS can mislead a reader when trying to interpret accurate hearing outcomes for a given therapeutic option. What is the optimal method of reporting hearing outcomes? In this paper, we will:

1. Describe historical methods of reporting hearing outcomes in lateral skull base surgery.
2. Describe current methods and recommendations for reporting hearing outcomes, as well as future directions for reporting hearing outcomes.

Hearing Measurement and Classification Systems

Gardner–Robertson Scale (1988)

The first widely adopted hearing classification in lateral skull base surgery was the Gardner–Robertson hearing scale (►Table 1).⁵ The objective of this 1988 publication was to create a 5-class scale that was simple, easy to remember, and clinically relevant. Wade and House had previously

Table 1 Gardner–Robertson classification for hearing preservation

Class	PTA or SRT (dB) ^a	Speech discrimination
1	0–30 and	70–100
2	31–50 and	50–69
3	51–90 and	5–49
4	91–max loss and	1–4
5	No response and	No response

Abbreviations: PTA, pure tone average; SRT, speech reception threshold.

^aUse better score. If PTA/SRT score and speech discrimination scores do not qualify for same class, use class appropriate for poorer of two scores.

Source: Reference 5.

described the “50/50 rule,” which defined serviceable hearing as a PTA of > 50 dB with a SDS of 50% or better.⁶ The Gardner–Robertson scale was based on the idea that the “50/50 rule” did not provide useful clinical information necessary to differentiate and classify the variety of hearing outcomes. Gardner and Robertson modified a classification system scale of hearing preservation initially proposed by Silverstein et al⁷ and became the widely standardized hearing scale used for reporting hearing outcomes in lateral skull base surgery for most of the following decade.

1995 American Academy of Otolaryngology–Head and Neck Surgery (AAO–HNS) Guidelines

In 1995, the AAO–HNS Committee on Hearing and Equilibrium established specialty-specific guidelines for reporting hearing outcomes after hearing preservation surgery for lateral skull base surgery.⁸ In these 1995 AAO–HNS guidelines, which were published specifically regarding vestibular schwannoma surgery, hearing thresholds were to be reported as an average of the pure tone hearing thresholds by air conduction at 0.5, 1, 2, and 3 kHz. The best WRS/SDS at presentation levels of up to 40 dB sensation level or maximum comfortable loudness (whichever is less) were also to be recorded before and after treatment.

Standardizing the reporting of hearing preservation outcomes allowed for the establishment of a simple normogram of hearing class based on the SDS and the PTA (►Table 2). Reporting of hearing outcomes was simplified by creating 4 classes of hearing—designated A, B, C, and D—from the previous 5 classes in the Gardner–Robinson system (►Fig. 1). For example, if using the Gardner–Robinson system, a patient with a SDS of 50 could potentially have one of 3 classes of

Table 2 AAO–HNS 1995 hearing classification system

Class	Pure tone thresholds	Speech discrimination (%)
A	≤30 dB and	≥70
B	> 30 dB, ≤50 dB and	≥50
C	> 50 dB and	≥50
D	Any level	< 50

Source: Reference 5.⁸

Fig. 1 The nomogram of hearing classification from the 1995 American Academy of Otolaryngology–Head and Neck Surgery guidelines for the evaluation of hearing preservation in acoustic neuroma. Word recognition (speech discrimination) is along the horizontal axis, and pure tone threshold average is along the vertical axis. Source: reference 8.

hearing depending on their PTA (► **Table 1**). Using the 1995 AAO–HNS guidelines; however, all patients with a SDS < 50 are considered as having nonserviceable hearing whereas the Gardner–Robinson system could classify these patients variably as class 3, 4, or 5 despite all having essentially nonserviceable hearing. Ultimately, the AAO–HNS 1995 guidelines proposed that investigators should report pre- and posttreatment pure tone hearing thresholds, the best WRS/SDS, and hearing class which was to be reported as unchanged, improved, or worse.^{8,9}

The 1995 AAO–HNS update was an improvement over previously reported systems as it provided more granularity for describing postoperative hearing outcomes, particularly related to WRS which was recognized as a key for identifying the potential for successful postoperative amplification if needed. This system was recognized as the standard method for reporting hearing preservation outcomes with lateral skull base surgery for more than 15 years.

Modified or “Simplified” Word Recognition Score Hearing Classification

Word recognition is arguably the most important metric of routine audiometry for determining a patient’s posttreatment functional hearing. Meyer et al simplified the hearing classification from the 1995 AAO–HNS guidelines, to create a classification system based solely on the patient’s word recognition score (Class I = 100–70% WRS; Class II = 69–50% WRS; Class III = 49–1% WRS; Class IV = 0%).¹⁰ Pure tone thresholds are excluded from this simplified system because the WRS is the best predictive value to determine if an ear would benefit from amplification. This simplified classification scheme has been used in many different publications reporting hearing outcomes.^{10–13}

2012 AAO–HNS Guidelines

In 2012, the AAO–HNS Hearing and Equilibrium Committee made significant modifications to the 1995 guidelines to update the minimal requirements for reporting hearing outcomes after lateral skull base surgery.¹⁴ These new guidelines were meant to be inclusive of any intervention in addition to surgery, including stereotactic radiation, observation, or medical management, in which hearing outcomes are reported. As an update to the 1995 guidelines, the 2012 guidelines no longer classified patients into one of four hearing classifications, that is, A, B, C, or D—instead relying on an organized presentation of the raw hearing data. A major limitation of the 1995 guidelines were that patients could be classified into the same group but have very different functional hearing. For example, using the 1995 classification, if two patients have a PTA in the 30 to 50 dB range, one with a WRS of 51% and the other with a WRS of 100%, both would be classified as having Class B hearing despite significant differences in functional hearing outcome. Raw hearing data are also cumbersome to report and interpret in both the Gardner–Robertson and the 1995 AAO–HNS classification as these systems attempted to classify heterogeneous populations into narrow categories. These can potentially include very disparate patient groups that can be clinically misleading and ineffective for reporting outcomes for research. The 2012 AAO–HNS guidelines improved upon these by recommending the creation of a scattergram relating average air conduction PTA to the WRS. This allows readers to quickly interpret hearing outcomes for multiple patients in one clear and concise figure (► **Fig. 2**). Pre- and postintervention scattergrams were also required to demonstrate the true hearing results more accurately from any attempted hearing preservation interventions.

Similar to the 1995 AAO–HNS guidelines, the 2012 guidelines describe standard ways of testing and recording the PTA and WRS. Air conduction pure tone hearing thresholds are measured at 0.5, 1, 2, and 3 kHz. Since 3 kHz is not always recorded on routine audiometry, this can be derived by averaging the 2 and 4 kHz values.¹⁵ Additionally, the WRS should be ideally measured using a validated recording in the patient’s native language at a standard presentation level, such as a 40 dB or maximum comfortable loudness level. Authors should describe the methods by which the WRS is determined. The postoperative or postintervention scattergram only records the number of changes in response to the decided intervention and quantifies the extent of those changes. For example, a postoperative scattergram after vestibular schwannoma surgery shows that no patients had improved hearing as expected; however, this also quantifies how many had complete hearing preservation (no change in hearing) or complete functional hearing loss (> 50 points worse WRS or PTA) and visually displays how the majority of patients fared along that spectrum (► **Fig. 2B**). Changes are recorded in intervals consisting of every 10% change in WRS or every 10 dB change in PTA. The percentage change for WRS is an absolute change, so for a pretreatment WRS of 80% and a posttreatment WRS of 40% the change would be reported as a 40% change despite being a 50% WRS worsening.

Fig. 2 (A) Scattergram of pretreatment hearing results in a hypothetical sample of patients. Pure tone averages are represented on the Y-axis and word recognition scores are represented on the X-axis. Each number represents the number of patients whose audiometric data place them into a certain square. (B) Posttreatment scattergram of hearing results for the same hypothetical sample of patients. As hearing improvement would be unlikely following lateral skull base surgery, this example shows that hearing was stable or worsened for many patients. The number of patients who had a decrease in hearing in word recognition score (WRS), pure tone average (PTA), or both is represented in the boxes of the right lower quadrant.

The 2012 AAO-HNS scattergram reporting method is different from the previous 4 and 5-grade classifications of the 1995 AAO-HNS and the Gardner-Robertson systems and offers several distinct advantages. While detailed data presentation avoids the granularity of prior hearing outcome scales, a major advantage is the ability of investigators to categorize their results in ways they believe are informative all while allowing subsequent investigators to reinterpret previous data in accordance to their preferred method. It is important to remember that the 2012 AAO-HNS guidelines represent the minimal dataset for comparison; authors are encouraged to report additional hearing data as needed to fully describe their study population. The 2012 AAO-HNS guidelines are the first universal standard for hearing outcome reporting in clinical trials, hopefully allowing for future meta-analyses and a more clear comparison of hearing preservation in otologic surgery and lateral skull base surgery.

Future Directions

How hearing outcomes are reported after skull base surgery has significantly evolved over time, creating a more refined and descriptive system. Early methods including the Gardner-Robertson and 1995 AAO-HNS classification systems, both which relied on broadly categorizing patients based on their hearing, have been replaced by the 2012 AAO-HNS guidelines which require more specific datasets to compare pre- and posttreatment hearing outcomes. There are, however, limitations of the 2012 AAO-HNS guidelines. Still needed are evidence-based guidelines that can define various categories of hearing based on patient-reported feedback. Previous classification systems have relied on relatively arbitrary boundaries to distinguish different types of functional hearing. An ideal reporting system would be able to classify patients based on nonsubjective outcomes to distinguish a patient's quality of hearing from another.

Historical hearing classification systems have also relied on historic data points from standard audiometry. There may be different and better ways to measure hearing that are not included in the standard audiogram and that may be more informative about a patient's "real-world" hearing acuity. For example, hearing in noise tests are not part of a routine audiologic evaluation; however, they may be more accurate to measure a patient's functional hearing before and after lateral skull base surgery. Such measures may give us further insight into how hearing outcomes should be classified.

Conclusion

Hearing outcomes reporting has evolved significantly and new standards for reporting now enable a more precise and comprehensive representation of hearing outcomes. Future

guidelines will ideally evolve to create a complete representation of a patient's functional hearing status.

Future research in lateral skull base surgery would benefit from precise, accurate, and easily understood reporting outcomes to allow for more efficient comparability between studies and pooling of data for meta-analysis.

Conflict of Interest

None.

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