

CONGRESS OF NEUROLOGICAL SURGEONS SYSTEMATIC REVIEW AND EVIDENCE BASED GUIDELINE ON SURGICAL RESECTION FOR THE TREATMENT OF PATIENTS WITH VESTIBULAR SCHWANNOMAS: UPDATE

Sponsored by: Congress of Neurological Surgeons (CNS) and the Section on Tumors

Endorsement: Reviewed for evidence-based integrity and endorsed by the American Association of Neurological Surgeons (AANS) and Congress of Neurological Surgeons (CNS)

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Abbreviations

AAO-HNS	American Academy of Otolaryngology-Head and Neck Surgery
AN	Acoustic Neuroma
CPA	Cerebellopontine Angle
DHI	Dizziness handicap inventory

FN	Facial nerve
GKRS	Gamma Knife radiosurgery
GTR	Gross total resection
HB	House–Brackmann
HP	Hearing preservation
IAC	Internal auditory canal
IC	Intracanalicular
IOM	Intraoperative monitoring
MF	Middle fossa
NTR	Near total resection
QOI	Quality of life
RS	Retrosigmoid
SDS	Speech discrimination score
SRS	Stereotactic radiosurgery
STR	Subtotal resection
TL	Translabyrinthine
VS	Vestibular schwannoma

ABSTRACT

Background: Surgical intervention remains an important option in the management of a vestibular schwannoma (VS)s. Development of a systematic approach to choose the most appropriate route for this intervention, based upon existing published evidence, is an important goal.

Objective: To review the literature published since the 2018 CNS Guideline on surgical intervention for patients with sporadic VS s and utilize this information to update that set of recommendations.

Methods: Literature in the PubMed and Medline databases from January 2015 through February 2022 was searched for manuscripts pertaining to surgical intervention for VS s. Those manuscripts meeting inclusion criteria were then analyzed for creation of recommendations in response to a set of updated questions.

Results: The resultant findings included a considerable amount of data that did not alter the recommendations from the 2018 publication on this topic. Thus, recommendations stating hearing preservation (HP) surgery via the middle fossa (MF) or retrosigmoid (RS) approach may be considered in individuals with good preoperative hearing as an alternative to simple observation remain. Additionally, if microsurgical resection is necessary after SRS, it is recommended that patients be counseled that there is an increased likelihood of a subtotal resection (STR) and decreased FN function. In some questions, insufficient data was present to create an answer and that is stated.

Conclusion: This guideline demonstrates surgical intervention for VS s represents a range of options and the choice of the intervention depends on the specific aspects of the lesion and the individual that harbors them. Objective refinement of those choices will require thoughtful research design by investigations that wish to address those items for which we still have insufficient information.

UPDATED QUESTIONS WITH UNCHANGED RECOMMENDATIONS FROM THE PRIOR VERSION OF THIS GUIDELINE

Question 1 In patients with a sporadic VS and serviceable hearing, is RS craniotomy as effective as MF craniotomy for facial nerve (FN) preservation with gross total resection (GTR)?

Target Population

These recommendations apply to adults with sporadic VS who are candidates for microsurgical resection via the RSRS or MF MF approach.

Recommendation

There is insufficient evidence to support superiority of either the MF or RS approach for complete VS resection and FN preservation when serviceable hearing is present.

Question 2 In patients with a sporadic VS without serviceable hearing is RS craniotomy as effective as translabyrinthine (TL) approach for facial nerve (FN) preservation and GTR?

Target Population

This recommendation applies to adults with sporadic VSs who are candidates for microsurgical resection via the RS or TL approach.

Recommendation

There is insufficient evidence to support superiority of either the RS or TL approach for complete VS resection and FN preservation when serviceable hearing is not present.

Question 3 In patients with a sporadic VS is there an optimal surgical approach (TL, RS, or MF) for tumors > 2cm in greatest diameter, compared to tumors < 2cm in greatest diameter for maintenance of FN function and GTR?

Target Population

This recommendation applies to adults with sporadic VSs who are candidates for microsurgical resection via the TL, RS, or MF approach.

Recommendation

There is insufficient data to support one approach over another for microsurgical tumor resection in terms of superiority of FN outcomes or gross total tumor resections.

Question 4 In patients with a sporadic VS who are eligible for microsurgical resection (typically less than 1.5 cm), should microsurgery be considered compared to observation for long term tumor control?

Target Population

This recommendation applies to adults with sporadic VSs who are eligible to undergo microsurgical resection or observation.

Recommendation

There are insufficient data to support surgery be the primary treatment for this subclass of VS.

Question 5 In patients with sporadic VS s who are eligible for microsurgical resection with serviceable hearing should microsurgery be considered compared to observation for long term HP?

Target Population

This recommendation applies to adults with a sporadic VSs undergoing microsurgical resection via the MF or RS approach.

Recommendation

Level III: HP surgery via the MF or the RS approach may be attempted in patients with good preoperative hearing and remains an option compared to initial observation.

Question 6 In patients with sporadic VS who are eligible for microsurgical resection; should STR followed by potential stereotactic radiosurgery (SRS) be considered compared to GTR for improved FN outcomes by House-Brachmann (HB)scale?

Target Population

This recommendation applies to adults with a sporadic VS who are eligible for microsurgical resection.

Recommendation

There is insufficient evidence to support STR followed by SRS provides comparable or favorable hearing and FN preservation compared to patients who undergo a complete surgical resection.

Question 7 In patients with sporadic VS schwannomas who are eligible for microsurgical resection with preoperative balance issues; should microsurgery be considered compared to stereotactic radiation to improve balance problems?

Target Population

This recommendation applies to adults with a sporadic VS who are candidates for microsurgical resection or SRS treatment.

Recommendation

There is insufficient evidence to support either surgical resection or SRS for treatment of preoperative balance problems.

Question 8 In patients with sporadic VS who are eligible for microsurgical resection with preoperative trigeminal neuralgia; should microsurgery be considered compared to stereotactic radiation to improve trigeminal neuropathy?

Target Population

This recommendation applies to adults with a sporadic VS who are candidates for microsurgical resection or SRS treatment.

Recommendation

Level III: Surgical resection of VSs may be used to better relieve symptoms of trigeminal neuralgia compared to SRS in patients with sporadic VSs.

Question 9 In patients with a sporadic VS who are eligible for microsurgical resection; does microsurgery after stereotactic radiation compared to microsurgery without stereotactic radiation lead to worse FN outcomes?

Target Population

This recommendation applies to adults with a sporadic VS who are candidates for microsurgical resection after SRS treatment.

Recommendation

Level III: If microsurgical resection is necessary after SRS, it is recommended that patients be counseled that there is an increased likelihood of a STR and decreased FN function.

Introduction

Sporadic VSs present many surgical challenges and the treatment is very nuanced as described in the prior CNS guidelines addressing surgery and VS.¹ Much has been written through the years regarding their surgical management which was summarized in our first CNS guidelines surgical article.¹ We now update the guidelines to include papers from 2015 to 2022 to further clarify the questions and update the evidence supporting the importance of surgery in the management of VS.

Rationale

Complete tumor removal and cranial nerve preservation are the goals of any VS surgical resection. The success of surgical resection of VSs may be impacted by the surgical approach and serviceable hearing status of the patient, tumor size and location, NF2 status, multidisciplinary team management, combination treatment with SRS, previous SRS treatment, and other preoperative symptoms. Sporadic VSs present many surgical challenges and the treatment is very nuanced as previously described in the prior CNS guidelines addressing surgery and VS.¹ Much has been written through the years regarding their surgical management which was summarized in our first CNS guidelines surgical article.¹ The guidelines have been updated to include papers from 2015 to 2022 to further clarify the questions of importance relative to surgery of VS.

Objectives

The objectives of this guideline are to assess both comparative and noncomparative studies of surgical management of VSs based on the following questions which were modified from the original guidelines which reported literature up to 2015 and made into PICO format which was not used in the first guidelines¹: Two of the eleven questions in the 2015 version, one dealing with management of neurofibromatosis type 2 schwannomas and another dealing with multidisciplinary tumor management, were not included in this update. Neither was amenable to PICO format and each had disparate preliminary search results and were therefore deemed unlikely to yield useful recommendations suitable for this update.

Methodology

The evidence-based clinical practice guideline taskforce members and the Joint Tumor Section of the American Association of Neurological Surgeons (AANS) and the Congress of Neurological Surgeons (CNS) have prioritized writing the updated guidelines for management of VSs. A series of authors for the development of guidelines related to surgical management of VSs were identified and screened for conflict of interest. This group in turn agreed on a set of questions addressing the topic at hand and conducted a systematic review of the literature relevant to the surgical management of VSs. Additional details of the systematic review are provided below and within the introduction and methodology chapter of the guideline (add link).

Literature Search

The task force collaborated with a medical librarian to search for articles published from January 2015 through February 2022. Two electronic databases, Ovid Medline and EMBASE (see below), were searched. Strategies for searching electronic databases were constructed by the Evidence-based clinical practice guideline taskforce members and the medical librarian using standard strategies to identify relevant studies.^{6–13}

The authors supplemented the searches of electronic databases with manual screening of the bibliographies of all retrieved publications. The authors also searched the bibliographies of recent systematic reviews and other review articles for potentially relevant citations. All articles identified were subject to the study selection criteria listed below. As noted above, the guideline committee also examined lists of included and excluded studies for errors and omissions. The authors went to great lengths to obtain a complete set of relevant articles. Having a complete set ensured that this guideline is not based on a biased subset of articles.

Inclusion/Exclusion Criteria

A total of 810 citations were manually reviewed by the team with specific inclusion and exclusion criteria as outlined below. Two independent reviewers evaluated and abstracted full text data for each article, and the 2 sets of data were compared for agreement by a third party. Inconsistencies were re-reviewed, and disagreements were resolved by consensus. Citations that considered adult patients focusing on surgical treatment of VSs were considered. To be included in this guideline, an article must be a report of a study that:

- Investigated patients suspected of having spontaneous VSs
- Patients ≥ 18 years of age
- Was of humans
- Published between January 1, 2015, and December 31, 2021
- Quantitatively presented results
- Was not an in vitro study (for novel molecular markers, in vitro studies were included on patient samples)
- Was not a biomechanical study
- Was not performed on cadavers
- Was published in English
- Was not a meeting abstract, editorial, letter, or commentary

- Examined mixed pathologies or if so, the data pertaining to VSs was abstractable from the rest of the tumor types in the paper
- Had five or more patients or patient samples
- Primary studies that did not include national abstracted big databases like SEER or NSQIP
- Did not involve primary study of novel technologies or new applications of technologies (e.g., flexible, and rigid endoscope, laser fibers, monitoring devices or techniques, etc.)
- Did not mainly focus on variant approach techniques, patient positioning, or major tumor variability (including implanted devices)
- Did not involve primary categorization of data by metrics not relevant to the study questions (e.g., patient age, unique radiographic features, quality of life (QOI) questionnaires, etc.)
- Primarily NF2 population focused papers were excluded to ensure this guideline focuses on sporadic VS

The authors did not include systematic reviews, guidelines, or meta-analyses conducted by others. These documents are developed using different inclusion criteria than those specified in this guideline. The summary of the search and screening process is provided in the PRISMA diagram in Appendix III.

Assessment for Risk of Bias

All the literature reviewed was class III evidence (i.e., case series or retrospective comparative studies with flawed historical controls, prospective case control series with flawed control groups, prospective comparative studies with incomplete data or study design flaws). Because the data analyzed were all class III, bias could be present because of selective case choice for study and selective results reporting, lack or loss of information over time, the biases of the interpreting investigator in regard to the study, publication bias regarding positive studies or positive cases, misclassification, survivorship bias, publication bias, recognition that data collected in this retrospective or prospective manner does not imply causation, selection bias, attrition bias, change in methods over time, ascertainment bias, hidden

agenda bias, and variability caused by random error related to problems with unintentional data entry oversight and neglect.

Rating Quality of Evidence

The quality of evidence was rated using an evidence hierarchy for each of four different study types; therapeutic, prognostic, diagnostic, and decision modeling. These hierarchies are shown in Appendix II: Rating Evidence Quality. Additional information regarding the hierarchy classification of evidence can be located here: <https://www.cns.org/guidelines/guideline-procedures-policies/guideline-development-methodology>.

Revision Plans

In accordance with the Institute of Medicine’s standards for developing clinical practice guidelines and criteria specified by the National Guideline Clearinghouse, the task force will monitor related publications following the release of this document and will revise the entire document and/or specific sections “if new evidence shows that a recommended intervention causes previously unknown substantial harm; that a new intervention is significantly superior to a previously recommended intervention from an efficacy or harms perspective; or that a recommendation can be applied to new populations.”² In addition, the task force will confirm within five years from the date of publication that the content reflects current clinical practice and the available technologies for the evaluation and treatment for patients with perioperative spinal disease.

RESULTS

Microsurgical Approach and Presence or Absence of Serviceable Hearing

Question 1: In patients with sporadic VSs and serviceable hearing, is RS craniotomy as effective as MF craniotomy for FN preservation with GTR?

Target Population

This recommendation applies to adults with sporadic VSs who candidates for microsurgical resection via the RS or MF approach.

Recommendation

There is insufficient evidence to support superiority of either the MF or RS approach for complete VS resection and FN preservation when serviceable hearing is present.

Study Selection and Characteristics

The initial search strategy included 810 candidate citations. A total of 600 citations were removed because they did not meet the inclusion/exclusion criteria on title and abstract review. After title and abstract review, 210 articles remained for full-text review. From these 210 articles, eight articles remained after the inclusion/exclusion criteria and were applicable to question 1 and are summarized in Table 1 below. Data extraction included study design, class of evidence, total number of patients, study selection parameters, mean or median tumor size, mean or median follow-up, other study results and exclusion of NF2.

Results of Individual Studies, Discussion of Study Limitations, and Risk of Bias

Two main microsurgical approaches were analyzed for FN function preservation in VS patients when serviceable hearing was present at the time of surgery. Both the RS and MF approaches afford the opportunity to preserve hearing during VS resection. All the studies analyzed were retrospective and had class 3 evidence. The HB scale was used to classify FN function results. At least 12 months of clinical follow-up of patients was also required to be included in the final analysis.

Successful HP and FN function were found in patients undergoing an MF microsurgical approach for resection of their VS in general, however the average tumor sizes were smaller in those cases managed with MF than with RS. The MF approach is selected mainly for patients with intrameatal VS tumors. Functional HP rates of 34% to 100% were reported with the MF approach.³⁻⁹ FN function preservation rates (HB I) were between 78% and 95%.³⁻⁹

The RS approach also provided excellent HP and FN function after VS resection.^{3,6,7} HP rates between 14% and 70% were found in patients undergoing an RS approach.^{3,6,7,9,10} FN function preservation rates ranged between 81% and 92%.^{3,6,9,10}

There were 4 studies analyzing both the MF and RS approaches for VS resection that included data on HP and FN function.^{3,6,7,9} In those studies, HP was higher with the MF approach, while FN function preservation was greater with the RS approach. All selected publications were either retrospective or nonrandomized prospective studies, there is a high probability of treatment selection bias in these groups. While there is some overlap of tumors eligible for RS and MF, there are clearly situations in which some surgeons believe one is better than the other and further there are more attempts at treating larger tumors via the RS to see if hearing can be maintained. In these studies, while mean tumor size can be assessed individual tumor volumes and locations of course cannot be abstracted therefore it is impossible to compare MF and RS directly.

Synthesis

Both the MF and RS surgical approaches can permit preservation of hearing and FN function. Small, lateral-based VS tumors in the IAC may permit greater HP by an MF approach in which vestibular nerves are not resected with the tumor.

The evidence for this guideline was drawn from studies with class III evidence; currently, no class I or II evidence exists to guide recommendations for this subject. These data should be used when counseling patients regarding the probability of long-term maintenance of serviceable hearing and FN preservation after microsurgery for sporadic VSs. Thus, there is insufficient evidence to support superiority of either the MF or RS approach for complete VS resection and FN preservation when serviceable hearing is present.

Question 2: In patients with sporadic VSs without serviceable hearing is RS craniotomy effective as TL approach for FN preservation and GTR?

Target Population

This recommendation applies to adults with sporadic VSs who are candidates for microsurgical resection via the RS or TL approach.

Recommendation

There is insufficient evidence to support superiority of either the RS or TL approach for complete VS resection and FN preservation when serviceable hearing is not present.

Study Selection and Characteristics

The initial search strategy included 810 candidate articles. A total of 600 articles were removed because they were outside the date range specified by the inclusion/exclusion criteria. After title and abstract review, 210 articles remained for full-text review. From these, 210 articles were included in the final review for question 2. Eight articles remained after the inclusion/exclusion criteria were applied and are included in Table 2 below. Data extraction included study design, class of evidence, total number of patients, study selection parameters, mean or median tumor size, mean or median follow-up.

Results of Individual Studies, Discussion of Study Limitations, and Risk of Bias

Two microsurgical approaches (RS and TL) were analyzed to determine the best approach for VS resection and FN function preservation in patients with nonserviceable hearing who had ≥ 12 months of clinical follow-up after their surgery. Most of the studies in this analysis classified normal to good FN function as HB grade I/II.

A total of 3 studies described the RS approach and provided detailed FN functional preservation rates in patients who are candidates for VS resection.¹¹⁻¹³ Two studies described the TL approach for VS resection and FN functional preservation.^{14,15} Three studies compared the TL approach with the RS approach for VS patients undergoing surgery with nonserviceable hearing.^{3,12,16}

Among patients undergoing an RS approach and complete VS resection, normal FN function (HB I) ranged from 84% to 92%, while good FN function (HB I/II) ranged from 77 to 96%.^{10,11,13} The size of the tumor was a confounding variable as the larger sized tumors had lower FN function preservation.

Among patients undergoing a TL approach, FN function preservation rates (HB I) ranged from 29% to 95%.^{14,15} No studies demonstrated within a single study statistically significant FN outcomes by approach.³

Because all the selected publications were either retrospective or nonrandomized prospective studies, there is a substantial risk of treatment selection bias. Tumor selection by approach also comes into play when comparing RS or TL approaches. Surgeon preference may be biased toward an RS approach because the TL approach usually requires the assistance of a neurotologist. In addition, larger VS tumors (>3 cm) have been typically resected by an RS approach instead of a TL approach because of the smaller bony opening with a TL approach. However, some groups prefer the TL approach for large VS tumors and contend that tumor size is not an obstacle when using extended or modified TL approaches.

Synthesis

Both the TL and RS approaches permit FN function preservation in patients with no serviceable hearing undergoing complete removal of VSs. The evidence for this guideline was drawn from studies with class III evidence; currently, no class I or II evidence exists to guide recommendations on this subject. These data should be used when counseling patients regarding the probability of FN preservation after microsurgery for sporadic VSs when nonserviceable hearing is present.

Question 3: In patients with sporadic VSs is there an optimal surgical approach (TL, RS, or MF) for tumors ≥ 2 cm in greatest diameter, compared to tumors < 2 cm in greatest diameter for maintenance of FN function and GTR?

Target population

This recommendation applies to adults with sporadic VSs who are candidates for microsurgical resection via the TL, RS, or MF approach.

Recommendation

There is insufficient data to support one approach over another for microsurgical tumor resection in terms of superiority of FN outcomes or gross total tumor resections.

Study Selection and Characteristics

The initial search strategy included 810 candidate articles. A total of 600 articles were removed because they were outside the date range specified by the inclusion/exclusion criteria. After title and abstract review, 210 articles remained for full-text review. From these, 210 articles were included in the final review for question resulting in 23 articles incorporated into table 3.

Results of Individual Studies, Discussion of Study Limitations, and Risk of Bias

The key results of individual studies are outlined in Table 3 below and are summarized within the guideline recommendations. In total, there were 23 retrospective studies with proper clinical follow-up of ≥ 12 months.

RS reported good FN outcomes between 72% and 98%, and TL reported good FN outcomes between 75% and 98%.^{3,6,7,9-12,17-32} Kiyofugi et al. looked specifically at very large VS over 4 cm and small VS under 1 cm, noting good FN outcomes in large tumors were 50% and in those that were less than 1 cm near 99%.²⁹ Data from the 23 retrospective studies largely corroborated these results.^{3,6,7,9-12,17-32}

Collectively, these data demonstrate that tumor size is among the most reliable prognostic factors for HP and FN function after microsurgery of VSs.

Surgeons' choice based on tumor size and location comes into play when comparing RS or TL craniotomy. Some surgeons will manage any tumor size through a TL, while others believe giant VS should be approached through a RS. Therefore, when comparing outcomes, it is critical that the same size class is compared between approaches because size is one of the primary predictors FN outcome. Further, the authors report substantial variation in the GTR rates which would substantially impact FN outcome rates. Finally, reporting bias must be considered. Specifically, series with better patient outcomes are more likely to be reported compared to series with mediocre or suboptimal surgical results.

Synthesis

Class III evidence supports the conclusion that tumor size is a strong predictor of FN preservation after microsurgery resection, however one does not recommend a specific approach over another.

The evidence for this guideline was drawn from studies with class III evidence. Currently, no class I or II evidence exists to guide recommendations on this subject. These data should be used when counseling patients regarding the probability of long-term maintenance of FN preservation after microsurgery for sporadic VSs.

Small Intracanalicular(IC) Vs. Tumor and Surgical Resection

Question 4: In patients with sporadic VSs who are eligible for microsurgical resection (typically less than 1.5 cm), should microsurgery be considered compared to observation for long term tumor control?

Target Population

This recommendation applies to adults with sporadic VSs who are candidates for microsurgical resection.

Recommendation

There are insufficient data to support surgery be the primary treatment for this subclass of VS.

Study Selection and Characteristics

The initial search strategy included 810 candidate articles. A total of 600 articles were removed because they were outside the date range specified by the inclusion/exclusion criteria. After title and abstract review, 210 articles remained for full-text review. From these, 210 articles were included in the final review with 6 studies ultimately addressing question 4.

Results of Individual Studies, Discussion of Study Limitations, and Risk of Bias

While little controversy accompanies the management of large VSs that abut or compress the brainstem, the appropriateness of surgery for IC VSs continues to inspire debate. The natural history of this subset of tumors, when studied independently, appears to be that growth and some degree of hearing loss is expected over reported follow-up intervals.

Interestingly, hearing loss was similar across patients with stable, growing, and shrinking tumors.

Schwartz et al. reported on 100 patients undergoing TL resection with 97% achieving GTR, 96% had HB 1 or 2 at last follow up with no recurrences seen.¹⁴ Anaizi et al. reported on 80 patients with small VS,

GTR was achieved in 89% of RS, 88% of TL, and 100% of MF with 95% HB 1 or 2 FN outcome at last follow up, 2 recurrences occurred that underwent SRS treatment.⁷ Chiluwal et al had similar results with a relatively limited 30 patient series as did Huo et al in a series of 138 patients.^{9,25} Hunter et al. reported a series of 564 observed VS with a median follow up of 22.9 months.³³ 33% ultimately went on to some form of treatment, 22% underwent surgery and 11% SRS.³³ Patro et al had both observed cases (120) and surgically managed cases (100), and they noted observation did not seem to impact outcome of ultimate surgery.³⁴

Synthesis

Excellent rates of resection, FN preservation function results, and HP have been reported after surgery for IAC VSs. However, there are insufficient data to support a firm recommendation that surgery be the primary treatment for this subclass of VS, especially considering close observation does not appear to impact long term FN outcomes. However, observation may impact HP success. A comparison study between surgery, observation, and SRS for IAC VSs may provide better evidence to support one treatment over the other.

Routine HP and VS Surgical Resection

Question 5: In patients with sporadic VSs who are eligible for microsurgical resection with serviceable hearing should microsurgery be considered compared to observation for long term HP?

Target Population

This recommendation applies to adults with both sporadic VSs undergoing microsurgical resection via the MF or RS approach.

Recommendation

Level 3: HP surgery via the MF or the RS approach may be attempted in patients with good preoperative hearing and remains an option compared to initial observation.

Study Selection and Characteristics

The initial search strategy included 810 candidate articles. A total of 600 articles were removed because they were outside the date range specified by the inclusion/exclusion criteria. After title and abstract review, 210 articles remained for full-text review. From these 210 articles 25 scientific articles applied to question 5.

Results of Individual Studies, Discussion of Study Limitations, and Risk of Bias

The 25 retrospective studies, representing class III data were summarized and included in Table 5. Notably, tumor size appears to be the best predictor of postoperative HP with smaller tumors more commonly associated with preserved hearing regardless of approach.³⁵

MF HP rates were reported between 25% to 87%.^{7-9,35-44} RS HP rates were reported between 29% and 100% (commonly larger tumor sizes reported).^{7,9,25,35,37,40,41,45-51} Observation was associated with a 24% chance of decline in the observation period (mean observation 34.8 months) to nonserviceable hearing.^{52,53}

Synthesis

Class III evidence suggests HP surgery using the MF or the RS approach for removal of small to medium VSs can result in good preoperative hearing function. The definition of hearing success after VS resection remains controversial. Many audiologic classification schemes have been developed to determine “HP,” and the fact that there are multiple schemes indicates that none is universally accepted.

VS STR Followed by SRS

Question 6: In patients with sporadic VSs who are eligible for microsurgical resection; should STR followed by potential SRS be considered compared to GTR for improved FN outcomes by HB scale?

Target Population

This recommendation applies to adults with sporadic VSs who are candidates for microsurgical resection.

Recommendation

There is insufficient evidence to support STR followed by SRS provides comparable or favorable hearing and FN preservation compared to patients who undergo a complete surgical resection.

Study Selection and Characteristics

The initial search strategy included 810 candidate articles. A total of 600 articles were removed because they were outside the date range specified by the inclusion/exclusion criteria. After title and abstract review, 210 articles remained for full-text review. From these 210 articles 7 full-text articles were applied to this question. (Table 6).

Results of Individual Studies, Discussion of Study Limitations and Risk of Bias

Of the 7 included articles reviewed, all were retrospective reviews of patients who underwent radiosurgery after receiving subtotal VS resection and provided class III information. All of the papers discussed tumor control rate, and each discussed variably FN function or HP. None of the articles offer direct comparison to a GTR group but cite historical outcomes from other papers in their discussion.

Landry et al. reported a series of 5 patients that underwent planned STR with follow up SRS of 205 VS patients.⁵⁴ All patients had HB1 function postoperatively.⁵⁴ Mackenzie et al. reported on 63 patients with planned STR then SRS in which 72% were HB1 or 2 and serviceable hearing was maintained in 29%.¹⁹ Iwai et al reported on 40 patients with large VS, with planned RS STR then SRS.⁵⁵ 10 year tumor control with this management technique as 86%, with 4 patients requiring salvage surgery.⁵⁵ HB 1 or 2 was achieved in 95% of patients.⁵⁵ Additionally studies supported NTR when possible with FN preservation with reasonable rates of local control.^{12,56-58}

All of these studies were retrospective and are therefore subject to the inherent bias associated with any retrospective analysis. None of the included studies had their own internal control of patients undergoing GTR, but instead included some comparison to the results of other studies or largely generalized averages of HP and local tumor control. Without randomization, there was certainly inherent differences in surgical decision making and anatomy that would play a role in whether a patient received primary GTR or STR. It is unknown what effect these pretreatment variables would have on outcomes regardless of

treatment approach. The number of included studies is small studying a small number of patients providing low level of evidence.

Synthesis

When a VS is treated with STR followed by radiosurgery either primarily or because of tumor remnant growth, tumor control rates are reasonable however FN preservation rates can be unpredictable. At this time due to low numbers, the effectiveness of this strategy is difficult to ascertain. However, if the goal of treatment is FN preservation in the short term this strategy appears to achieve that compared to historical GTR at all costs.

Additional Analysis/Future Research

Future studies directly comparing GTR to STR plus radiosurgery with regard to outcomes for similar patients with similar tumors on a prospective basis in regard to cranial nerve function as well as long-term tumor control would provide the strongest data to address the stated question.

VS Resection and Preoperative Balance Difficulties

Question 7: In patients with sporadic VSs who are eligible for microsurgical resection with preoperative balance issues; should microsurgery be considered compared to stereotactic radiation to improve balance problems?

Target Population

This recommendation applies to adults with sporadic VSs who are candidates to undergo microsurgical resection or SRS treatment.

Recommendation

There is insufficient evidence to support either surgical resection or SRS for treatment of preoperative balance problems.

Study Selection and Characteristics

The initial search strategy included 810 candidate articles. A total of 600 articles were removed because they were outside the date range specified by the inclusion/exclusion criteria. After title and abstract review, 210 articles remained for full-text review. From these, 210 articles were included in the final review and 4 were pertinent to question 7 (reported in table 7).

Results of Individual Studies, Discussion of Study Limitations, and Risk of Bias

It was observed that 45 to 89% of patients had resolution of vestibular symptoms after surgery with these 4 studies.^{7,19,31,59} Overall, there was a trend for improvement in a core group of patients after surgery however the overall rate of vestibular symptom worsening after surgery was not reported therefore it is difficult to draw any conclusion from these studies.

Synthesis

Vestibular symptoms seem to worsen in a minority of patients treated with both methods of therapy as previously reported in the prior guidelines with a broader depth of studies available in those older studies to support this contention. However, in this guideline with the available data we are able to support a statement that there will be improvement in vestibular symptoms in 45 to 89% of surgical patients. A single study to determine the factors associated with improved balance after treatment is worthy of further exploration. Presently, there are limited data to support using SRS or microsurgery with the goal of improving balance, and what data exist are fraught with the expected selection biases, especially related to tumor size. In general, smaller tumors are treated with SRS and larger tumors are surgically resected. Tumor size, as a result, can be perceived as a significant confounding variable. In addition, the existing literature suggests that vestibular dysfunction is likely to be related to tumor size and patient age, among other factors. This makes the exact relationship between treatment modality and balance problems difficult to infer.

VS Resection and Trigeminal Neuralgia

Question 8: In patients with sporadic VSs who are eligible for microsurgical resection with preoperative trigeminal neuralgia; should microsurgery be considered compared to stereotactic radiation to improve trigeminal neuropathy?

Target Population

This recommendation applies to adults with sporadic VSs who candidates for are microsurgical resection or SRS treatment.

Recommendation

Level III: Surgical resection of VSs may be used to better relieve symptoms of trigeminal neuralgia compared to SRS in patients with sporadic VSs.

Study Selection and Characteristics

The initial search strategy included 810 candidate articles. A total of 600 articles were removed because they were outside the date range specified by the inclusion/exclusion criteria. After title and abstract review, 210 articles remained for full-text review. From these, 210 articles were included in the final review and 4 met criteria for question 8.

Results of Individual Studies, Discussion of Study Limitations, and Risk of Bias

There were few studies available to address this question, in the first guidelines 3 reports met criteria and in this update there were 4. Landry et al. reported 67% of patients improved trigeminal neuralgia symptoms with surgery at last follow up.⁵⁴ MacKenzie et al. and Won et al. reported similar improvement in trigeminal neuropathy of 33% of patients with surgery.^{19,26} Huang et al. reported a 69% improvement of patients with preoperative symptoms.^{20,31} Notably no included studies had information regarding the outcome of trigeminal neuralgia after SRS treatment in this update.

Synthesis of Results/Discussion

In the prior guidelines three studies of VSs treated with surgical resection had excellent results with >87.5% of patients reporting, at minimum, partial relief of trigeminal pain. These additional four studies report less optimistic at improvements, ranging from 69% down to 33%. However, these studies did not primarily address trigeminal neuropathy so therefore the outcome of surgery may not have been fully reported in these studies. Furthermore, no additional papers in this grouping reported outcomes of patients with preexisting trigeminal neuralgia and its outcome after SRS.

VS Surgical Resection after initial SRS Treatment

Question 9: In patients with sporadic VSs who are eligible for microsurgical resection does microsurgery after stereotactic radiation compared to microsurgery without stereotactic radiation lead to worse FN outcomes?

Target Population

This recommendation applies to adults with sporadic VS who are candidates for microsurgical resection after SRS treatment.

Recommendation

Level III: If microsurgical resection is necessary after SRS, it is recommended that patients be counseled that there is an increased likelihood of a STR and decreased FN function.

Study Selection and Characteristics

The initial search strategy included 810 candidate articles. A total of 600 articles were removed because they were outside the date range specified by the inclusion/exclusion criteria. After title and abstract review, 210 articles remained for full-text review. From these, 210 articles were included in the final review for question 9 and 7 met criteria as applied to the question.

Results of Individual Studies, Discussion of Study Limitations, and Risk of Bias

Overall, perhaps due to devascularization or potentially due to wanting to avoid retreatment, FN outcomes are poorer after resection after SRS and STR appear to be common.⁶⁰ Aboukais et al. reported on 11 patients in which 8 they achieved GTR after SRS, final facial function was good (HB1-2) in 64%.⁶⁰ Kay-Rivest et al. reported on an additional 7 patients in which GTR was achieved in 43%, with 71% maintaining good facial function.⁶¹ Lee et al. reported on 6 patients failing SRS, 66% had poor facial function that was new after surgery.⁶² Nonaka et al. reported on 39 patients failing SRS, after salvage surgery 69% received GTR, 20% of patients had worse postoperative facial function at last follow up.⁶³ Breshears et al reported on 10 patients whom failed SRS, 80% had good postoperative FN outcome, GTR was performed in 70%.⁶⁴ Wise et al. reported on 37 patients that failed SRS and underwent MS.⁶⁵ Only 49% of patients received a GTR, however no cases of tumor regrowth was seen in the follow up period which was a median follow up of 36 months.⁶⁵ 73% of patients had good postoperative facial function.⁶⁵ All studies that were included in this analysis were retrospective in nature and therefore have biases inherent in that study method and provide class III data. In particular, many studies included anecdotal or relative evaluations of the extent of tumor adherence and difficulty of surgery. Thus, this study question is inherently subject to treatment and selection bias.

Synthesis

Class III evidence supports STR in patients with previous radiation to preserve FN function. The evidence for this guideline was drawn from studies with class III evidence. Currently there are no class I or II evidence to guide recommendations on this topic. There were multiple studies with anecdotal reports on the experience of surgical resection after radiation, although there was no consensus that surgery was more difficult after radiation. The class III evidence that was available suggests that STR should be considered to preserve FN function if surgery is considered necessary after previous radiation therapy.

DISCUSSION

These guidelines reflect contemporary surgical management approaches for VSs (VS) in patients without NF2. The treatment strategy for VS involves careful clinical assessment, considering factors such as age, overall health, and preoperative hearing status, which significantly influence treatment recommendations. Dividing tumors into small (less than or equal to 1.5 cm), medium (greater than 1.5 to 2.5 cm), and large (greater than 2.5 cm) VS allows a framework to apply categories in which observation, surgery or/and SRS, and surgery can be applied respectively. Treatment also must weigh heavily preoperative hearing status as a major determinant of final recommendations.

Most of the current controversy in VS management lies in the small VS, or tumors less than or equal to 1.5 cm, treatment category where current practice allows for observation, surgery or treatment with SRS. Question 1 updates an ongoing debate, where MF and RS operations are at this time excellent options weighing patient specific factors for VS complete tumor resection, serviceable hearing, and FN preservation. Question 3 further explores the individual value of TL, RS, and MF approaches for VS and what is clear is that practice differences and preferences make it difficult to establish if any approach as a standalone is truly superior to another. Question 4 looks at the complicated question as to whether observation aimed at the best rate of short term HP impacts long term tumor control which it does not appear to do, Question 5 extends this analysis looking at the value of hearing over time, therefore observation as an initial strategy continues to be a validated option for patients presenting with small VS. Ultimately, for small VS these guidelines support current practice.

In medium sized tumors, greater than 1.5 cm to 2.5 cm, treatment is currently recommended with either SRS or surgical removal as prior studies supported observation in this cohort resulted in worse long term FN outcomes. This finding is not absolute as pointed out by the excellent analysis by Dr. Macielak showing the asymptotic outcome is probably around 1.7 cm.⁶⁶ Further, for medium sized tumors surgical management begins to weigh the advantages of STR and combined therapy of surgery and SRS as outlined in questions 3 and 6. Notably there is an ongoing trial to assess if STR followed by SRS is a good treatment strategy, this has been slow to enroll and results are not available yet.

For larger tumors (greater than 2.5 cm) surgery remains the mainstay with TL and RS seemingly having similar results in available retrospective series as addressed in question 2 and question 3. Further, preoperative balance issues do not appear to be impacted by surgical approach or strategy and is addressed in question 7. Overall, these guidelines support current standard of care surgical practice.

FUTURE RESEARCH

To advance and clarify surgical questions regarding the management of these incredibly complex tumors, either detailed multicenter surgical registry data or well-designed randomized trials will need to be performed. Given the variance in size, presenting hearing, location of tumors ultimately controlling for statistical variability would be difficult to answer a generalized surgical question. However the goal of a national or international registry may be one of the best ways to understand best practices going forward and also still allow patient autonomy in decision making. Moreover, in review of this updated literature SRS papers routinely report growth control, pseudoprogession, and results of salvage surgery with 7th nerve outcomes, however outcomes relative to trigeminal neuropathy, vestibulopathy, balance, and QOI are lacking.

CONCLUSIONS

Surgical intervention for VSs will remain a mainstay in the management of this disease for the foreseeable future. The indications for surgery, techniques to accomplish it, and supportive measures available are likely to change over time. Clinical and basic research in imaging, optics, surgical tools, and monitoring can be expected to deliver changes will improve safety and disease control. For instance, these developments may eventually sufficient information for some of the questions in this guideline that are currently not easily answered. This data may eventually show the superiority in the safety and ability to remove more tumor via either TL, MF or RS approaches allowing one of them to emerge as a superior approach over the others. Better planned studies of combinations of approaches such as observation to certain point, followed by surgery, or partial surgical resection followed by radiation therapy may provide longer periods of functional preservation. The planned updates on this set of guidelines will capture these changes to improve the likelihood of their dissemination to the medical community.

Conflicts of Interest

All Guideline Task Force members were required to disclose all potential COIs prior to beginning work on the guideline, using the COI disclosure form of the AANS/CNS Joint Guidelines Review Committee. The CNS Guidelines Committee and Guideline Task Force Chair reviewed the disclosures and either approved or disapproved the nomination and participation on the task force. The CNS Guidelines Committee and Guideline Task Force Chair may approve nominations of task force members with possible conflicts and restrict the writing, reviewing, and/or voting privileges of that person to topics that are unrelated to the possible COIs. See Appendix V for a complete list of disclosures.

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Disclaimer of Liability

This clinical systematic review and evidence-based guideline was developed by a physician volunteer task force as an educational tool that reflects the current state of knowledge at the time of completion. Each chapter is designed to provide an accurate review of the subject matter covered. This guideline is disseminated with the understanding that the recommendations by the authors and consultants who have collaborated in their development are not meant to replace the individualized care and treatment advice from a patient's physician(s). If medical advice or assistance is required, the services of a competent physician should be sought. The proposals contained in these guidelines may not be suitable for use in all circumstances. The choice to implement any particular recommendation contained in these guidelines must be made by a managing physician in light of the situation in each particular patient and on the basis of existing resources.

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Appendix I: Literature Searches

Search Strategies

Ovid Medline

- 1 exp Craniotomy/ 17095
- 2 retrosigmoid*.mp. 1649
- 3 (Craniectom* or craniotom*).ti,ab,kw. 20595
- 4 Cranial Fossa, Middle/ 899
- 5 (middle adj3 fossa).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] 3709
- 6 TRANSLABRYNTHINE.mp. 3
- 7 TRANSLABYRINTHIN*.mp. 1149
- 8 (trans-labyrinthine or TL approach* or translabyrinth or translabyrinthal or translabyrinthian or translabyrinthic).ti,ab,kw. 99
- 9 (MICROSURG* or MICRO-SURG*).mp. 44091
- 10 (microscale surg* or microscopic surg*).ti,ab,kw. 353
- 11 or/1-10 76196
- 12 exp Neuroma, Acoustic/8763
- 13 ((vestib* or acoustic) adj3 (neuroma* or neurilemmoma* or neurilemoma* or neurinoma* or tumor* or tumour* or schwannoma*)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] 11046
- 14 (acoustic nerve cancer* or acoustic neurofibroma* or acusticus neurinoma* or auditory nerve neurinoma* or ear schwannoma* or angle tumor* or angle tumour* or cerebellopontine angle tumor* or

neurinoma of the acoustic nerve or neurosensory deafness* or sensoryneural deafness* or sensory neural deafness*).ti,ab,kw. 1211

15 12 or 13 or 14 12489

16 limit 15 to english language 10469

17 Animals/ not Humans/ 4974929

18 16 not 17 10374

19 comment/ or editorial/ or letter/ or review/ or systematic review/ 5102112

20 18 not 19 8685

21 exp adolescent/ or exp child/ or exp infant/ 3849849

22 exp Adult/ 7797507

23 21 not 22 2052582

24 20 not 23 8366

25 limit 24 to dt=20150101-20220522 2297

26 in vitro techniques/ 387712

27 Culture Techniques/ 47809

28 Drug Evaluation, Preclinical/ 54481

29 Disease Models, Animal/ 383220

30 Xenograft Model Antitumor Assays/ 44247

31 25 not (26 or 27 or 28 or 29 or 30) 2275

32 11 and 31 658

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('craniotomy'/exp OR craniotom*:ti,ab,kw,de OR 'craniectomy'/exp OR craniectom*:ti,ab,kw OR 'retrosigmoid approach'/exp OR retrosigmoid:ti,ab,kw,de OR 'middle cranial fossa'/exp OR 'middle cranial fossa':ti,ab,kw OR 'fossa cranialis media':ti,ab,kw OR (middle NEAR/2 fossa) OR 'translabyrinthine approach'/exp OR translabyrinth*:ti,ab,kw OR 'tl approach':ti,ab,kw OR translabyrinthine*:ti,ab,kw OR 'microsurgery'/exp OR microsurg*:ti,ab,kw OR 'microsurgery':ti,ab,kw OR 'microscale surgery':ti,ab,kw OR 'microscopic surgery':ti,ab,kw) AND ('acoustic nerve cancer':ti,ab,kw OR 'acoustic nerve neurinoma':ti,ab,kw OR 'acoustic nerve tumor':ti,ab,kw OR 'acoustic nerve tumour':ti,ab,kw OR 'acoustic neurofibroma':ti,ab,kw OR 'acusticus neurinoma':ti,ab,kw OR 'auditory nerve neurinoma':ti,ab,kw OR 'ear schwannoma':ti,ab,kw OR 'angle tumor':ti,ab,kw OR 'angle tumour':ti,ab,kw OR 'neurinoma of the acoustic nerve':ti,ab,kw OR 'neurosensory deafness':ti,ab,kw OR 'sensoryneural deafness':ti,ab,kw OR 'sensory neural deafness':ti,ab,kw OR ((vestib* OR acoustic) NEAR/3 (neuroma* OR neurilemmoma* OR neurilemoma* OR neurinoma* OR tumor* OR tumour* OR schwannoma*))) AND [english]/lim NOT ('animal'/exp NOT 'human'/exp) NOT ('juvenile'/exp NOT 'adult'/exp) NOT ('letter'/exp OR 'editorial'/exp OR 'conference paper'/exp OR

'review'/exp) NOT ('case report'/exp NOT 'case control study'/exp) NOT (('acoustic nerve cancer':ti,ab,kw OR 'acoustic nerve neurinoma':ti,ab,kw OR 'acoustic nerve tumor':ti,ab,kw OR 'acoustic nerve tumour':ti,ab,kw OR 'acoustic neurofibroma':ti,ab,kw OR 'acusticus neurinoma':ti,ab,kw OR 'auditory nerve neurinoma':ti,ab,kw OR 'ear schwannoma':ti,ab,kw OR 'angle tumor':ti,ab,kw OR 'angle tumour':ti,ab,kw OR 'neurinoma of the acoustic nerve':ti,ab,kw OR 'neurosensory deafness':ti,ab,kw OR 'sensoryneural deafness':ti,ab,kw OR 'sensory neural deafness':ti,ab,kw OR ((vestib* OR acoustic) NEAR/3 (neuroma* OR neurilemmoma* OR neurilemoma* OR neurinoma* OR tumor* OR tumour* OR schwannoma*))) AND [english]/lim NOT ('animal'/exp NOT 'human'/exp) NOT ('juvenile'/exp NOT 'adult'/exp) NOT ('letter'/exp OR 'editorial'/exp OR 'conference paper'/exp OR 'review'/exp) NOT ('case report'/exp NOT 'case control study'/exp) AND 'conference abstract'/it) AND [01-01-2015]/sd NOT ('preclinical study'/exp OR 'animal experiment'/de OR 'in vitro study'/exp)

Appendix II: Rating Evidence Quality

Classification of Evidence on Therapeutic Effectiveness and Levels of Recommendation

Class I Evidence Level I (or A) Recommendation	Evidence from one or more well-designed, randomized controlled clinical trial, including overviews of such trials.
Class II Evidence Level II (or B) Recommendation	Evidence from one or more well-designed comparative clinical studies, such as non-randomized cohort studies, case-control studies, and other comparable studies, including less well-designed randomized controlled trials.
Class III Evidence Level III (or C) Recommendation	Evidence from case series, comparative studies with historical controls, case reports, and expert opinion, as well as significantly flawed randomized controlled trials.

Classification of Evidence on Prognosis and Levels of Recommendation

Class I Evidence Level I (or A) Recommendation	All 5 technical criteria above are satisfied.
Class II Evidence Level II (or B) Recommendation	Four of five technical criteria are satisfied.
Class III Evidence Level III (or C) Recommendation	Everything else.

Classification of Evidence on Diagnosis and Levels of Recommendation

Class I Evidence Level I (or A) Recommendation	Evidence provided by one or more well-designed clinical studies of a <i>diverse</i> population using a “gold standard” reference test in a blinded evaluation appropriate for the diagnostic applications and enabling the assessment of sensitivity, specificity, positive and negative predictive values, and, where applicable, likelihood ratios.
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Class II Evidence Level II (or B) Recommendation	Evidence provided by one or more well-designed clinical studies of a <i>restricted</i> population using a “gold standard” reference test in a blinded evaluation appropriate for the diagnostic applications and enabling the assessment of sensitivity, specificity, positive and negative predictive values, and, where applicable, likelihood ratios.
Class III Evidence Level III (or C) Recommendation	Evidence provided by expert opinion or studies that do not meet the criteria for the delineation of sensitivity, specificity, positive and negative predictive values, and, where applicable, likelihood ratios.

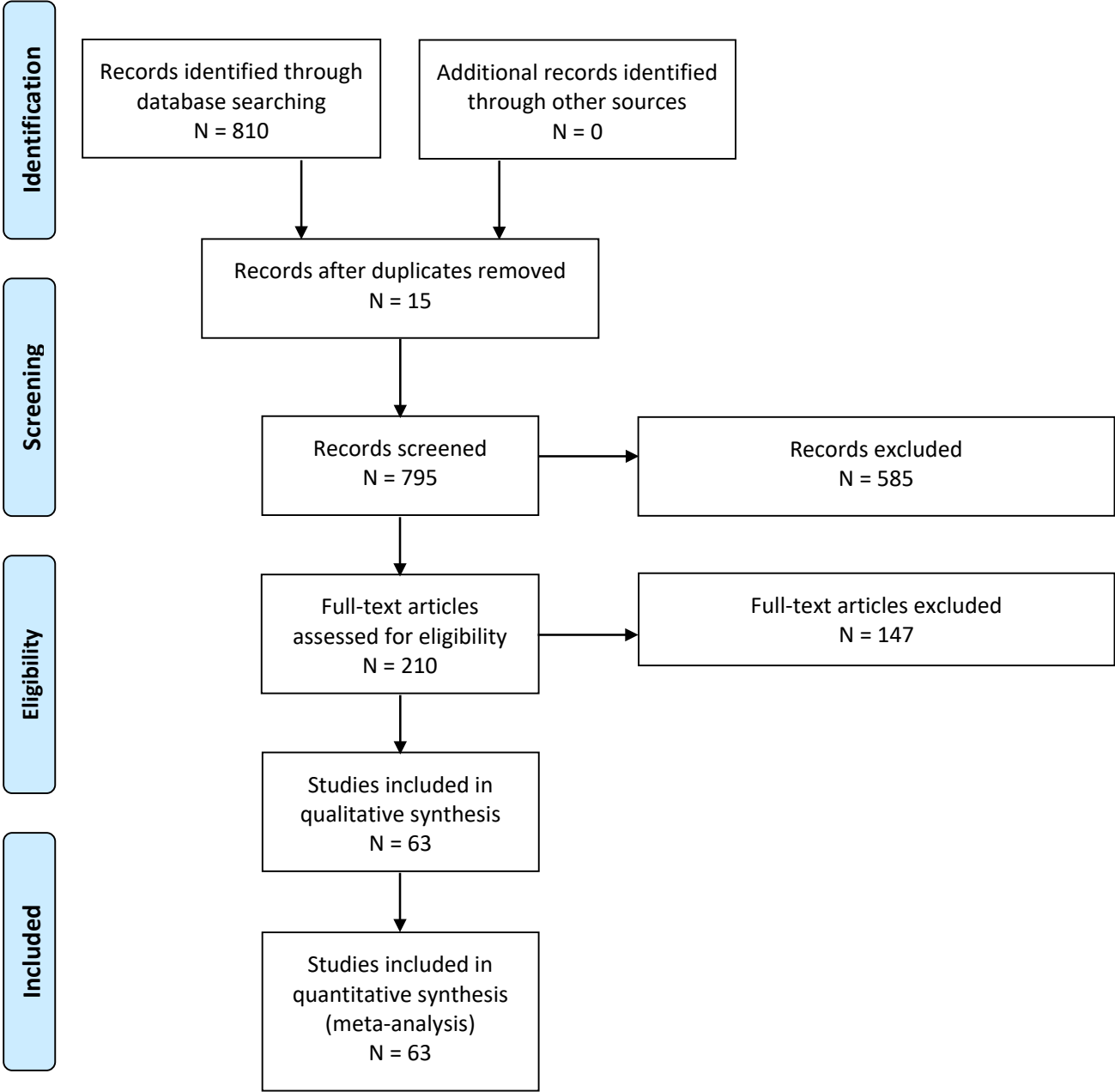
Classification of Evidence on Clinical Assessment and Levels of Recommendation

Class I Evidence Level I (or A) Recommendation	Evidence provided by one or more well-designed clinical studies in which interobserver and/or intraobserver reliability is represented by a Kappa statistic > 0.60.
Class II Evidence Level II (or B) Recommendation	Evidence provided by one or more well-designed clinical studies in which interobserver and/or intraobserver reliability is represented by a Kappa statistic > 0.40.
Class III Evidence Level III (or C) Recommendation	Evidence provided by one or more well-designed clinical studies in which interobserver and/or intraobserver reliability is represented by a Kappa statistic < 0.40.

Appendix III: PRISMA Flowchart



PRISMA 2009 Flow Diagram



Appendix IV. Evidence Tables

Table 1. RS versus MF Approach for FN Preservation

Author, Year	Results	Data Class	Conclusion
Xian-hao ⁵ et al 2022	Single institution, retrospective case series of 19 patients who underwent MF approach (with or without endoscopic assistance) for VS. M/F 42/58%. All patients had AAO-HNS class C or better hearing (68% A-B). All patients had HB1 preop. Follow up mean 52 months (range 48-60).	III	GTR obtained in all MF with endoscope, and 75% standard MF patients. MF standard: 75% had immediate postop HB1, 25% HB4. At last f/u 83% HB1, 17% HB4. MF w/ endoscope: 100% had HB1-2 immediately postop (86% HB1). At last f/u, 86% had HB1, 14% had HB3. Endoscope found residual in 43% cases. Residual of MRI found on 25% standard MF. AAO-HNS A-B hearing preserved in 66% (2/3) of MF with endoscope, 50% (6/12) standard MF. Authors conclusions: Using an endoscope in VS resection through the MCF approach could facilitate complete removal of the lesion while minimizing the risk of hearing loss and facial paralysis. The endoscope assisted MCF approach is especially suitable for removing an IC VS with lateral extension involving the space below the transverse crest Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Huo ⁹ et al 2019	Single institution, retrospective case series of 138 patients that underwent MS for small/medium VS via (71) RS or (67) MF for HP. Minimum follow up was 2 years. 79% of patients had at least AAO-HNS A-B hearing.	III	97.8% of tumors underwent GTR, no difference between approaches. Postoperative hearing levels were preserved (AAO-HNS A-B) in 41.2% of those with preop hearing. Hearing outcomes were significantly better in patients with normal intraoperative I wave on ABR. Hearing loss within 6 months had a positive effect on postoperative hearing. Better preoperative hearing and tumors from SVN were correlated with better postoperative hearing outcomes. The different surgical approaches (RS or MF) resulted in no significant differences in postoperative hearing. Good FN (HB1-2) was obtained in 92% RS and 90% MF; no differences in early or last HB scores.

			Authors conclusions: Better preoperative hearing, shorter hearing loss period, tumors from SVN, and normal intraoperative I wave are prognostic factors for serviceable hearing. RSA and MFA are effective and safe for tumor removal and HP. Comments and Conclusions: The retrospective nature of the data yields class III data.
Kosty ⁸ et al 2019	Single institution, retrospective case series of 63 patients that underwent MF approach for VS. The mean postoperative follow up was 21 ± 21 months (range 5-78). The mean tumor size was 10 ± 4 mm. 76% of patients had preop AAO-HNS hearing class A-B. All patients preop had HB1-2.	III	GTR was achieved in 97% of patients. In 2 patients, a capsular rind was left on the C. Tumor recurred in 1 of these patients. Three additional patients had recurrent tumor (6.3% recurrence rate). Of the 4 recurrences, 3 are being observed with serial imaging. One patient underwent hypofractionated radiation and achieved tumor quiescence. The tumor control rate was 98.5%. 51 patients (81%) achieved an HB 1 outcome and 11/63 (17%) achieved HB 2 FN outcome at last follow-up. The remaining patient suffered a complete FN transection requiring a cable nerve graft (great auricular nerve), ultimately achieving an HB V. The serviceable and usable HP rates were 54% and 50%, respectively. Some residual hearing was preserved in 71% of patients. Authors conclusion: In our series, the MCF approach for VS provided excellent rates of tumor and FN function, with durable serviceable HP Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Lee et al 2016 ³	Single institution, retrospective case series of 353 patients. Male/Female 44/56%. Tumor size mean 3 cm (range 5-60). Preop symptoms: 56% hearing loss, 25% vertigo/balance issues, 17% trigeminal neuropathy, 5% facial weakness. 76% underwent RS, 23% TL, 1% MF.	III	Extent of resection: 52% GTR, 18% NTR, 30% STR. Disease recurrence/progression: 8% GTR, 16% NTR, 25% STR; 17% RS, 7% TL, 20% MF approaches. HB score: immediate (HB1 n= 100, HB2 n= 69, HB3 n= 92, HB4-6 n= 92), 1 year (HB1 n= 139, HB2 n= 91, HB3 n= 44, HB4-6 n= 37), >2 years (HB1 n= 113, HB2 n= 74, HB3 n= 34, HB4-6 n= 30). HB1-2 75% after 2 years. Approach and HB grade 1-3: immediate post op (RS 70%, TL 82%, MF 60%), 2 years (RS

	Follow up was at least 2 years after surgery.		84%, TL 92%, MF 100%); no statistical differences. HP achieved at 1 year in 12 of 88 patients (14%) Author Conclusion: H-B grade of immediate postoperative facial palsy can predict facial palsy at long-term follow-up. H-B grade 3 immediate postoperative facial palsy is the lowest tolerable grade that guarantees functional improvement on long-term follow-up. Planned FN preservation surgery followed by radiosurgery is thought to be optimal treatment in patients with vestibular schwannoma for both tumor control and FN function Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Raheja et al 2016 ⁴	Single institution, retrospective case series of 78 patients that underwent MF approach for VS. M/F 47/53%. Mean tumor size 7.5 mm (1-17.2). Preop: AAO-HNS A-B 78%, C 18%, D 4%. HB1 95%, HB2 5% Mean follow up was 15 months (0.25-132).	III	GTR obtained in 100% patients, no disease recurrence noted. 76% retained AAO-HNS hearing A-B. HB1 76% HB2 14% HB3 7% HB4-6 3% Author conclusion: Preliminary results from this single-center retrospective study of patients undergoing MFA for resection of VS showed that good HP and FN outcomes could be achieved with few complications. These results suggest that resection via the MFA is a rational alternative to watchful waiting or SRS Comments and Conclusions: The retrospective nature of the data yields class III data.
Mastronardi et al 2016 ¹⁰	Single institution, retrospective case series of 100 that underwent RS approach for VS. M/F 53/47%. Mean tumor size 2.4 cm. Follow up minimum 6 months.	III	GTR/NTR 68%, STR 25%, <STR 7%. HP (AAO-HNS A-B) in 30 of 43 patients with good preop hearing (70%). HB grade immediate: - HB1 58%, HB2 19%, HB3-6 22% >6 months: - HB1 92%, HB2 4%, HB3-6 4% Author conclusion: The anterior position and course and adhesion of the FN to the tumor capsule were the 2 factors most strongly associated with worse postoperative FN results.

			Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Zhang ⁶ et al 2016	Single institution, retrospective case series of 1006 VS patients. 63% TL, 20% % RS, 9% MF, 8% transotic. Study evaluated practiced changes over time (1990-2006).42% had serviceable preop hearing.	III	GTR 99.4%. 1.2% had disease recurrence; mean interval 2.8 years (range 1-6). Postop HB at 1 year: HB1-2 - TL 88%, RS81%, MF 78%, TO 82% HB3-4 - T: 11%, RS19%, MF 22%, TO 18% HB5-6: TL 1%, zero for RS/MF/TO. HP rate was 62%, 34% had serviceable hearing (no delineation of approach). Authors conclusions: Surgical outcomes of sporadic vestibular schwannoma have improved concerning FN function outcomes, HP and cerebrospinal fluid (CSF) leaks, mainly due to the neuro-otological team's experience. Functional results after complete microsurgical removal of large VS depend on experience gained on small VS removal Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Anaizi ⁷ et al 2016	Retrospective case series, single institution, 80 patients with small (Koos grade 1-2) that underwent RS (52%), TL (40%), or MF (8%) for VS. M/F 44/56%. 92% of patients had some hearing loss at presentation, 49% had serviceable hearing. 43% were observed for 1 year. 36% patients presented with vertigo/balance issues. Follow up mean 34 months.	III	89% GTR, 11% NTR (GTR: RS 89%, TL 88%, MF 100%). 2 of NTR demonstrated growth on next interval scan and received SRS. 95% patients had HB1-2 at last follow up. At last follow up, 36% retained serviceable hearing that had it preop (37% RS, 25% MF). 93% reported resolution in vertigo/imbalance. Patients with postop complications (5% RS, 18% TL, 33% MF) Authors conclusions: As one of the largest contemporary surgical series of small vestibular schwannomas, we discuss some nuances to help refine treatment algorithms. Although observation and radiosurgery have established roles, our results reinforce microsurgery as a viable, safe option for a subgroup of patients Comments and Conclusions: The retrospective nature of the data yields class III data.

Abbreviations: cm = centimeter; Preop = preoperative; RS retrosigmoid; TL = Translabyrinthine; MF = middle fossa; GTR = gross total resection; NTR = near total resection; STR = subtotal resection; HB = House Brachmann; n = number; AAO-HNS, American Academy of Otolaryngology-Head and Neck Surgery; CNAP = cochlear nerve action potential; FN = facial nerve; GR= Gardner–Robertson; HP = hearing preservation; IAC = internal auditory canal; PTA = pure tone average; VS = vestibular schwannoma; WRS = word recognition score; M = male; F = female; obs = observation; m = month

Table 2. RS versus TL Approach for FN Preservation

Author, Year	Results	Data Class	Conclusions
de Boer ¹⁵ et al 2020	Single institution, retrospective case series of 596 patients that underwent TL for VS. Mean follow-up after surgery was 50 m (median, 36 m; range, 3–209 m)	III	The extent of tumor removal was GTR in 32%, NTR in 58%, and STR in 10%. In 5.5% (33/596) of patients the tumor recurred. STR, young age, and tumor progression preoperatively significantly increased the risk of recurrence, whereas tumor size or histologic composition did not. Mean follow-up until the diagnosis of recurrence was 46 m (median, 39; range, 6–131 m). Salvage treatment for recurrences consisted of second surgery in eight patients and radiotherapy in 25 patients. A good postoperative FN function (HB1–2) was achieved in 85% at 1 year. The risk of postoperative FN paresis or paralysis increased with tumor size (HB1-2 90% IC, 79% small, 76% medium, 69% mod large, 54% large, 47% giant), but was not associated with the extent of tumor removal, histologic composition, or patient demographics. Authors conclusions: TL surgery is an effective treatment for VS, with a good local control rate and FN outcome. The extent of tumor removal is a clinically relevant predictor for tumor recurrence, as are young patient age and preoperative tumor progression. A large preoperative tumor size is associated with a higher risk of postoperative FN paresis or paralysis Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Tawfik ⁶⁷ et al 2020	Single institution, retrospective case series of 290 VS patients undergoing MS, 158 (54%) TL, 131 (45%) RS. Mean 37.7 months of follow up.	III	GTR was achieved in 98% of patients, no difference between RS and TL. Four of seven patients who underwent NTR had tumors more than or equal to 40 mm in maximal diameter (all TL). Long term facial outcome at last follow up: HB1-2: 84% TL, 98% RS HB3: 13% TL, 2% RS HB4-6: 4% TL, <1% RS. When accounting for tumor size, the TL and retrosigmoid approaches yield equivalent FN and extent of resection results. Authors conclusions: In patients with VS and retained serviceable hearing, SHL is an independent predictor of HP after RS

			microsurgical resection when the cochlear nerve is preserved Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Breun ¹³ et al 2019	Single institution, retrospective case series of 502 VS operated via RS approach. F 53%. 36% small, 64% large (T3B or T4). 73% had preop useful hearing. 12% had preop facial weakness. Follow up not detailed.	III	GTR 70%, NTR 26.9%, PTR 4%. HP in 43% with small tumors, 23% large tumors. 86% HB1-3 in small tumors 77% large tumors. HB1 GTR 26%, NTR 8%, PTR 2% HB2 GTR 21%, NTR 6%, PTR <1% HB3 GTR 10%, NTR 5%, PTR <1% HB4-6 GTR 12%, NTR 8%, PTR 1% Authors conclusions: In a standardized setting, the semi-sitting position allowed a safe approach. This setting offers the advantage of bimanual tumor nerve handling by the surgeon and an optimal visualization of important functional structures Comments and Conclusions: The retrospective nature of the data yields class III data.
Troude ¹² et al 2019	Single institution, retrospective case series of 169 large VS (>3 cm) operated via RS approach. M/F 40/60%. 10% had preop facial weakness, 13% had nervous intermediate symptoms, 25% had preop GR 1-2 class hearing. 36% had imbalance issues, 4% had trigeminal neuralgia. 36% operated through TL, 64% through RS approach. Follow up mean 62 months (54-71).	III	11% GTR, 59% NTR, 21% STR, 9% PTR. No tumor recurrence for GTR. Mean delay till recurrence/progression 37 months for NTR/STR/PTR. Of 143 patients with non-GTR, 66 followed obs, 77 underwent adjuvant SRS. Tumor control 82% in obs, 81% in SRS; 7-year PFS in obs 76%, SRS 78%. Immediate postop: HB1 45% HB2 22% HB3 11% HB4-6 22%. 3 months: HB1 57% HB2 17% HB3 11% HB4-6 15% Last f/u: HB1 68% HB2 16% HB3 15% HB4-6 1%. Surgical approach (RS vs TL) was not predictive of postop HB grade.

			Authors conclusions: As long as the extent of resection or additional Gamma Knife surgery have not been identified as predictive risk factors of postoperative FN palsy, we suggest that optimal resection is the main option for patients harboring large VS Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Hoshide ¹¹ et al 2018	Retrospective case series, single institution, 45 patients underwent keyhole RS approach for VS >3 cm. M/F 47/53. Mean tumor size 4.4 cm (3-7.5). Pre-op: 78% had hearing loss, 98% had HB1. Follow up mean 49m (14-145).	III	NTR/GTR 100%. No patients required reoperation for tumor recurrence. 40% of patients experienced transient facial weakness. At last follow up: HB1-2 84% HB3 9% HB4-6 7% Author conclusion: It is the experience of the senior author that complete or near-complete resection of large VSs can be successfully achieved via a keyhole approach. In this series of 45 large VSs, a greater extent of resection was achieved while demonstrating high rates of FN preservation and low approach-related and postoperative complications compared with the literature Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Schwartz ¹⁴ et al 2018	Single institution, retrospective case series of 100 patients that underwent TL resection of VS. M/F 45/55%. 74% had severe hearing loss. Tumor size 1.3 cm (0.4-2.0).	III	97 patients (97%) underwent GTR. 70 patients had at least 1 year follow up, without any disease recurrence. 99% had initial HB1-2 after surgery. 1 patient had HB4 post-op, with 7 developing delayed FN palsy; 2 patients had HB3 and 2 had HB5 at last follow up. Authors conclusions: It is the experience of the senior author that complete or near-complete resection of large VSs can be successfully achieved via a keyhole approach. In this series of 45 large VSs, a greater extent of resection was achieved while demonstrating high rates of FN preservation and low approach-related and postoperative complications compared with the literature Comments and Conclusions: The retrospective nature of the data yields class III data.
Lee ³ et al 2016	Single institution, retrospective case series of	III	Extent of resection: 52% GTR, 18% NTR, 30% STR. Disease recurrence/progression: 8%

	353 patients. M/F 44/56%. Tumor size mean 3 cm (range 5-60). Preop symptoms: 56% hearing loss, 25% vertigo/balance issues, 17% trigeminal neuropathy, 5% facial weakness. 76% underwent RS, 23% TL, 1% MF. Follow up was at least 2 years after surgery.		GTR, 16% NTR, 25% STR; 17% RS, 7% TL, 20% MF approaches. HB score: immediate (HB1 100, HB2 69, HB3 92, HB4-6 92), 1 year (HB1 139, HB2 91, HB3 44, HB4-6 37), >2 years (HB1 113, HB2 74, HB3 34, HB4-6 30). HB1-2 75% after 2 years. Approach and HB grade 1-3: immediate post op (RS 70%, TL 82%, MF 60%), 2 years (RS 84%, TL 92%, MF 100%); no statistical differences. Authors conclusions: H-B grade of immediate postoperative facial palsy can predict facial palsy at long-term follow-up. H-B grade 3 immediate postoperative facial palsy is the lowest tolerable grade that guarantees functional improvement on long-term follow-up. Planned FN preservation surgery followed by radiosurgery is thought to be optimal treatment in patients with VS for both tumor control and FN function Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Mastronardi ¹⁰ et al 2016	Single institution, retrospective case series of 100 that underwent RS approach for VS. 57% patients had no serviceable preop hearing. Follow up minimum 6 months.	III	GTR/NTR 68%, STR 25%, <STR 7%. HB grade immediate HB1 58% HB2 19% HB3-6 22%) >6 months HB1 92% HB2 4% HB3-6 4%) Authors Conclusions: The AS pattern was most common for smaller VSs. The A position and course and adhesion of the FN to the tumor capsule were the 2 factors most strongly associated with worse postoperative FN result. Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.

Abbreviations: cm = centimeter; Preop = preoperative; RS retrosigmoid; TL = Translabyrinthine; MF = middle fossa; GTR = gross total resection; NTR = near total resection; STR = subtotal resection; HB = House Brachmann; n = number; AAO-HNS, American Academy of Otolaryngology-Head and Neck Surgery; CNAP = cochlear nerve action potential; FN = facial nerve; GR= Gardner–Robertson; HP = hearing preservation; IAC = internal auditory canal; PTA = pure tone average; VS = vestibular schwannoma; WRS = word recognition score; M = male; F = female; obs = observation; m = month

Table 3. Comparison of Surgical Approach, Tumor Size and FN Functional Preservation

Author, Year	Results	Data Class	Conclusions
Rujimethapass ²⁴ et al 2022	Single institution, retrospective case series of 48 patients that underwent resection of large (>3cm, mean size 3.8 cm) or small (<3cm, mean size 1.5 cm) VS. In large lesions, 97% patients had hearing loss, 67% gait imbalance, 50% trigeminal neuropathy. In small lesions, 100% hearing loss, 5.6% gait imbalance, 11% trigeminal neuropathy.	III	At 1 month, 30% of large and 83.3% small had HB1-3. At 1 year follow up, 40% large and 94.4% small VS patients had HB1-3. 2). Comparing FN outcome at 1 year between GTR/NTR and STR showed HB1-3 in 7 patients (46.7%) in GTR/NTR group and 5 patients (33.3%) in STR group, HB4-6 was found in 8 (53.3%) and 10 (66.7%) in GTR/NTR group and STR group, respectively. Large-sized VS (≥ 3 cm) microsurgical resection had significantly poorer FN outcomes than those who had VS <3 cm. Authors conclusions: In patients with large size VS, microsurgical resection had poor FN outcomes compared with those of their counterparts with small to medium size VS. Planned STR with postoperative radiosurgery might attain superior FN outcomes and result in better QOI in subjects with large VS Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Stastna ²³ et al 2022	Single institution, retrospective case series of 125 patients with large cystic VS largely operated through TL (mean volume 9.5 cm ³ , range 1.8-52.7). M/F 52/48%. 98% had TL, 2% had RS.	III	GTR obtained in 62.4%, NTR in 34.4%, STR in 3.2%. Trend towards more NTR/STR in RS than TL. 3 months postop, 52% had HB1, 22.8% had HB2, 15.5% HB3-4, 9.6% HB5-6. 1 year postop, 76% had HB1-2, 16% HB3-4, 8% HB5-6. Poor FN outcome associated with larger size (>25 cm³). Authors Conclusions: Our study confirmed that microsurgery of cystic VS has worse outcomes of FN preservation and extent of resection compared with solid VS. Greater attention should be paid to the above-mentioned risk factors. Comments and Conclusions: The retrospective nature of the data yields class III data.
Kiyofuji ²⁹ et al 2021	Single institution, retrospective case series of 48 large (>4 cm) and 38 small (<1 cm) VS. Small tumors presented more commonly with tinnitus	III	Patients with large VS underwent more STR than small VS (50.0% vs. 2.6%). In small VS, GTR/NTR achieved in 97.4%, while GTR/NTR obtained in 50%. The rate of recurrence/progression needing treatment was not different between the groups (12.5% in

	and sudden hearing loss. RS was selected in 43 patients (89.6%), while TL approach (TL) was used in 5 patients (10.4%) in large VS. In small VS, RS was selected in 17 patients (44.7%), while TL was used in 19 patients (50%) and MF approach in 2 (5.3%).		large vs. 7.9% in small). In large VS, recurrence/progression was noted in 6 patients (12.5%) at a median of 35 months (range 13–84 months): four cases were progressions following STR, and two cases were recurrences following GTR and NTR. In small VS, recurrence was noted in 3 patients (7.9%, $p = 0.49$) at a median of 53 months (range 44–95 months). Two recurrences followed GTR, while one patient experienced recurrence after NTR. All recurrences were treated with SRS. These three patients were followed at a median of 36 months (range 0–55) after SRS, and they did not encounter further recurrence/progression. In large VS, 24 patients (50%) had good (HB I-II) facial function at last follow-up, while in small VS, only one patient demonstrated unsatisfactory postoperative facial function. In large VS, patients who underwent STR had better FN function at last follow-up than those who underwent GTR/NTR (66.7% vs. 33.3%) Large tumors have more unsatisfactory outcomes in FN function and postoperative hearing despite maximal efforts undertaken toward function-preservation strategy; however, similar tumor control was achieved. Authors conclusions: Large and small VS present differently. LTG showed more unsatisfactory outcomes in FN function and postoperative hearing despite maximal efforts undertaken toward function-preservation strategy; however, similar tumor control was achieved Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Kim ²⁸ et al 2021	Single institution, retrospective case series of 86 patients comparing RS vs TL approach for large (>3 cm) VS. 53 underwent RS, 33 underwent TL. Median follow up 34.5 months. 96% (RS) and 97% (TL) had preop HB1-2.	III	GTR: 8% RS, 18% TL. NTR: 55% RS, 55% TL. STR: 37% RS, 27% TL. Tumor recurrence/progression: 4% RS, 3% TL. 82% RS, 88% TL preservation of FN function. 26% HP RS. Surgical outcomes, including the extent of resection, tumor recurrence, and FN preservation, showed no significant differences between the two groups. Patients who underwent the RS approach showed a marginal trend for postoperative lower cranial nerve (LCN) dysfunction.

			Both surgical approaches show equivalent surgical and clinical outcomes. Authors conclusions: Both surgical approaches show equivalent surgical outcomes. Notably, the TL approach for large VS has advantages in that it reduces cerebellar injury and related morbidities. Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Mastronardi ⁶⁸ et al 2021	Single institution, retrospective case series of 60 patients with Koos grade IV VS (>3 cm) that underwent RS approach. In 11 cases, a preoperative HB 2-4 FN deficit was present.	III	GTR/NTR was accomplished in 46 cases (76.7%), 65.8% in cases with, and 95.4% without tight adhesion of capsule to nervous structures. At a mean follow-up of 59.3 months, a recurrence/regrowth of residue was observed in 8 (13.3%) cases operated on with STR/PTR: in 2 of them, a second surgery was necessary for large cystic transformation, 2 and 4 years after the first operation, respectively. In the other 6 cases, the initial growth of tumor was stable on serial scans. At last follow-up, 34 (56.7%) patients had a normal postoperative FN outcome (HB1), 9 (15%) were HB2, 8 (13%) HB3, and 9 (15,0%) HB4-6. The GTR/NTR resection of solid and low-bleeding VS, without tight capsule adhesion, was associated with better FN outcome. Long-term FN results seem to be worse in patients with cystic Koos grade IV VS, in cases with tight capsule adherences to nervous structures and in high-bleeding tumors. Authors conclusions: Microsurgery of Koos grade IV VS seems to be associated with more than acceptable functional results, with high rate of T and NT removal of tumor. Long-term FN results seem to be worse in patients with cystic Koos grade IV VS, in cases with tight capsule adherences to nervous structures and in high-bleeding. Comments and Conclusions: The retrospective nature of the data yields class III data.
Refaat ³⁰ et al 2021	Single institution, retrospective case series of 15 giant (>4.5 cm) VS operated via RS. 4 patients had preop facial weakness, and 1 of those had complete palsy. Median	III	GTR in 73.3%, STR 26.7%. There was no tumor recurrence/progression (although short follow up). Twelve cases (80%) had postoperative facial palsy, HB<3 in 5 cases (33.3%), and >3 in 7 cases (46.7%).

	follow up was 12 months (range 7-14).		Authors conclusions: Large and giant VSs are still commonly met in neurosurgical practice in developing countries; they have different behaviors and presentations from those of smaller tumors. Both patient and surgeon expectations from surgery should be toward no mortality and mild or no morbidities.
Killeen ³² et al 2020	Single institution, retrospective case series of 167 VS patients that underwent TL (76.7%), MF (14.4%), RS (7.2%) or other (1.8%) approaches. The median tumor diameter and volume were 25.3 mm(range: 4.1–47.1 mm) and 3.17 cm ³ (range: 0.01–30.6 cm ³), respectively. The median follow-up was 24.2 months (range: 12–114.2 months).	III	GTR was performed in 79% of cases, with residual tumor identified on MRI in 17% of cases. For patients with tumors <3 cm³, 92.7% had grade 1 or 2 facial function after at least 1 year follow-up, compared to 81.2% for those with tumors >3 cm³ (OR = 2.9). Logistic regression OR for postop facial weakness: TL 0.18, MF 1.14, RS 0.09 (not significant). Tumor volume >3 cm³ was predictive of facial weakness on multivariate regression analysis (OR = 7.4) when controlling for surgical approach, internal auditory canal extension, anterior extension, age, gender, and extent of resection. Tumor conclusions: Tumor volume >3 cm³ is associated with worse FN outcomes 12 months following surgical resection. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Won ²⁶ et al 2020	Single institution, retrospective case series of 58 patients with Koos grade IV tumors (mean volume 17.1 +/- 9.2 cm³) operated via RS approach. At admission, 49 patients (96.1%) had good FN function (HB 1–3) and 2 patients (3.9%) had poor FN function (HB 4–6). Follow up after surgery median time of 28 months (range 4.3– 53.8).	III	12 (21%) patients underwent GTR. There was no tumor recurrence in these patients at last follow up. In those 46 patients with residual tumors, stable disease was documented in 21 patients (45.7%), tumor regression in 12 patients (26.1%) and residual tumor progression in 11 patients (23.9%). After surgery, good FN function was observed in 66.7%. At follow-up, the number of patients with good FN function had increased, now present in 82.4%; however, pre-existing FN palsy (HB 5 or 6) had neither improved after surgery nor at follow-up examination. Authors conclusions: Subtotal tumor resection is a good therapeutic concept in patients with KOOS IV VS resulting in a high rate of good hearing and FN function and a very low rate of subsequent tumor progression. The goal of surgery should be to achieve more than 87% of

			tumor resection to keep residual tumor progression low. Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Huo ⁹ et al 2019	Single institution, retrospective case series of 138 patients that underwent MS for small/medium VS via (71) RS or (67) MF for HP. Minimum follow up was 2 years. 79% of patients had at least AAO-HNS A-B hearing.	III	97.8% of tumors underwent GTR, no difference between approaches. Postoperative hearing levels were preserved (AAO-HNS A-B) in 41.2% of those with preop hearing. Hearing outcomes were significantly better in patients with normal intraoperative I wave on ABR. Hearing loss within 6 months had a positive effect on postoperative hearing. Better preoperative hearing and tumors from SVN were correlated with better postoperative hearing outcomes. The different surgical approaches (RS or MF) resulted in no significant differences in postoperative hearing. Good FN (HB1-2) as obtained in 92% RS and 90% MF; no differences in early or last HB scores. Authors conclusions: Better preoperative hearing, shorter hearing loss period, tumors from SVN, and normal intraoperative I wave are prognostic factors for serviceable hearing. RSA and MFA are effective and safe for tumor removal and HP. Comments and Conclusions: The retrospective nature of the data yields class III data.
Troude ¹² et al 2019	Single institution, retrospective case series of 169 large VS (>3 cm) operated via RS approach. M/F 40/60%. 10% had preop facial weakness, 13% had nervous intermediate symptoms, 25% had preop GR 1-2 class hearing. 36% had imbalance issues, 4% had trigeminal neuralgia. 36% operated through TL, 64% through RS approach. Follow up mean 62 months (54-71).	III	11% GTR, 59% NTR, 21% STR, 9% PTR. No tumor recurrence/growth at last f/u in 83%. Mean delay till recurrence/progression 37 months. Of 143 patients with non-GTR, 66 followed obs, 77 underwent adjuvant SRS. Tumor control 82% in obs, 81% in SRS. 7 year PFS in obs 76%, SRS 78%. Complementary adjuvant SRS not predicted of remnant growth. Immediate postop: HB1 45%, HB2 22%, HB3 11%, HB4-6 22%. 3 months: HB1 57%, HB2 17%, HB3 11%, HB4-6 15%. Last f/u: HB1 68%, HB2 16%, HB3 15%, HB4-6 1%. Surgical approach (RS vs TL) was not predictive of postop HB grade. Authors conclusions: As long as the extent of resection or additional Gamma Knife surgery have not been identified as predictive risk factors of postoperative FN palsy, we suggest

			that optimal resection is the main option for patients harboring large VS Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Chiluwal ²⁵ et al 2018	Single institution, retrospective case series of 30 patients with small VS (Hannover grade T1-3b, mean 1.7 cm) operated through RS. 57% had AAO-HNS class 1-2.	III	90% underwent GTR. All patients had HB1 immediately postop. At 1 year, 97% had HB1-2, 3% had HB3. 59% of those with preop hearing preserved it postop ta 3 months (hearing preserved in smaller lesions, all T1-2 patients). 7 patients with hearing had f/y >2 years (range 24-70), all maintained class A-B hearing, one did go from A to B. Authors conclusions: Although both observation and radiosurgery are valid options in the management of smaller size VSs, surgical treatment seems to offer a high rate of FN preservation, a reasonable rate of hearing sparing, and a high total resection rate. Clinicians should consider surgical treatment as a valid option in the initial management of symptomatic small VSs in younger patients. Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Hoshide ¹¹ et al 2018	Retrospective case series, single institution, 45 patients underwent keyhole RS approach for VS >3 cm. M/F 47/53. Mean tumor size 4.4 cm (3-7.5cm). Pre-op: 78% had hearing loss, 98% had HB1. Follow up mean 49 m (14-145 m).	III	100% NTR/GTR (not distinguished). 40% of patients experienced transient facial weakness. At last F/U, 84% had HB1-2, 9% HB3, 7% HB 4-6. Authors conclusions: It is the experience of the senior author that complete or near-complete resection of large VSs can be successfully achieved via a keyhole approach. In this series of 45 large VSs, a greater extent of resection was achieved while demonstrating high rates of FN preservation and low approach-related and postoperative complications compared with the literature Comments and Conclusions: The retrospective nature of the data yields class III data.
MacKenzie ¹⁹ et al 2018	Single institution retrospective case of 63 patients with planned preop STR through RS approach. Preop: 96% HB1-2, 58% serviceable hearing, 46% vertigo, 46% cerebellar balance issues,	III	Extent of resection: STR 81%, NTR 19%. Discussion of adjuvant SRS, but no clear numbers provided. Immediate post-op: 71% HB1-2, 13% HB3, 16% HB4-6.

	27% trigeminal symptoms. Mean tumor volume 7.7 cm (0.74-41.44). Median follow-up 3 months.		At last follow up: 72% HB1-2, 10% HB3, 18% HB4-6. Authors conclusions: Intended submaximal resection provides satisfactory neurological outcome for patients with large VS. Risk factors for postoperative neurological deterioration remain unclear. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Zumofen ²⁷ et al 2018	Single institution, retrospective case series of 44 patients who underwent NTR of Koos grade IV VS via RS (mean tumor volume 10.9 cm³). At baseline HB1 (75%), HB2 (23%), HB4 (2%). Follow up mean 22 months (range 0.5-72).	III	The mean extent of resection was 89%. At the last radiological follow-up, the residual tumor had become smaller or remained the same size in 84% of patients. Mean time to volumetric progression 31 months (range 19-50); 18-24 months (7%), 24-36 (5%), 36-72 (16%). Volumetric progression was negatively correlated with the original extent of resection and positively correlated with postoperative residual tumor volume. At first clinical follow up (mean 26 days, range 7-126), 50% had HB1, 30% HB2, 5% HB3, 15% HB4-6. At the last clinical follow-up, FN function was good (HB I-II) in 89%, fair (HB III) in 9%, and poor (HB IV-VI) in 2% of the patients. Authors conclusions: Intended near-total removal results in excellent preservation of FN function and has a low recurrence rate. Any progressive residual tumor may be treated by radiosurgery Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Boublata ²¹ et al 2017	Single institution, retrospective case series of 151 large/giant VS (>3 cm) operated via RS approach. M/F 28/72%. 42% had preop hearing loss. 49% had balance issues. 3% had trigeminal neuralgia. Mean follow up 28 months (range 3-54).	III	GTR 83%, STR 14%, PTR 3%. FN anatomically intact in 99%. Immediate postop, 76% HB1-2, 18% HB3-4, 6% HB5-6. After two years: 82% HB1-2, 14% HB3-4, 4% HB5-6. Authors conclusions: The development of anesthesia techniques and microsurgery and the systematic use of IOM of the FN have allowed us to move from a life preservation era to another era of preservation of function Comments and Conclusions: The retrospective nature of the data yields class III data.

Huang ²⁰ et al 2017	Single institution, retrospective case series of 1167 patients with large (> 3 x 2 cm) approached through a RS craniotomy. M/F 46/54%. 60% had preop hearing of AAO-HNS A or B. Follow up mean 57 months (range 6-187).	III	86% GTR, 14% NTR, 0.2% STR. 4.9% had recurrent tumor at last follow up. Anatomical FN preservation was 93%. Immediate postop: 13% HB1, 23% HB2, 46% HB3, 36% HB4-6. For GTR: HB1-2 35%, HB3 47%, 36% HB4-6. NTR: HB1-2 44%, HB3 37%, 19% HB4-6. At last follow up: 32% HB1, 56% HB2, 6% HB3, 6% HB4-6. 81% lost complete hearing after surgery. Serviceable HP was 12%, and at last follow up 6% had class A-B hearing. Authors conclusions: The key factors for reducing surgical complications include careful assessment of the functions of acoustic and FNs as well as a thorough understanding of anatomy via the RS approach before operation, skillful microsurgical technique, and monitoring of multiple cranial nerves during resection. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Grahnke ²² et al 2017	Single institution, retrospective case series of 105 large (>2.5 cm) VS who underwent TL or RS approach. M/F 57/43%. Mean tumor diameter 3.4 cm. All patients presented with hearing loss. Mean follow up 36.5 months.	III	Resection: 33% STR, 67% GTR. 68% GTR had HB1-2, 60% STR had HB1-2. HB1-2 by approach: 75% RS, 60% TL, 60% combined RS-TL post-op; at 1 year: 92, 88, 86% (RS, TL, combined). Immediate postop, 65% had HB1-2. At 1 month, HB1-2 72% and at 1 year or last follow up 89% HB1-2. 11 patients (11%) experience HB6 postop, of those, 4 improved to HB3, 1 improved to HB4, 2 to HB5, 1 showed no improvement. No meaningful difference in FN outcomes between the RS, TL, and combined approaches for FN outcomes or tumor control long term. Authors conclusions: Our prognostic index may be useful to assess the risk of FN injury preoperatively for large acoustic neuromas, while also providing information about the tumor-nerve relationship. Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.

Huang ³¹ et al 2017	Single institution, retrospective case series of 657 giant (>4 cm) VS treated via RS approach. The other most frequent clinical symptoms were facial paresthesia/trigeminal neuropathy (453 cases, 68.9%), balance issues/disequilibrium (293 cases, 44.6%), facial paralysis (HB III + IV 204 cases, 31.1%). Mean follow up 60 months (range 6-191).	III	GTR in 556 patients (84.6%); NTR was achieved in 99 patients (15.1%). The mortality rate is 0.6%. The FN was preserved anatomically in 589 cases (89.7%). Good FN functional outcome (HB1-2) postoperatively was achieved in 216 patients (32.9%). Other 308 cases (46.9%) were HB3, and 133 patients (20.2%) were HB4-6. Authors conclusions: Trends in the data lead the authors to suggest that the microsurgical technique, intraoperative nerve monitoring, and multidisciplinary cooperation, were the keys to improving prognostic outcomes in giant intracranial VS patients. Comments and Conclusions: The retrospective nature of the data yields class III data.
Anaizi ⁷ et al 2016	Retrospective case series, single institution, 80 patients with small (Koos 1-2) that underwent RS (52%), TL (40%), or MF (8%) for VS. M/F 44/56%. 92% of patients had some hearing loss at presentation, 49% had serviceable hearing, 43% were observed for 1 year.	III	89% GTR, 11% NTR (GTR: RS 89%, TL 88%, MF 100%). 2 of NTR demonstrated growth on next interval scan and received SRS. 95% patients had HB1-2 at last follow up. At last follow up, 36% retained serviceable hearing that had it preop (37% RS, 25% MF). Patients with postop complications (5% RS, 18% TL, 33% MF) Authors conclusions: As one of the largest contemporary surgical series of small VSs, we discuss some nuances to help refine treatment algorithms. Although observation and radiosurgery have established roles, our results reinforce microsurgery as a viable, safe option for a subgroup of patients. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Lee ³ et al 2016	Single institution, retrospective case series of 353 patients. M/F 44/56%. Tumor size mean 3 cm (range 5-60). 5% patients had preop facial weakness. 76% underwent RS, 23% TL, 1% MF.	III	Extent of resection: 52% GTR, 18% NTR, 30% STR. Disease recurrence/progression: 8% GTR, 16% NTR, 25% STR; 17% RS, 7% TL, 20% MF approaches. HB score: Immediate (HB1 100, HB2 69, HB3 92, HB4-6 92), 1 year (HB1 139, HB2 91, HB3 44, HB4-6 37) >2 years (HB1 113, HB2 74, HB3 34, HB4-6 30). HB1-2 75% after 2 years.

			Approach and HB grade 1-3: immediate post op (RS 70%, TL 82%, MF 60%), 2 years (RS 84%, TL 92%, MF 100%); no statistical differences in approach. Authors conclusions: H-B grade of immediate postoperative facial palsy can predict facial palsy at long-term follow-up. H-B grade 3 immediate postoperative facial palsy is the lowest tolerable grade that guarantees functional improvement on long-term follow-up. Planned FN preservation surgery followed by radiosurgery is thought to be optimal treatment in patients with VS for both tumor control and FN function Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Zhang ⁶ et al 2016	Single institution, retrospective case series of 218 VS that were >4cm in diameter and underwent RS craniotomy. M/F 50/50%. 95% had preop hearing loss. Follow up mean 40 months (12-72).	III	29% GTR, 51% NTR, 64% STR. During F/U, 20 patients had disease progression (treated with SRS). Progression/recurrence rate: 3% GTR, 8% NTR, 24% STR. HB grade: Immediate (1: 6%, 2 41%, 3 27%, 4-6 27%). At 3 months HB1-2 40% GTR, 62% NTR, 64% STR At last follow up HB1-2 obtained in 59% of GTR, 80% NTR, 83% STR. Authors conclusions: Surgical outcomes of sporadic VS have improved concerning FN function outcomes, HP and cerebrospinal fluid (CSF) leaks, mainly due to the neuro-otological team's experience. Functional results after complete microsurgical removal of large VS depend on experience gained on small VS removal. Comments and Conclusions: The retrospective nature of the data yields class III data.
Sepehrnia ¹⁷ et al 2015	Multi-institution, retrospective case series of 446 patients with VS <2 cm (n=292; M/F 54/46%; mean follow up 63 months) or >2 (n=154, M/F 57/43%, mean follow up 67 months). All patients operated through RS craniotomy.	III	All patients had GTR in both cohorts. VS <2 cm: 94% HB1, 6% HB2. 51% HP (GR1-3). 34% serviceable HP. VS >2cm: 78% HB1, 20% HB2, 2% HB3. 34% HP (GR1-3). 27% preservation of serviceable hearing.

			Authors conclusions: Even a small increase in tumor size correlated with a significant reduction in good hearing and facial preservation postoperatively, which implies that tumor removal should be performed at the earliest stage possible. Furthermore, these results contradict recommending the wait-and-see approach for intra/extrameatal tumors. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Liu ¹⁸ et al 2015	Single institution, retrospective case series of 106 large (>3 cm) VS operated through a RS approach (tumor size range 3.0-5.7 cm). 2-year follow up.	III	82% GTR, 14% STR. No recurrence at 2 years for all GTR. All STR showed tumor growth by 2 years. 98% patients had anatomic preservation of CN7; 3 patients had mild laceration of CN7 due to tumor adherence. 3 patients had HB6 post-op, 2 improved to HB3 at 2 years, and one to HB4. Even within large VS, larger tumor size increased risk of worse HB score. No difference between cystic/solid lesions. Authors conclusions: Indicative factors of both immediate and long-term postoperative FN function in large VSs include tumor size, intraoperative train time, start to final FMEP ratios and proximal to distal MRA ratios. Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.

Abbreviations: cm = centimeter; Preop = preoperative; RS retrosigmoid; TL = Translabyrinthine; MF = middle fossa; GTR = gross total resection; NTR = near total resection; STR = subtotal resection; HB = House Brachmann; n = number; AAO-HNS, American Academy of Otolaryngology-Head and Neck Surgery; CNAP = cochlear nerve action potential; FN = facial nerve; GR= Gardner–Robertson; HP = hearing preservation; IAC = internal auditory canal; PTA = pure tone average; VS = vestibular schwannoma; WRS = word recognition score; M = male; F = female; obs = observation; m = month

Table 4. Microsurgery Compared to Observation for Tumor Control in Small Tumors

Author, Year	Results	Data Class	Conclusions
Patro ³⁴ et al 2021	Single institution, retrospective case series of 220 VS patients, 120 initially observed, 100 underwent microsurgery	III	Median time from consultation to microsurgery was 7.3 months (IQR 2.2–18.2), with 174 (79%) achieving GTR, 33 (15%) achieving NTR, and 13 (6%) achieving STR. There was no significant difference by logistic regression for STR, FN function at 2-3 weeks or 12 months, FN interventions, major complications, minor complications, tumor recurrence rate, or salvage therapy. Time from initial consultation to surgery did not significantly impact the probability of postoperative outcomes: STR, FN function at 2-3 weeks or 12 months, FN interventions, major complications, minor complications, tumor recurrence rate, or time to salvage therapy. Patients most frequently proceeded with surgery due to tumor growth alone (67%), followed by tumor growth and worsening symptoms (23%), worsening symptoms alone (8%), and patient preference without any tumor growth or worsening symptoms (2%). Median growth prior to microsurgery was 3.6 mm (IQR 1.4–5.4). Patients with worse hearing, larger tumor volume, and brainstem compression were more likely to pursue upfront microsurgery. A watchful waiting period does not appear to worsen outcomes and can be considered for patients with better hearing and smaller tumors without brainstem compression. Authors conclusions: Patients with worse hearing, larger tumor volume, and brainstem compression were more likely to pursue upfront microsurgery. A watchful waiting period does not appear to worsen outcomes and can be considered for patients with better hearing and smaller tumors without brainstem compression Comments and Conclusions: This is class III data based on the retrospective nature

			of data collection and the associated inherent biases.
Huo ⁹ et al 2019	Single institution, retrospective case series of 138 patients that underwent MS for small/medium VS via (71) RS or (67) MF for HP. Minimum follow up was 2 years. 79% of patients had at least AAO-HNS A-B hearing.	III	97.8% of tumors underwent GTR, no difference between approaches. Postoperative hearing levels were preserved (AAO-HNS A-B) in 41.2% of those with preop hearing. Hearing outcomes were significantly better in patients with normal intraoperative I wave on ABR. Hearing loss within 6 months had a positive effect on postoperative hearing. Better preoperative hearing and tumors from SVN were correlated with better postoperative hearing outcomes. The different surgical approaches (RS or MF) resulted in no significant differences in postoperative hearing. Good FN (HB1-2) was obtained in 92% RS and 90% MF; no differences in early or last HB scores. Authors conclusions: Better preoperative hearing, shorter hearing loss period, tumors from SVN, and normal intraoperative I wave are prognostic factors for serviceable hearing. RSA and MFA are effective and safe for tumor removal and HP. Comments and Conclusions: The retrospective nature of the data yields class III data.
Chiluwal ²⁵ et al 2018	Single institution, retrospective case series of 30 patients with small VS (Hannover grade T1-3b, mean 1.7 cm) operated through RS. 57% had AAO-HNS class 1-2.	III	90% underwent GTR, 2 patients required salvage treatment (SRS) due to growth. Twenty-three patients also had MRI beyond 2 years postoperatively, with no new changes compared to 1-year follow-up. All patients had HB1 immediately postop. At 1 year, 97% had HB1-2, 3% had HB3. 59% of those with preop hearing preserved it postop to 3 months (hearing preserved in smaller lesions, all T1-2 patients). 7 patients with hearing had follow up >2 years (range 24-70), all maintained class A-B hearing, one did go from A to B. Authors conclusions: Although both observation and radiosurgery are valid options in the management of smaller size

			VSs, surgical treatment seems to offer a high rate of FN preservation, a reasonable rate of hearing sparing, and a high total resection rate. Clinicians should consider surgical treatment as a valid option in the initial management of symptomatic small VSs in younger patients. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Schwartz ¹⁴ et al 2018	Single institution, retrospective case series of 100 patients that underwent TL resection of VS. M/F 45/55%. 26% had preop serviceable hearing. Tumor size 1.3 cm (0.4-2.0).	III	97 patients (97%) underwent GTR. 70 patients had at least 1 year follow up, without any disease recurrence. 1 patient had HB4 post-op, with 7 developing delayed FN palsy; 2 patients had HB3 and 2 had HB 5 at last follow up. Authors conclusions: TL resection of small VSs provides excellent results in terms of complication avoidance, tumor control, and FN outcomes. This is a hearing-destructive operation that is advocated for selected patients. Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Anaizi ⁷ et al 2016	Retrospective case series, single institution, 80 patients with small (Koos 1-2) that underwent RS (52%), TL (40%), or MF (8%) for VS. M/F 44/56%. 92% of patients had some hearing loss at presentation, 49% had serviceable hearing. 43% were observed for 1 year. 36% patients presented with vertigo/balance issues. Follow up mean 34 months.	III	89% GTR, 11% NTR (GTR: RS 89%, TL 88%, MF 100%) . 2 of NTR demonstrated growth on next interval scan and received SRS. 95% patients had HB1-2 at last follow up. At last follow up, 36% retained serviceable hearing that had it preop (37% RS, 25% MF). At last follow up, 93% reported resolution in vertigo/inbalance. Patients with postop complications (5% RS, 18% TL, 33% MF) Authors conclusions: As one of the largest contemporary surgical series of small VSs, we discuss some nuances to help refine treatment algorithms. Although observation and radiosurgery have established roles, our results reinforce

			microsurgery as a viable, safe option for a subgroup of patients. Comments and Conclusions: The retrospective nature of the data yields class III data.
Hunter ³³ et al 2016	Single institution, retrospective case series of 564 observed VS. Median age 59.2 years; 53.5% female. Median f/u 22.9 months (11.7-42.7). Median tumor diameter 1 cm.	III	In all, 40.8% of tumors demonstrated growth and 32.1% underwent intervention (21.5% microsurgery, 10.5% radiation) during the surveillance period. By 22 months from baseline, 50% of the tumors had experienced growth or had undergone intervention. VS growth was associated with older patients (60.2 years vs. 58.2 years, p=0.02), those presenting with symptoms of asymmetric hearing loss (82.6% vs. 73.7%). Authors conclusions: To date, this is the largest series of observed VS reported in the literature. Risk of VS growth is significantly increased among patients who present with larger tumors and who have concomitant disequilibrium. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.

Abbreviations: cm = centimeter; Preop = preoperative; RS retrosigmoid; TL = Translabyrinthine; MF = middle fossa; GTR = gross total resection; NTR = near total resection; STR = subtotal resection; HB = House Brachmann; n = number; AAO-HNS, American Academy of Otolaryngology-Head and Neck Surgery; CNAP = cochlear nerve action potential; FN = facial nerve; GR= Gardner–Robertson; HP = hearing preservation; IAC = internal auditory canal; PTA = pure tone average; VS = vestibular schwannoma; WRS = word recognition score; M = male; F = female; obs = observation; m = month

Table 5. Microsurgical Resection Compared to Observation for HP

Author, Year	Results	Data Class	Conclusions
La Monte ³⁹ et al 2022	Single institution, retrospective case series of 63 patients that underwent MF for HP of VS. All patients had preop WRS >50%.	III	Hearing preserved in 58.7% of patients. Better preop hearing predicted higher rate of HP, however no mention of long-term hearing rates. Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data,
Bozhkov ⁴⁶ et al 2021	Single institution, retrospective case series of 138 VS operated via RS. Mean tumor size 2.0 cm. Preop hearing in 70.3%. Follow up at 3 months.	III	76% GTR, 17%NTR, 7% STR. 22.5% serviceable hearing in those with it preop. 55% AAO-HNS A-B preop to 15% postop at 3 months. Small tumors (intrameatal, Koos grade 1) versus tumors <12 mm (Erlangen grade 1) had functional HP rates of 100% versus 83.3%. Good HP rates in small tumors, however short-postop follow up. Authors conclusions: Surgery on small VSs can achieve excellent HP. Different grading has a significant influence on and correlates with postoperative HP. Tumor size seems more important than anatomic relationship. Comments and Conclusions: The retrospective nature of the data yields class III data.
Jia ⁵³ et al 2021	Single institution, retrospective case series of 201 VS patients that underwent observation (120, 67.5%), MS (72, 37%), or SRS. 64% had serviceable hearing at first clinical interaction.	III	After 6 years, among the 31 VS still under observation, serviceable hearing declined from 58% at diagnosis to 48% at the last visit. Among 27 VS with initial class A, 20 VS (74%) remained class A (8 still obs), and seven other presented hearing loss (5 still under obs). For 24 VS with initial class B, 17 VS (71%) remained class B (7 still under observation), and the remaining six VS lost hearing to class C (3 still under obs, and 3 operated on because VS was growing) and one to class D (later SRS).

			Serviceable hearing at diagnosis was found in 60% of patients, with a subsequent low rate of deterioration in small and mid-sized observed tumors that did not implicate a change of policy. Delayed microsurgery on growing VS achieved similar FN function outcomes as immediate surgery and does not preclude attempting to preserve residual hearing. Authors conclusions: This longitudinal study of a large number of VS, which were diagnosed over a short period of time and followed for 12 years, provides new information on both the natural history of these benign tumors and individual patient concerns. This study recommends use of the WaS policy for small and mid-sized VS before active therapeutic decision making Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Macielak ³⁵ et al 2021	Single institution, retrospective case series, 603 patients underwent microsurgery, M/F 50/50%, tumor size 1.8 (1.2-2.5), 40% pre-op AAO-HNS A-B. Follow up not detailed.	III	18% had serviceable hearing at last F/U. Smaller tumor size, 1.2 (0.8-1.5) vs 1.8 (1.2-2.4) cm lead to increased HP. Authors conclusions: The probability of incurring less optimal microsurgical outcomes begins to significantly increase at 14-20 mm of CPA extension. Although many factors ultimately influence decision-making, when considering timing of microsurgical resection, using a size threshold range as depicted in this study offers an evidence-based approach that moves beyond reflexively recommending treatment for all tumors after detecting ≥ 2 mm of tumor growth on serial MRI studies. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data..
Wallerius ³⁵ et al 2021	Single institution, retrospective case series of 243 patients with serviceable preop hearing who underwent MS. Fifty (21%) tumors	III	Serviceable hearing was maintained in 64% of patients with tumors confined to the IAC, 28% with CPA extension <15 mm, and 9% with CPA extension ≥ 15 mm. On multivariable analysis, the odds ratios of acquiring nonserviceable hearing postop

	were confined to the IAC, and the median tumor size was 16.2 mm (IQR 11.3–23.2) for tumors with CPA extension. 92% underwent RS, 8% MF. Median time from MS to audiogram f/u 4.1 months (IGR 3.2-29.8).		for tumors extending <15 mm and ≥15 mm into the cerebellopontine angle were 5.75 (95% confidence interval [CI] 2.13–15.53) and 22.11 (95% CI 7.04–69.42), respectively, compared with IC tumors. The strongest predictor of HP with microsurgery after multivariable adjustment is tumor size. Approximately 10% of patients with tumors ≥15 mm of CPA extension will retain serviceable hearing after microsurgery. When categorized by tumor size, there was a strong inverse relationship between tumor size and likelihood of successful HP. Authors conclusions: The strongest predictor of HP with microsurgery after multivariable adjustment is tumor size. Approximately 10% of patients with tumors ≥15 mm of cerebellopontine angle extension will retain serviceable hearing after microsurgery. Furthermore, HP techniques offer cochlear nerve preservation and cochlear patency allowing for possible future cochlear implantation. An attempt at HP, including avoiding surgical approaches that necessarily sacrifice hearing, is worthwhile even in larger tumors if serviceable hearing is present preoperatively Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Han ⁵¹ et al 2020	Single institution, retrospective case series of 267 VS patients managed with MS or SRS. 21% were small to medium sized tumors (<25 mm). 51 patients had serviceable hearing for inclusion here, 21 undergoing RS, and 30 SRS.	III	In the MS group, the HP rate was 71.4% and the tumor control rate was 100% at a median interval of 41.5 months. MS/RS had a HP rate at 5 years of 71.4% (higher than SRS at 53.3%). Authors conclusions: MS was more suitable for patients who are younger, have good physical status, good preoperative hearing status including AAO-HNS class B, and medial type VS. GKS was more suitable for patients who are elderly, have poor physical status, preoperative AAO-HNS class A hearing.

			Comments and Conclusions: The retrospective nature of the data yields class III data.
Ichimasu ⁴² et al 2020	Single institution, retrospective case series of 91 VS operated on for HP. Mean age, 39.5 years; mean tumor size, 18.9 mm)	III	At last follow-up (mean 63.0 months), useful hearing was maintained in 79 patients (87%), and the hearing class remained unchanged during the follow-up period in 40 patients (44%). Significant predictors of useful hearing maintenance were AAO-HNS class A immediately after surgery, improvement of ABR, and the absence of postoperative DPOAE deterioration. Postoperative DPOAE deterioration correlated with hearing class deterioration. Despite hearing being preserved in VS patients immediately after surgery, Thirteen percent lost their useful hearing during the long follow-up period, and hearing class worsened in 55% of the patients. Authors conclusions: Despite hearing being preserved in VS patients immediately after surgery, Thirteen percent lost their useful hearing during the long follow-up period, and hearing class worsened in 55% of the patients. This study, which analyzed one of the largest series of VS patients, demonstrated that retrocochlear condition is a key factor for useful hearing maintenance. In patients with VS who have preserved hearing function, regular postoperative monitoring of hearing function is as important as regular MRI. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Tawfik ⁵⁰ et al 2020	Single institution, retrospective case series of 153 patients that underwent HP RS surgery for VS. Mean follow up 41.6 months.	III	Hearing was preserved and lost in 64 (41.8%) and 89 (58.2%) patients, respectively. HP rates were higher for intrameatal tumors than for tumors with extrameatal extension (57.6% versus 29.4%). Tumor size (per mm increase) was a negative predictor of HP. Preop AAO-HNS class was also predictive of HP. Class A hearing (compared with class B hearing) was the strongest positive risk factor for HP.

			Authors conclusions: In patients with VS and retained serviceable hearing, SHL is an independent predictor of HP after RS microsurgical resection when the cochlear nerve is preserved Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Zanoletti ⁴⁸ et al 2020	Single institution, retrospective case series of 100 patients operated through RS for HP.	III	Preoperative hearing class was preserved after surgery in 31% (AAO-HNS class A-B). According to the AAO-HNS classification, the tumor size in CPA, PTA, and speech discrimination score cutoffs for predicting good postoperative hearing function were 7 mm, 21 dB, and 90%, respectively. On multivariable analysis, tumor size and PTA were independent prognostic factors for preserving postoperative hearing. Authors conclusions: The estimated cutoffs for tumor size and PTA were independently associated with HPS. These factors should be prospectively investigated before they are adopted as selection criteria for HPS. Comments and Conclusions: The retrospective nature of the data yields class III data.
Dowling ⁴¹ et al 2019	Single institution, retrospective case series of 43 patients who had serviceable hearing (AAO-HNS class A-B) after MS of VS (RS or MF).	III	The median immediate postoperative pure-tone average (PTA) and word recognition score (WRS) were 31 dB and 95%, respectively. At last follow-up, the median PTA was 38 dB with a median change of 5 dB from initial postoperative audiogram, and the median WRS was 90% with a median change of 0% from initial postop audiogram. Eight patients developed non-serviceable hearing at a median of 4.1 years following microsurgical resection (IQ range, 2.9–7.0). The median duration of hearing follow-up for the 35 patients who maintained serviceable hearing was 3.1 years (IQ range, 2.2–7.5). Tumor control was achieved in 41 (95%) patients.

			The rate of maintaining serviceable hearing at 5 years was 81%. Authors conclusions: Microsurgical resection provides excellent tumor control and durable long-term hearing in those with AAO-HNS class A or B hearing postoperatively. The paradigm of proactive microsurgical resection-when the tumor is small and hearing is good-hinges on the surgeon's ability to preserve residual hearing in a very high percentage of cases at or near preoperative hearing levels to maintain an advantage over conservative observation with regard to long-term HP. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Huo ⁹ et al 2019	Single institution, retrospective case series of 138 patients that underwent MS for small/medium VS via (71) RS or (67) MF for HP. Minimum follow up was 2 years. 79% of patients had at least AAO-HNS A-B hearing.	III	97.8% of tumors underwent GTR, no difference between approaches. Postoperative hearing levels were preserved (AAO-HNS A-B) in 41.2% of those with preop hearing. Hearing outcomes were significantly better in patients with normal intraoperative I wave on ABR. Hearing loss within 6 months had a positive effect on postoperative hearing. Better preoperative hearing and tumors from SVN were correlated with better postoperative hearing outcomes. The different surgical approaches (RS or MF) resulted in no significant differences in postop hearing. Good FN (HB1-2) were obtained in 92% RS and 90% MF; no differences in early or last HB scores. Authors conclusions: Better preoperative hearing, shorter hearing loss period, tumors from SVN, and normal intraoperative I wave are prognostic factors for serviceable hearing. RSA and MFA are effective and safe for tumor removal and HP. Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.

Kosty ⁸ et al 2019	Single institution, retrospective case series of 63 patients that underwent MF approach for VS. The mean postoperative follow up was 21 ± 21 mo (range 5-78). The mean tumor size was 10 ± 4 mm. 76% of patients had preop AAO-HNS hearing class A-B. All patients had HB1-2.	III	The serviceable and usable HP rates were 54% and 50%, respectively. Some residual hearing was preserved in 71% of patients. GTR was achieved in 97% of patients. Three patients had recurrent tumor (6.3% recurrence rate). Of the 4 recurrences, 3 are being observed with serial imaging. One patient underwent hypofractionated radiation and achieved tumor quiescence. The long-term tumor control rate was 98.5%. Authors conclusions: In our series, the MCF approach for VS provided excellent rates of tumor and FN function, with durable serviceable HP. Comments and Conclusions: The retrospective nature of the data yields class III data.
Ahmed ⁴³ et al 2018	Single institution, retrospective case series of 155 VS that underwent MF for HP. Seventy-one patients with measurable hearing met criteria for long-term data analysis.	III	Class A or B hearing was preserved in 70% of the entire cohort after recovery. AAO-HNS class A-B HP was 82% at 3 to 5 years and declined thereafter. The rate of word recognition score class I or II HP was 98% at 3 to 5 years and declined less rapidly thereafter. Patients with preoperative Class A hearing had significantly higher rates of successful HP at all postop intervals. Delayed hearing loss occurs in a progressively increasing fashion but speech understanding remains durable for a majority of patients whose hearing is initially preserved with the MF approach. Authors conclusions: delayed hearing loss occurs in a progressively increasing fashion but speech understanding remains durable for a majority of patients whose hearing is initially preserved with the MCF approach. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Chilawal ²⁵ et al 2018	Single institution, retrospective case series of 30 patients with	III	90% underwent GTR. All patients had HB1 immediately postop. At 1 year, 97% had HB1-2, 3% had HB3.

	small VS (Hannover grade T1-3b, mean 1.7 cm) operated through RS. 57% had AAO-HNS class 1-2.		59% of those with preop hearing preserved it postop at 3 months (hearing preserved in smaller lesions, all T1-2 patients). 7 patients with hearing had f/y >2 years (range 24-70), all maintained class A-B hearing, one did go from A to B. Authors conclusions: Although both observation and radiosurgery are valid options in the management of smaller size VSs, surgical treatment seems to offer a high rate of FN preservation, a reasonable rate of hearing sparing, and a high total resection rate. Clinicians should consider surgical treatment as a valid option in the initial management of symptomatic small VSs in younger patients. Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Zhu ⁴⁹ et al 2018	Single institution, retrospective case series of 110 patients with small VS (<15 mm) that underwent hearing-preservation surgery with RS approach for VS, and 160 patients that underwent serial observation, were reviewed	III	Preoperative hearing levels of the RS surgery patients were Class A in 49 patients, Class B in 43 patients, and Class C in 18 patients. In all RS surgery patients, 97.3% maintained the same level during postoperative follow-up (mean follow-up time was 49 +/- 28 months) and 78.2% had complete radiologic and audiometric data at least 4 years follow-up for review. In the 4 years follow-up surgery group, postoperative hearing levels were Class A, B, C, and D for 22, 11, 18, and 35 patients, and postoperative rates of preservation of serviceable and useful hearing were 59.3% and 47.1%, respectively. In serial observation group, mean follow-up time was 35 +/- 33 months. Overall mean tumor growth rate was 1.08 +/- 2.3 mm/yr; serviceable HP rate of 98 patients was 54.1% (53/98) at the 5-year end point and 48.7% (37/76) at the 7-year end point. Better preoperative hearing predicted a higher rate of postoperative HP; patients without fundal extension were more likely to achieve HP than those with fundal extension.

			Authors conclusions: Tumor removal should be the first treatment option for patients with small VSs and preserved hearing, especially for young patients with good hearing; RS approach is an effective and safe approach for small VSs removal with excellent functional outcomes; better preoperative hearing predicted a higher rate of postoperative HP; patients without fundal extension were more likely to achieve HP than those with fundal extension, but no difference had been detected when RS removal assisted with endoscope was performed; patients with small tumors originating from SVN were more likely to achieve HP compared with those with IVN-originating tumors. Comments and Conclusions: The retrospective nature of the data yields class III data.
Zanoletti ⁴⁰ et al 2018	Single institution, retrospective case series of 91 patients with VS. 71% underwent planned observation, 22% underwent HP RS/MF, 7% underwent TL. Median follow up 25 months.	III	OBS: 25% abandoned observation for active intervention after tumor growth (20% TL surgery, 5% SRS). 28% hearing deteriorated, only coinciding with tumor growth in 35% of cases. Cumulative hazard of tumour growth after diagnosis was 3.4% for intrameatal tumors and 15.6% for extrameatal tumors in the first year, rising to 12.3% and 26.2%, respectively, in the first two years. Hearing-preserving RS/MF: 68% maintained AAO-HNS class A-B. HPS should be considered when preoperative hearing and tumour size are within the ranges of PTA $\leq$ 30 dB, SDS $\geq$ 70% and $\leq$ 10 mm in the CPA. Otherwise, observation seems to be the choice, as shown by the poor results of pre-treatment unfavorable cases. Under a wait-and-see policy, hearing remains adequately stable in the short term, but seems to become unsatisfactory over time. Authors conclusions: In this cohort of patients undergoing MCF resection of VS, rates of HP were higher for patients with excellent preoperative hearing. Postoperatively, +HP patients reported

			improved hearing-related PANQOL scores compared to -HP patients Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Abboud ⁴⁷ et al 2016	Single institution, retrospective case series of 64 patients that underwent RS approach for VS. Mean tumor size 2.2 cm (range 0.5-5.0). Follow up mean 77 months (range 15-159). 66% had preop serviceable hearing.	III	43% of those with preop serviceable hearing maintained it postop. At last follow up, 5% had GRHS class 1, 24% class 2. Logistic regression identified younger patient age and smaller tumour size as independent factors associated with improved rates of postoperative serviceable hearing, with the risk of developing non-serviceable hearing postoperatively increasing by a factor of 1.7 for every 10 patient years and a factor of 2.2 for every 10 mm in tumor size. Authors conclusions: Resection of VS via the retro-sigmoid approach is associated with improvement in postoperative vertiginous symptoms. Absence of central compensation leads to increased postoperative balance disturbances. Preservation of serviceable postoperative hearing is associated with good preoperative hearing status, younger age, and smaller tumors. Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Mendelsohn ⁴⁵ et al 2016	Single institution, retrospective case series of 85 patients with large (>3cm VS) who underwent RS approach with planned HP attempt. M/F 51/49%. 51% had preop serviceable hearing. Older age, DM, HTN risk factors for worse preop hearing function.	III	Postop HP was 42%. Large IAC tumor volume associated with reduced HP. CSF cleft in IAC improving hearing outcomes. 77% had HB1-2 immediately postop, at last follow up 86% had HB1-2. Authors conclusions: Systemic comorbidities may influence hearing loss preoperatively in patients with large VSs. The absence of tinnitus may reflect hearing reserve and propensity for HP. Preoperative radiographic features did not predict HP despite some associations with postoperative facial weakness.

			Comments and Conclusions: The retrospective nature of the data yields class III data.
Anaizi ⁷ et al 2016	Retrospective case series, single institution, 80 patients with small (Koos 1-2) that underwent RS (52%), TL (40%), or MF (8%) for VS. M/F 44/56%. 92% of patients had some hearing loss at presentation, 49% had serviceable hearing. 43% were observed for 1 year. 36% patients presented with vertigo/balance issues. Follow up mean 34 months.	III	89% GTR, 11% NTR (GTR: RS 89%, TL 88%, MF 100%); 2 of NTR demonstrated growth on next interval scan and received SRS. 95% patients had HB1-2 at last follow up. At last follow up, 36% retained serviceable hearing that had it preop (37% RS, 25% MF). Authors conclusions: As one of the largest contemporary surgical series of small VSs, we discuss some nuances to help refine treatment algorithms. Although observation and radiosurgery have established roles, our results reinforce microsurgery as a viable, safe option for a subgroup of patients. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Wilkinson ³⁷ et al 2016	Single institution, retrospective review of 377 patients that underwent MF (305) vs RS (75) approach for VS with the goal of understanding hearing outcomes. No differences in pre-op hearing, larger tumors in RS (1.78 cm) than MF group (0.97 cm). M/F 52/48% (MF), 40/60% (RS). Mean times to last audiometric follow-up were MF 1.0 year and RS 0.7 years.	III	Mean decline in hearing from preoperative to last follow-up was greater in the RS group (55.5 dB in PTA and 45.6% in discrimination) than the MF group (38.9 dB and 31.7%). The effect of surgical approach on hearing outcome remained after controlling for tumor size. FN outcomes and cerebrospinal fluid leak rates were not significantly different. GTR in 97% MF, 93% RS. Authors conclusions: Loss of hearing was greater with the RS approach than the MF approach, even when accounting for differences in tumor size. Postoperative FN function and other complications did not differ between approaches. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Aihara ³⁶ et al. 2015	Single institution, retrospective case series of 48 patients	III	HP in 34 of 48 (70.8%) patients (AAO-HNS class A-B) at 2 weeks post-op.

	undergoing MF approach for IC VS. M/F 52/48%. Median tumor volume 1.4 cm. Follow up hearing test 2 weeks after surgery.		Authors conclusions: Enlargement of the IAC on coronal reconstruction computed tomography scan before surgery can predict HP using the MF approach. Patients without IE may represent good surgical candidates for the MF approach Comments and Conclusions: The retrospective nature of the data yields class III data.
Quist ³⁸ et al 2015	Single institution, retrospective review of 57 VS that underwent MF approach for HP. Preop serviceable hearing present in 86%.	III	Immediate postoperative serviceable hearing was maintained in 27 (55%) patients, with an average PTA and WRS of 31 dB (5-50 dB) and 96% (70%-100%), respectively. Five-year follow-up was available for 16 of the 27 patients. Twelve (75%) of the 16 patients maintained serviceable hearing with an average PTA and WRS of 35 dB (4-49 dB) and 95% (84%-100%), respectively. Of the 16 subjects who did maintain class A or B hearing, the mean change in PTA and WRS was 5 dB and 0.4%, respectively. Of the 4 patients who did not maintain class A/B hearing, average change in PTA and WRS was 16 dB (4.5-23 dB) and 16% (0%-40%), respectively. For patients who undergo MF resection of VS in whom serviceable hearing is preserved after surgery, there is a high rate of long-term HP. Authors conclusions: For patients with VS in whom serviceable hearing is preserved following the MCF approach, the long-term hearing outcome remains durable in most patients Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Jethanamest ⁵² et al 2015	Single institution, retrospective case series of 94 patients that underwent serial observation for VS. Mean follow up 34.8 months. Mean tumor growth rate 1.14 mm/year.	III	While undergoing observation, 22.3% of patients underwent a change in management strategy to microsurgical excision or stereotactic radiotherapy. For patients with initial serviceable hearing, 24.3% observed a decline to a nonserviceable level. No significant clinical factors were identified to predict changes in hearing.

			Survival analysis revealed that, for patients with serviceable hearing at onset of observation, the median time to hearing loss worsening to a nonserviceable level was 76 months, and the median time to detecting tumor growth (1 mm/year) was 67 months Authors conclusions: Serial observation of VS is a viable treatment strategy for selected patients, with two-thirds of patients electing to continue this management option after 5 years. Disequilibrium as a presenting symptom may be associated with subsequent tumor growth Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
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Abbreviations: cm = centimeter; Preop = preoperative; RS retrosigmoid; TL = Translabrynthine; MF = middle fossa; GTR = gross total resection; NTR = near total resection; STR = subtotal resection; HB = House Brachmann; n = number; AAO-HNS, American Academy of Otolaryngology-Head and Neck Surgery; CNAP = cochlear nerve action potential; FN = facial nerve; GR= Gardner– Robertson; HP = hearing preservation; IAC = internal auditory canal; PTA = pure tone average; VS = vestibular schwannoma; WRS = word recognition score; M = male; F = female; obs = observation; m = month

Table 6. STR and Radiation Compared to Total Resection for FN Function Preservation

Author, Year	Results	Data Class	Conclusions
Landry ⁵⁴ et al 2022	Single institution retrospective case of 205 VS patients, 5 underwent planned STR and adjuvant radiation. No hearing information. 4 patients had preoperative trigeminal symptoms.	III	All patients had HB1-2 preop. 2 patients went from HB1 to 2 post-op, and 1 patient with preop HB2 recovered to HB1. 1 patient had recovery of trigeminal symptoms postoperatively. Authors conclusions: We comprehensively explore the clinical landscape of surgically treated VS and highlight important outcome predictors and disease subgroups. This may have important implications in risk stratifying these challenging cases Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Lee ⁵⁷ et al 2021	Single institution, retrospective case series of 68 patients that underwent STR VS resection followed by planned adjuvant SRS with a minimum follow up of 24 months. The median residual TV was 2.5 cm ³ (range: 0.3–27.4). The median follow-up period after the first adjuvant GKRS was 64 months (range: 25.7–152.4). Sixty-seven (99%) patients had a preoperative good FN function.	III	Eight (12%) patients showed tumor progression. In multivariate analyses, residual tumor volume was associated with tumor progression. A good FN function was observed in 50 (74%) patients in the immediate postoperative period and 54 (81%) patients at the time of the first GKRS. Two patients experienced worsening of the FN function after GKRS. One patient showed worsened FN function (H-B grade 3 → 4) due to the tumor bleeding after the first GKRS. Another patient showed worsened FN function (H-B grade 3 → 5) after the second GKRS after the additional surgery. At the last follow-up, 57 (84%) patients maintained a good FN function. Residual tumor volume was not associated with good FN function during the immediate postoperative period or at the last follow-up. Preservation of FN function was not correlated with the extent of resection. Authors conclusions: In this study, residual TV was associated with tumor progression in VS after adjuvant GKRS following STR. As preservation of FN

			function is not correlated with the extent of resection, optimal volume reduction is imperative to achieve long-term tumor control. Our findings will help surgeons predict the prognosis of residual VS after FN-preserving surgery. Comments and Conclusions: The retrospective nature of the data yields class III data.
Troude ¹² et al 2019	Single institution, retrospective case series of 169 large VS (>3 cm) operated via RS approach. M/F 40/60%. 10% had preop facial weakness, 13% had nervous intermediate symptoms, 25% had preop GR 1-2 class hearing. 36% had imbalance issues, 4% had trigeminal neuralgia. 36% operated through TL, 64% through RS approach. Follow up mean 62 months (54-71).	III	11% GTR, 59% NTR, 21% STR, 9% PTR. No tumor recurrence at last f/u in 83% in GTR. Mean delay till recurrence/progression 37 months in NTR/STR/PTR. Of 143 patients with non-GTR, 66 followed obs, 77 underwent adjuvant SRS. Tumor control 82% in obs, 81% in SRS. 7-year PFS in obs 76%, SRS 78%. Complementary adjuvant SRS not predicted of remnant growth. Immediate postop: HB1 45%, HB2 22%, HB3 11%, HB4-6 22%. 3 months: HB1 57%, HB2 17%, HB3 11%, HB4-6 15%. Last f/u: HB1 68%, HB2 16%, HB3 15%, HB4-6 1%. Surgical approach (RS vs TL) was not predictive of postop HB grade. No differences in HB grade between obs and adjuvant SRS treatment. Authors conclusions: As long as the extent of resection or additional Gamma Knife surgery have not been identified as predictive risk factors of postoperative FN palsy, we suggest that optimal resection is the main option for patients harboring large VS Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
MacKenzie ¹⁹ et al 2018	Single institution retrospective case of 63 patients with planned preop STR through RS approach. Preop: 96%	III	Immediate post-op: 71% HB1-2, 13% HB3, 16% HB4-6. Serviceable hearing 29%. 27% vertigo, 22% cerebellar balance issues, 100% trigeminal symptoms.

	HB1-2, 58% serviceable hearing, 46% vertigo, 46% cerebellar balance issues, 27% trigeminal symptoms. Mean tumor volume 7.7 cm (0.74-41.44). Median follow-up 3 months.		At last follow up: 72% HB1-2, 10% HB3, 18% HB4-6. Serviceable hearing 14%. 94% vertigo, 29% cerebellar balance issues, 12% trigeminal symptoms. Authors conclusions: Intended submaximal resection provides satisfactory neurological outcome for patients with large VS. Risk factors for postoperative neurological deterioration remain unclear Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Iwai ⁵⁵ et al 2015	Single institution retrospective case of 40 patients with large VS (>2.5 cm) treated with planned RS STR followed by SRS 1-12 months after surgery (median 3 months; median dose 12 Gy). 93% had hearing loss, 33% had facial weakness (13 patients, 11 had HB2, 2 had HB3).	III	Follow up median after SRS was 65 months (18-156 months). HB1 92.5%, HB2: 2.5%, 5% HB4-6. Tumor control 3 year (92%), 5 year (86%), and 10 year 86%), 4 patients (10%) required salvage surgery. Authors conclusions: Planned partial removal of large VS followed by GKS achieved a high rate of FN and HP. To achieve long-term tumor growth control, the tumor volume at GKS after planned partial surgical resection should be smaller than 6 cm³. Our results revealed that patients with HP postoperatively have a chance of maintaining hearing function, even though the possibility exists of deterioration by long-term follow-up after surgical intervention and GKS. Furthermore, some patients with severe hearing loss before treatment have the chance of hearing improvement, even those with large VS Comments and Conclusions: The retrospective nature of the data yields class III data.
Jeltema-Rinck ⁵⁸ et al 2015	Single institution, retrospective case series of 55 patients that underwent RS. 81.8% underwent NTR/STR, and 7 patients were deemed necessary at	III	Normal FN function (HB I) was preserved in 30 patients (57.7%), 17 patients (32.7%) experienced a permanent mild FN deficit (HB II, III), and five patients (9.6%) experienced a severe FN deficit (HB grade IV–VI). Seventeen patients (32.7%) experienced a permanent mild FN deficit

	follow up for SRS (follow up mean 35.4 months)		(HB II or III), whereas five patients (9.6%), including three patients needing adjuvant SRS, suffered a severe permanent FN deficit (HB IV, V, or VI) at the last follow-up. The seven patients with growth who underwent salvage SRS had no complications of the treatment, including any or further deterioration of FN function. Authors conclusions: Initial observation after near total surgical removal of VS is a feasible strategy, with only a minority requiring salvage radiosurgery during follow-up Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
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Abbreviations: cm = centimeter; Preop = preoperative; RS retrosigmoid; TL = Translabrynthine; MF = middle fossa; GTR = gross total resection; NTR = near total resection; STR = subtotal resection; HB = House Brachmann; n = number; AAO-HNS, American Academy of Otolaryngology-Head and Neck Surgery; CNAP = cochlear nerve action potential; FN = facial nerve; GR= Gardner–Robertson; HP = hearing preservation; IAC = internal auditory canal; PTA = pure tone average; VS = vestibular schwannoma; WRS = word recognition score; M = male; F = female; obs = observation; m = month

Table 7. Microsurgical Resection Compared to SRS to Improve Balance

Author, Year	Results	Data Class	Conclusions
MacKenzie ¹⁹ et al 2018	Single institution retrospective case of 63 patients with planned preop STR through RS approach. Preop: 96% HB1-2, 58% serviceable hearing, 46% vertigo, 46% cerebellar balance issues, 27% trigeminal symptoms. Mean tumor volume 7.7 cm (0.74-41.44). Median follow-up 3 months.	III	Immediate post-op: 71% HB1-2, 13% HB3, 16% HB4-6. Serviceable hearing 29%. 27% vertigo, 22% cerebellar balance issues, 100% trigeminal symptoms. At last follow up: 72% HB1-2, 10% HB3, 18% HB4-6. Serviceable hearing 14%. 94% vertigo, 29% cerebellar balance issues, 12% trigeminal symptoms. Cerebellar/balance symptoms resolved in 18 of 29 patients (62%) after surgical decompression. Authors conclusions: Intended submaximal resection provides satisfactory neurological outcome for patients with large VS. Risk factors for postoperative neurological deterioration remain unclear Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Samii ⁵⁹ et al 2017	Retrospective, single institution case series of 19 patients with primarily vestibular symptoms at presentation evaluating surgery via RS craniotomy for largely intracannalicular VS. M/F 53/47%. Duration of pre-op symptoms 15 months (range 2-48). All patients had disabling vertigo and dizziness (Dizziness Handicap Inventory/DHI >53; mean 66, range 54-94). F/u 1 year.	III	3 months: 12 patients (63%) had complete resolution of vestibular symptoms at 3 months post-op (DHI 9.8, range 2-44). 1 year: 17 patients 89% had resolution of vertigo (4.3, range 0-32). At 1 year, all patients had negative Rhomberg and Unterberger's tests. Authors conclusions: Disabling vestibular dysfunction that affects QOI should be considered an indication for surgery, even in otherwise asymptomatic patients with IC VS. Surgical removal of the tumor is safe and very effective in regard to symptom relief. All patients had excellent FN function within 1 year after surgery, with a very good chance of HP. Comments and Conclusions: The retrospective nature of the data yields class III data.

Anaizi ⁷ et al 2016	Retrospective case series, single institution, 80 patients with small (Koos 1-2) tumors that underwent RS (52%), TL (40%), or MF (8%) for VS. M/F 44/56%. 92% of patients had some hearing loss at presentation, 49% had serviceable hearing. 43% were observed for 1 year. 36% patients presented with vertigo/balance issues. Follow up mean 34 months.	III	89% GTR, 11% NTR (GTR: RS 89%, TL 88%, MF 100%). 2 of NTR demonstrated growth on next interval scan and received SRS. 95% patients had HB1-2 at last follow up. At last, follow up, 36% retained serviceable hearing that had it preop (37% RS, 25% MF). Patients with postop complications (5% RS, 18% TL, 33% MF) 93% reported resolution in vertigo/imbalance. Authors conclusions: As one of the largest contemporary surgical series of small VSs, we discuss some nuances to help refine treatment algorithms. Although observation and radiosurgery have established roles, our results reinforce microsurgery as a viable, safe option for a subgroup of patients. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Huang ³¹ et al 2017	Single institution, retrospective case series of 657 giant (>4 cm) VS treated via RS approach. The other most frequent clinical symptoms were facial paresthesia/trigeminal neuropathy (453 cases, 68.9%), balance issues/disequilibrium (293 cases, 44.6%), facial paralysis (HB III + IV 204 cases, 31.1%). Mean follow up 60 months (range 6-191).	III	GTR in 556 patients (84.6%); NTR was achieved in 99 patients (15.1%). The mortality rate is 0.6%. The main short-term complication included ‘new’ deafness (47.6%). The FN was preserved anatomically in 589 cases (89.7%). Good FN functional outcome (HB1-2) postop was achieved in 216 patients (32.9%). Other 308 cases (46.9%) were HB3, and 133 patients (20.2%) were HB4-6. Facial numbness/trigeminal neuropathy improved from 68.9% to 15.7%. Balance issues/disequilibrium improved from 44.6% to 6.71% at last follow up.

Abbreviations: cm = centimeter; Preop = preoperative; RS retrosigmoid; TL = Translabyrinthine; MF = middle fossa; GTR = gross total resection; NTR = near total resection; STR = subtotal resection; HB = House Brachmann; n = number; AAO-HNS, American Academy of Otolaryngology-Head and Neck Surgery; CNAP = cochlear nerve action potential; FN = facial nerve; GR= Gardner–Robertson; HP = hearing preservation; IAC = internal auditory canal; PTA = pure tone

average; VS = vestibular schwannoma; WRS = word recognition score; M = male; F = female; obs = observation; m = month

Table 8. Microsurgery Compared to SRS for Trigeminal Neuropathy

Author, Year	Results	Data Class	Conclusions
Landry ⁵⁴ et al 2021	Single institution retrospective case of 205 VS patients, 41 having undergone previous surgery; 164 included for this review. M/F 45/55%. Mean tumor size 2.9. Mean preop HB 1.1. No hearing information. 51 patients had trigeminal neuropathy/CN5 symptoms pre-op. 94 patients underwent RS, 70 underwent TL approaches. Mean follow up 60 months (0-179).	III	75 patients underwent STR, and 71 underwent GTR. Mean HB 2.3 (SD 1.4) at final follow up. No difference in HB between TL and RS. Large tumor size (>3cm), higher Koos grade, preop edema, and GTR resulted in worse FN outcomes. TL had higher rate of GTR than RS, but thought to be patient selection. 17 patients (33.3%) had trigeminal neuropathy at last follow up; with 34 improving after surgery (66.7%). Authors conclusions: We comprehensively explore the clinical landscape of surgically treated VS and highlight important outcome predictors and disease subgroups. This may have important implications in risk stratifying these challenging cases Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Won ²⁶ et al 2020	Single institution, retrospective case series of 58 patients with KOOS grade IV tumors (mean volume 17.1 +/- 9.2 cm3) operated via RS approach. Most common clinical symptoms at admission were hearing loss in 54 patients (93.4%) followed by vertigo in 26 patients (44.8%), facial dysesthesia in 26 patients (44.8%), ataxia in 24 patients (41.4%), imbalance in 16 patients and	III	12 (21%) patients underwent GTR. There was no tumor recurrence in these patients at last follow up. In those 46 patients with residual tumors, stable disease was documented in 21 patients (45.7%), tumor regression in 12 patients (26.1%) and residual tumor progression in 11 patients (23.9%). After surgery, good FN function was observed in 34 patients (96.1 vs 66.7%). At follow-up, the number of patients with good FN function had increased, now present in 42 patients (96.1 vs 82.4%, p=0.01); however, pre-existing FN palsy (HB 5 or 6) had neither improved after surgery nor at follow-up examination. After surgery, the number of patients with trigeminal dysfunction was significantly reduced (43.1 vs 23.5%) and at last

	headache in 10 patients (17.2%). Only 1 patient (1.7%) was asymptomatic at presentation. At admission, 49 patients (96.1%) had good FN function (HB 1–3) and 2 patients (3.9%) had poor FN function (HB 4–6). Among 51 patients, 22 patients (43.1%) displayed trigeminal neuropathy prior to surgery. Follow up median time of 28 months (range 4.3– 53.8) and a mean time of 33.7 months (SD 35.6).		follow-up, a further reduction was noted (43.1 vs 17.6%). Authors Conclusions: Subtotal tumor resection is a good therapeutic concept in patients with KOOS IV VS resulting in a high rate of good hearing and FN function and a very low rate of subsequent tumor progression. The goal of surgery should be to achieve more than 87% of tumor resection to keep residual tumor progression low Comments and Conclusions: The retrospective nature of the data yields class III data.
MacKenzie ¹⁹ et al 2018	Single institution retrospective case of 63 patients with planned preop STR through RS approach. Preop: 96% HB1-2, 58% serviceable hearing, 46% vertigo, 46% cerebellar balance issues, 27% trigeminal symptoms. Mean tumor volume 7.7 cm (0.74-41.44). Median follow-up 3 months.	III	Immediate post-op: 71% HB1-2, 13% HB3, 16% HB4-6. Serviceable hearing 29%. 27% vertigo, 22% cerebellar balance issues, 100% trigeminal symptoms. At last follow up: 72% HB1-2, 10% HB3, 18% HB4-6. Serviceable hearing 14%. 94% vertigo, 29% cerebellar balance issues, 12% trigeminal symptoms. Frequency of trigeminal nerve function clearly improved after surgery in about one third of the patients, whereas CN III, IV or VI deficits rarely improved. No correlations between worsening of trigeminal symptoms, signs of cerebellar compression or CN III, IV or VI deficits and any of the analyzed variables were found Authors conclusions: Intended submaximal resection provides satisfactory neurological outcome for patients with large VS. Risk factors for postoperative neurological deterioration remain unclear

			Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Huang ³¹ et al 2017	Single institution, retrospective case series of 657 giant (>4 cm) VS treated via RS approach. The other most frequent clinical symptoms were facial paresthesia/trigeminal neuropathy (453 cases, 68.9%), balance issues/disequilibrium (293 cases, 44.6%), facial paralysis (HB III + IV 204 cases, 31.1%). Mean follow up 60 months (range 6-191).	III	GTR in 556 patients (84.6%); NTR was achieved in 99 patients (15.1%). The mortality rate is 0.6%. The main short-term complication included ‘new’ deafness (47.6%). The FN was preserved anatomically in 589 cases (89.7%). Good FN functional outcome (HB1-2) postoperatively was achieved in 216 patients (32.9%). Other 308 cases (46.9%) were Hb3, and 133 patients (20.2%) were HB4-6. Facial numbness/trigeminal neuropathy improved from 68.9% to 15.7% at last follow up. Authors conclusions: Trends in the data lead the authors to suggest that the microsurgical technique, intraoperative nerve monitoring, and multidisciplinary cooperation, were the keys to improving prognostic outcomes in giant intracranial VS patients. Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.

Abbreviations: cm = centimeter; Preop = preoperative; RS retrosigmoid; TL = Translabirithine; MF = middle fossa; GTR = gross total resection; NTR = near total resection; STR = subtotal resection; HB = House Brachmann; n = number; AAO-HNS, American Academy of Otolaryngology-Head and Neck Surgery; CNAP = cochlear nerve action potential; FN = facial nerve; GR= Gardner–Robertson; HP = HP; IAC = internal auditory canal; PTA = pure tone average; VS = vestibular schwannoma; WRS = word recognition score; M = male; F = female; obs = observation; m = month

Table 9. Microsurgery After Stereotactic Radiation and FN Preservation

Author, Year	Results	Data Class	Conclusions
Kay-Rivest ⁶¹ et al 2022	Single institution retrospective case series of 7 patients that underwent MS after SRS. Mean age 62 years, 2 male/7 female. Median interval between SRS and MS was 42 months. 1 underwent RS, 6 TL. Median follow up after MS 15 months (3-52).	III	GTR 3 patients (43%). 2 patients had worsened HB, one went from HB2 to HB4, the other went from HB1 to HB6. In the operative reports reviewed, salvage MS was described as more difficult than usual, with lack of the normal tissue planes or “sticky” planes. Authors conclusions: For MS recurrences/residuals, SRS is the mainstay of treatment and does not preclude facial function recovery. If salvage microsurgery is required, an alternate approach should be considered. For SRS failures, when MS is required, less-than GTR may be preferable, and reirradiation is a potential safe alternative. Comments and Conclusions: The retrospective nature of the data yields class III data.
Troude ⁶⁹ et al 2022	Single institution, retrospective case series of 23 patients that underwent failed GKS followed by MS (and a control cohort of 170 that underwent MS allocated to obs or adjuvant GKS). The mean delay between GKS and salvage surgery was 66 months (median 47 months). Nine (39%) patients underwent surgery via TL and 14 (61%) via RS approach. The overall mean follow-up was 74 months (range 12–175).	III	Two patients (9%) underwent GTR, 9 underwent NTR (39%), 9 (39%) STR, and 3 (13%) PTR. Tumor control was achieved in 91% and 83% of cases with a mean follow-up of 74 and 63 months in the GKS failure and the genuine VS populations, respectively. The 1-, 5-, and 7-year progression-free survival were 100%, 95%, and 85% respectively in the GKS failure group and 97%, 80%, and 81% in the genuine VS group. Immediately after surgery, among the 21 patients with normal preoperative FN function, 19 (90%) retained a good FN function (HB1-2), 1 (5%) displayed an intermediate FN function (HB3), and 1 (5%) a poor FN function (HB4-6). No patient exhibited a delayed FN palsy. At last follow-up examination, good HB grade I and II FN function was observed in 20 patients (95%). Only one patient (5%) presented moderate deficit (HB3).

			Despite significant modifications of the microsurgical environment associated to salvage surgery after GKS failure, a functional nerve-sparing resection is an effective strategy to optimize the results on FN function, with similar long-term tumor control to those observed in the genuine VS population. Authors conclusions: Despite significant modifications of the microsurgical environment associated to salvage surgery after GKS failure, a functional nerve-sparing resection is an effective strategy to optimize the results on FN function, with similar long-term tumor control to those observed in the genuine VS population. Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Aboukais ⁶⁰ et al 2018	Single institution retrospective case series of 11 patients that underwent TL microsurgery after VS progression after primary SRS. Mean SRS dose 11.8 Gy (11-12), mean f/u 9.4 years (4-13), mean duration between SRS and progression was 32 months (18-72).	III	8 of the 11 patients obtained GTR, 3 patients had tumor residual left on the FN due to adherence. Formal FN anatomic preservation was noted in 9 of 11 patients (82%). No tumor progression was noted at 26 month follow up. At one year, 7 patients had HB1-2, 1 had HB3, and 3 had HB4. Authors conclusions: Salvage surgery of recurrent VS after failed initial GKS remains a good treatment. However, FN preservation is more challenging in this case and small tumor remnant could be sometimes deliberately left. Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Breshears ⁶⁴ et al 2017	Single institution, retrospective case series of 10 patients who underwent previous radiation followed by MS for VS. 4 underwent RS, 6 TL. Median follow up 15 months (range	III	Eight of 10 patients had a postoperative HB1 at a median follow-up of 14 months, while 2 patients had HB4. GTR was achieved in 7 of 10 cases, NTR was achieved in 2 cases, and STR was achieved in 1 case. Salvage surgery is a safe and effective option after failure of primary radiation.

	0-85). All patients had preop HB1. Median interval from radiation to MS 3 years (range 2-6)		Authors conclusions: Salvage surgery is a safe and effective option after failure of primary radiation and may offer benefits over repeat radiosurgery. Comments and Conclusions: The retrospective nature of the data yields class III data.
Lee ⁶² et al 2017	Single institution, retrospective case series of 6 patients who underwent salvage MS following VS progression. All patients were operated via the TL/TO. Pre-salvage median tumor size 2.8 (range 1.8-3.7), median SRS dose 13 (range 12.5-14), median duration from SRS to MS 38 months (range 19-168). Preop HB 1 in 3 patients, HB2 in 2 patients, and HB3 in 1 patient.	III	The decision to perform salvage surgery was based on the progressive worsening of neurologic symptoms (three patients), continuous tumor growth after 2 years of follow-up (two patients), and cystic degeneration (one patient). 3 patients underwent NTR, 3 STR. There was no evidence of disease progression at 1 year. Post-op HB: HB1 in 1 patient, HB2 in 1 patient, HB3 in 3 patients. 66% of patients demonstrated worsening of HB grade. Authors conclusions: H-B grade of immediate postoperative facial palsy can predict facial palsy at long-term follow-up. H-B grade 3 immediate postoperative facial palsy is the lowest tolerable grade that guarantees functional improvement on long-term follow-up. Planned FN preservation surgery followed by radiosurgery is thought to be optimal treatment in patients with VS for both tumor control and FN function Comments and Conclusions: The study provides class III data based on the retrospective nature of the data.
Nonaka ⁶³ et al et al 2016	Single institution, retrospective case series of 39 patients that failed SRT that underwent MS. 36 patients (92.3 %) demonstrated steady tumor growth after SRT. Two (5.1 %) patients with slight increase of the mass underwent surgical resection because of development of	III	Severe adhesions between the tumor capsule and cranial nerves, vessels, and the brainstem were observed in 69.2 %. GTR obtained in 33.3%, NTR in 35.9%, and STR in 30.8%. Patients with preop HB weakness had no worsening of facial weakness following surgery. Seven out of 36 patients (19.4 %) developed a new FN weakness after surgery. HB 3 was seen in two patients and grade 4 in four patients, and one patient had grade 5 FN palsy.

	unbearable facial pain. Preexisting FN palsy or weakness was seen in 3 out of 39 patients (7.7 %) at the time of surgery.		Authors conclusions: Findings suggest that patients with VS who fail SRT with either tumor progression or worsening of clinical symptoms will have an increased rate of adhesions to the neurovascular structures and may have radiation-influenced neuromalacia. Salvage surgery of radiation-failed tumors is more difficult and will have a higher risk of postoperative complications. Radical total resection may not be feasible, and conservative modality of subtotal resection needs to be considered to avoid new neurologic deficits Comments and Conclusions: This is class III data based on the retrospective nature of data collection and the associated inherent biases.
Wise ⁶⁵ et al 2016	Multi-institution, retrospective case series of 37 patients that underwent salvage MS after failed radiation for VS. Median time from radiation to surgical salvage was 36 months (range 9.6–153 months).	III	Following tumor progression after SRS, 18 (49%) patients underwent GTR, 10 (27%) underwent NTR, and nine (24%) underwent STR. There were no cases of tumor recurrence or regrowth after a median length of 26 months following microsurgical salvage (range 3–114 months). Twenty-seven (73%) patients had good postoperative FN outcome (HB1-2) at long-term follow-up. The rate of satisfactory postoperative FN function was not different between study and control subjects (73% vs. 76%); however, less-than-complete resection was utilized more frequently among previously radiated patients. Less-than-complete resection is required in a greater percentage of patients to preserve FN integrity and prevent neurological complications. Authors conclusions: Microsurgical salvage of VS following primary radiation therapy is challenging. Less-than-complete resection is required in a greater percentage of patients to preserve FN integrity and prevent neurological complications. Long-term follow-up is needed to determine the risk of delayed progression following incomplete tumor removal

			Comments and Conclusions: The retrospective nature of the data yields class III data.
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Abbreviations: cm = centimeter; Preop = preoperative; RS retrosigmoid; TL = Translabrynthine; MF = middle fossa; GTR = gross total resection; NTR = near total resection; STR = subtotal resection; HB = House Brachmann; n = number; AAO-HNS, American Academy of Otolaryngology-Head and Neck Surgery; CNAP = cochlear nerve action potential; FN = facial nerve; GR= Gardner– Robertson; HP = hearing preservation; IAC = internal auditory canal; PTA = pure tone average; VS = vestibular schwannoma; WRS = word recognition score; M = male; F = female; obs = observation; m = month

Appendix V. Conflicts of Interest

Task Force Member	Disclosure
<i>Julie Honaker PhD, AuD</i>	Nothing to Disclose
<i>Ben Allen Strickland, MD</i>	Nothing to Disclose
<i>Eric J. Lehrer, MD</i>	Servier Pharmaceuticals, Novocure Inc.
<i>Sheryl Green, MBBCh</i>	Nothing to Disclose
<i>John P. Marinelli MD</i>	Medtronic
<i>Christopher S. Graffeo MD, MS</i>	Nothing to Disclose
<i>Isabelle M. Germano, MD, MBA</i>	Brianlab
<i>Mateo Ziu, MD</i>	Omniscient Neurotechnology America Ltd; GT Medical Technologies, Inc
<i>Walavan Sivakumar, MD</i>	Stryker Corporation
<i>Sherwin Tavakol, MD</i>	IRRAS USA, Inc.; Globus Medical, Inc.
<i>Lucas Paul Carlstrom, MD, PhD</i>	Kuros Biosciences USA, Inc
<i>Jamie J. Van Gompel, MD</i>	Medtronic, Cadence
<i>Ian Dunn, MD</i>	Nothing to Disclose
<i>Jeffrey J. Olson, MD</i>	Verastem, Inc., Research Grant American Cancer Society, Editorial Consultant; Azurity Pharmaceuticals, Inc.
<i>Ghazal S. Daher MD</i>	Nothing to Disclose
<i>Matthew L. Carlson, MD</i>	Cochlear Americas, Advanced Bionics, Stryker Corporation; IotaMotion, Inc.; Stryker Corporation
<i>Neil S. Patel, MD</i>	Cochlear Americas, Zeiss, Viridian Therapeutics, IotaMotion, Inc.
<i>Michael Sughrue, MD</i>	Omniscient Neurotechnology America Ltd

<i>Constantinos G. Hadjipanayis, MD, PhD</i>	Stryker Corporation; Integra LifeSciences Corporation; Omniscient Neurotechnology America Ltd
<i>Jeffrey Jacob, MD</i>	Stryker Corporation; KLS; Synthes