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Long-term quality of life outcomes in patients undergoing microsurgical resection of vestibular schwannoma☆

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ABSTRACT

Background: While previous studies have assessed patient reported quality of life (QOL) of various vestibular schwannoma (VS) treatment modalities, few studies have assessed QOL as related to the amount of residual tumor and need for retreatment in a large series of patients. Objective: To assess patient reported QOL outcomes following VS resection with a focus on extent of resection and retreatment.

Methods: A retrospective chart review was performed using single-center institutional data of adult patients who underwent VS resection by the senior authors between 1989-2018 at Loyola University Medical Center. The Penn Acoustic Neuroma Quality of Life (PANQOL) survey was sent to all patients via postal mail.

Results: Fifty-five percent of 367 total patients were female with a mean age of 61.6 years (SD 12.63). The mean period between surgery and PANQOL response was 11.4 years (IQR: 4.74-7.37). The median tumor size was 2 cm (IQR: 1.5-2.8). The mean total PANQOL score was 70 (SD 19). Patients who required retreatment reported lower overall scores (μdiff = -10.11, 95% CI: -19.48 to -0.74; $p = 0.03$) and face domain scores (μdiff = -20.34, 95% CI: -29.78 to -10.91; $p < .001$). There was no association between extent of resection and PANQOL scores in any domain.

Conclusion: In an analysis of 367 patients who underwent microsurgical resection of VS, extent of resection did not affect PANQOL scores in contrast to previous reports in the literature, while the need for retreatment and facial function had a significant impact on patient-reported outcomes.

1. Introduction

Vestibular schwannomas (VS), formerly termed acoustic neuromas, are benign tumors of the cranial base with a natural history resulting in hearing loss, ataxia, hydrocephalus, and brainstem compression, all of which have been shown to negatively affect quality of life (QOL).[1–3] Historically, VS resection carried a high risk of morbidity and mortality. However, with technological advancements and the development of surgical practice, outcomes have dramatically improved while balancing extent of resection with optimized neurological outcomes, including facial function and hearing preservation.[4] Furthermore, analysis of these measures has resulted in improved preoperative treatment planning.[5–11] Patient-reported metrics have the ability to shed light onto the most clinically important outcomes that influence QOL, which can guide our focus and management of VS. The Penn Acoustic Neuroma Quality of Life (PANQOL) questionnaire has been validated as a method to assess QOL in patients with VS, and stratifies QOL outcomes into an overall score and subdomains relevant to various area of life functions.[12]

The PANQOL questionnaire has been applied in several studies

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analyzing QOL outcomes in patients between different VS treatment groups, such as microsurgery, stereotactic radiosurgery, and observation, and authors have suggested various factors that influence patient QOL.[13–21] Here, we utilize the PANQOL questionnaire in patients who elected to receive microsurgical resection of VS to determine the baseline and surgical characteristics that most significantly impact QOL outcomes. The present study not only analyzes QOL outcomes in a large microsurgical cohort, but also provides analysis of how facial and hearing preservation, extent of resection, and retreatment vary in their association with QOL outcomes.

2. Methods

2.1. Patient population

A retrospective review was conducted of patients aged 17 years and older who underwent microsurgical resection of VS by senior authors (D. E.A. and J.P.L) between 1989 and 2018 at Loyola University Medical Center. PANQOL surveys were mailed to patients' homes along with a return envelope with postage and a letter from corresponding author, D. E.A., detailing the study. Patients who did not respond within six weeks received a single follow-up phone call. This study was approved by the Loyola University Stritch School of Medicine Institutional Review Board (reference number 211402), and informed consent was received from all survey respondents.

2.2. Patient characteristics

A retrospective chart review was conducted to collect baseline demographic information and tumor characteristics, including tumor lateralization and size in the greatest dimension as seen on magnetic resonance imaging (MRI). Pre- and postoperative symptoms were recorded, including tinnitus, imbalance, headache, cerebrospinal fluid leak, and postoperative House-Brackmann (HB) grade.

2.3. PANQOL survey

The PANQOL questionnaire, developed in 2010 by Shaffer et al,[12] consists of 26 questions grouped into 7 domains determined to be most pertinent to quality of life (QOL): hearing, balance, facial, anxiety, energy, pain, and general health. Patients self-reported answers on a scale of 1–5, with 1 representing strong discordance and 5 representing strong accordance. Individual scores from each question were then converted to a 100-point scale as follows: for all questions except for question 25, a strong accordance reflected a lower quality of life. As such, a score of 5 was assigned a value of 0, a score of 4 was assigned a value of 25, and so forth. For question 25, a strong accordance reflected a higher quality of life, so a score of 5 was assigned a value of 100, a score of 4 was assigned a value of 75, and so forth. For each domain, the scores for the associated questions were averaged, with a higher score indicating a better QOL. The primary outcomes were individual domain and total PANQOL scores.

2.4. Extent of resection

The presence of residual tumor was assessed intraoperatively using a custom 1 cm graduated bayoneted micro-measuring instrument. Extent of tumor resection was divided into two groups: gross total resection (GTR) and less than GTR. GTR was defined as total removal by the surgeon's operative note with no observable residual tumor identified on postoperative MRI. Less than GTR was characterized by any presence of a residual tumor placode either measurable intraoperatively or postoperative imaging.

2.5. Retreatment

Retreatment was defined as requiring at least one additional microsurgical intervention for resection of residual or recurrent tumor. Decision for retreatment was made between operating surgeon and patient in the setting of residual or recurrent tumor causing return or continuation of symptoms associated with VS.

2.6. Hearing preservation

Postoperative hearing preservation was graded based on audiogram at most recent follow up according to the Gardner-Robertson hearing scale (GR).[22] Pure tone average (PTA) was calculated as a mean of 500, 1000, 2000, and 3000 Hz. Serviceable hearing was defined as GR grade 1 and 2.[22] Patients who were not candidates for hearing preservation surgery due to complete hearing loss prior to surgery or whose data were lost were excluded from analysis.

2.7. Facial outcome

Facial outcomes were graded using the House-Brackmann scoring system.[23] Grade I describes normal facial function, grade II describes mild dysfunction, grade III describes moderate dysfunction notably with complete eye closure with effort, grade IV describes moderately severe dysfunction with incomplete eye closure, grade V describes severe dysfunction, and grade VI describes total paralysis. For the purpose of our study, grade I and II were considered ideal facial nerve functional outcome.

2.8. Year of operation

Based on our previous study looking at the learning curve of VS resections of the operating neurosurgeons from 1988 to 2018, we looked at PANQOL scores from 1988-2004, 2005–2009, and 2010–2018. The probability of attaining a HB score of I was twofold higher in 2005–2009 and 2010–2018 as compared with 1988–2004.[24]

2.9. Statistical analysis

Continuous variables were summarized using mean with standard deviation or median with interquartile range (IQR). Nominal and ordinal variables were summarized using counts and proportions. A linear regression model was used to test whether PANQOL scores were associated with age, months since symptoms began, and tumor size. In this model, the assumptions of linearity, normality, and homoscedasticity were assessed using residual plots. An independent samples *t*-test was used to test whether the distribution of PANQOL scores varied by sex, residual symptoms, retreatment, hearing preservation status, presence of a CSF leak, and House-Brackmann grade. A general linear model was used to test whether the distribution of PANQOL scores varied by tinnitus, balance, and headache symptoms. A Kruskal–Wallis test was used to test for differences in the distribution of each PANQOL score among patients with a HB grade of I, II, III, and IV-VI; when the overall significance value was less than .05, all possible post-hoc pairwise comparisons were tested using the Dwass (1960), Steel (1960), Critchlow-Fligner method (1991).[25–27]

Following univariable analysis, multivariable general linear models were used to estimate adjusted PANQOL scores. In these models, covariates were included if they improved model fit as measured by Akaike's Information Criterion (AIC). In this study, a *p*-value less than .05 was considered statistically significant. All analyses were completed using SAS version 9.4 (Cary, NC).

3. Results

3.1. Baseline demographics

Of the 881 patients who underwent VS microsurgical resection, 175 patients were either deceased or lost to follow-up with no valid address or phone number available. Of the 706 remaining patients, 367 PANQOL surveys were returned (52%). Fifty-five percent of patients were female with a mean age of 61.6 years (SD 12.63). The mean time between surgery and PANQOL survey was 11.4 years (median 10.53; IQR: 4.74–17.37), and the median tumor size was 2 cm (IQR: 1.5–2.8). Two-hundred and four patients (55.6%) had a left-sided tumor, while the remaining 163 (44.4%) had a right-sided tumor. Zero patients had bilateral VS. The retrosigmoid approach was more commonly performed than the translabyrinthine or combined retrosigmoid/translabyrinthine approach (49% vs 37% vs 10%). A minority of patients underwent middle fossa approach. The mean period of follow-up between surgery and last clinical encounter was 81.3 months (median 40.05 months; IQR: 13.10–91.77) (Table 1).

3.2. Functional outcomes

House-Brackmann (HB) scores at most recent follow-up were recorded for 359 patients. Seventy-six percent of patients reported a HB grade I, 12.8% HB grade II, 8.4% HB grade III, .8% HB grade IV, .8% HB grade V, and 1.1% HB grade VI. HB scores were broken down into patients with ideal HB grade (I-II) (n = 319, 88.9%) and poor HB grade (III-VI) (n = 40, 11.1%) (Tables 2–5), in addition to further stratification (I vs II vs III vs IV-VI) in Table 6.

Gardner-Robertson (GR) scores were used to determine degree of hearing preservation, with serviceable hearing defined as GR I-II. Serviceable hearing at most recent follow-up was reported in 28% of patients with follow-up audiometric data.

3.3. PANQOL scores

3.3.1. Total

The mean total PANQOL score was 70/100 (SD 19). Controlling for sex, residual status, and retreatment status, patients with a poor HB grade (III-VI) reported lower overall quality of life (μdiff = −7.85, 95% CI: −14.76 to −.93; p = 0.03). Similarly, controlling for all other variables in the model, patients who required retreatment reported lower overall quality of life (μdiff = −10.11, 95% CI: −19.48 to −.74; p = 0.03). Conversely, controlling for all other variables in the model, male patients reported higher overall QOL compared to female patients (μdiff = 5.25, 95% CI: .90 to 9.61; p = 0.02) (Table 2).

Table 1
Baseline characteristics among 367 patients who underwent microsurgical resection of vestibular schwannoma.

Characteristic	N = 367
Age at survey *years*	
Mean (SD)	61.55 (12.63)
Median (IQR)	61.96 (53.32–71.21)
Sex *n (%)*	
Female	202 (55)
Male	165 (45)
Tumor size *cm*	
Mean (SD)	2.23 (1.03)
Median (IQR)	2 (1.5–2.8)
Laterality n (%)	
Left	204 (55.6)
Right	163 (44.4)
Extent of resection *n (%)*	
Gross total	334 (91)
Subtotal	33 (9)
Retreatment *n (%)*	20 (5.4)
Follow-up *years*	
Mean (SD)	6.78 (13.04)
Median (IQR)	3.34 (1.09–7.65)
Period from surgery to PANQOL survey *years*	
Mean (SD)	11.49 (7.50)
Median (IQR)	10.53 (4.74–17.37)

Table 2
PANQOL total scores as a function of patient characteristics.

	Valid N	Unadjusted		Adjusted	
		β (95% CI)	*p*	β (95% CI)	*p*
Age (per 1-year increase)	367	−.06 (−.22 to .09)	.41		
Sex: Male vs Female	367	4.27 (.43–8.10)	.03	5.25 (.90–9.61)	.02
Months since symptoms (per 1-month increase)	367	.01 (−.01 to .03)	.48	.03 (−.01 to .07)	.15
Residual: Yes vs No	366	−4.39 (−9.67 to .89)	.10	−1.91 (−7.45 to 3.63)	.50
Retreatment: Yes vs No	261	−8.75 (−16.96 to −.55)	.04	−10.11 (−19.48 to −.74)	.03
Tinnitus	364		.30		
Only post-op versus no post-op		−7.23 (−19.23 to 4.77)	.33		
Pre-and-post op versus no post-op		−2.18 (−8.94 to 4.58)	.73		
Pre-and-post op versus only post-op		5.05 (−8.24 to 18.35)	.64		
Balance	253		.33		
Only post-op versus no post-op		−2.32 (−10.19 to 5.54)	.77		
Pre-and-post op versus no post-op		−5.51 (−14.84 to 3.82)	.35		
Pre-and-post op versus only post-op		−3.19 (−14.62 to 8.24)	.79		
Headache	361		.01		
Only post-op versus no post-op		−12.09 (−21.28 to −2.89)	.01		
Pre-and-post op versus no post-op		−6.15 (−22.76 to 10.46)	.66		
Pre-and-post op versus only post-op		5.93 (−12.74 to 24.61)	.74		
Hearing Preservation: Yes vs No	93	3.83 (−4.26 to 11.92)	.35		
CSF Leak: Yes vs No	364	.16 (−4.96 to 5.28)	.95		
House–Brackmann: Score 3–6 versus Score 1–2	359	−5.61 (−11.76 to .55)	.07	−7.85 (−14.76 to −.93)	.03
Size (per 1 cm increase)	366	−.86 (−2.73 to 1.01)	.37		

Valid N = The number of patients used for the estimates. The sample size for the adjusted estimates = 260. PANQOL total scores range from 0 to 100 with higher scores indicating greater quality of life.

3.3.2. Hearing

The mean score in the hearing domain was 56/100 (SD 24). PANQOL hearing domain scores were higher for males (μdiff = 5.21, 95% CI: .26–10.15; p = 0.04) and for those with hearing preservation (μdiff = 11.22, 95% CI: 1.33–21.11; p = 0.03). Otherwise, PANQOL hearing domain scores were not associated with remaining patient characteristics in this sample of data (Supplemental Table 1).

Table 3
PANQOL face scores as a function of patient characteristics.

	Valid N	Unadjusted		Adjusted	*p*
		β (95% CI)	*p*	β (95% CI)	
Age (per 1-year increase)	367	−.09 (−.29 to .11)	.38		
Sex: Male vs Female	367	4.38 (−.76 to 9.53)	.09		
Months since symptoms (per 1-month increase)	367	−.03 (−.06 to .00)	.05		
Residual: Yes vs No	366	−6.84 (−13.90 to .22)	.06	−.23 (−6.68 to 6.21)	.94
Retreatment: Yes vs No	261	−25.34 (−40.43 to −10.25)	.002	−20.34 (−29.78 to −10.91)	<.001
Tinnitus	364		.34		
Only post-op versus no post-op		−4.25 (−20.22 to 11.72)	.81		
Pre-and-post op versus no post-op		4.85 (−4.15 to 13.85)	.41		
Pre-and-post op versus only post-op		9.10 (−8.60 to 26.80)	.45		
Balance	253		.30		
Only post-op versus no post-op		−6.05 (−16.41 to 4.32)	.36		
Pre-and-post op versus no post-op		−4.66 (−16.96 to 7.64)	.64		
Pre-and-post op versus only post-op		1.39 (−13.68 to 16.45)	.97		
Headache	361		.13		
Only post-op versus no post-op		−9.54 (−21.83 to 2.74)	.16		
Pre-and-post op versus no post-op		−9.27 (−31.47 to 12.93)	.59		
Pre-and-post op versus only post-op		.27 (−24.69 to 25.24)	.99		
Hearing Preservation: Yes vs No	93	3.98 (−5.10 to −13.06)	.39		
CSF Leak: Yes vs No	364	−6.04 (−15.48 to 3.40)	.21		
House–Brackmann: Score 3–6 versus Score 1–2	359	−35.34 (−42.79 to −27.88)	<.001	−35.31 (−43.45 to −27.17)	<.001
Size (per 1 cm increase)	366	−6.62 (−9.03 to −4.21)	<.001	−2.41 (−5.17 to .36)	.08

Valid N = The number of patients used for the unadjusted estimates. The sample size for the adjusted estimates = 260. PANQOL face ranges from 0 to 100 with higher scores indicating greater quality of life.

3.3.3. Balance

The mean score in the balance domain was 69/100 (SD 26). For every 1-year increase in age, PANQOL balance scores declined by approximately −.35 points (95% CI: −.56 to −.14; $p = 0.001$). Otherwise, PANQOL balance domain scores were not associated with remaining patient characteristics in this sample of data (Supplemental Table 2).

3.3.4. Face

The mean score in the face domain was 78/100 (SD 25). Controlling for tumor size, retreatment status, and residual status, patients with poor HB grades reported lower QOL scores in the face domain than patients with ideal HB grades (μdiff = −35.31, 95% CI: −43.45 to −27.17; $p < .001$). Similarly, controlling for all other variables in the model, patients who underwent retreatment reported lower quality of life scores in the face domain (μdiff = −20.34, 95% CI: −29.78 to −10.91; $p < .001$) (Table 3).

Table 4
PANQOL pain scores as a function of patient characteristics.

	N	Unadjusted		Adjusted	
		OR (95% CI)	*p*	OR (95% CI)	*p*
Age (per 1-year increase)	365	.99 (.98–1.00)	.16		
Sex: Male vs Female	365	.74 (.51–1.08)	.11		
Months since symptoms (per 24-month increase)	365	.94 (.89–.99)	.01	.94 (.90–1.00)	.06
Residual: Yes vs No	364	1.84 (1.11–3.07)	.02	1.42 (.82–2.44)	.21
Retreatment: Yes vs No	260	1.14 (.50–2.59)	.76		
Tinnitus	362		.002		.04
Only post-op versus no post-op		4.54 (1.72–11.98)	.002	3.31 (1.23–8.90)	.02
Pre-and-post op versus no post-op		1.70 (.99–2.93)	.06	1.45 (.83–2.53)	.20
Pre-and-post op versus only post-op		.37 (.13–1.09)	.07	.44 (.15–1.30)	.14
Balance	252		.33		
Only post-op versus no post-op		1.37 (.71–2.65)	.34		
Pre-and-post op versus no post-op		1.64 (.76–3.56)	.21		
Pre-and-post op versus only post-op		1.20 (.46–3.08)	.71		
Headache	359		.005		.02
Only post-op versus no post-op		3.30 (1.57–6.97)	.002	2.84 (1.32–6.14)	.01
Pre-and-post op versus no post-op		2.03 (.54–7.72)	.30	1.59 (.41–6.13)	.50
Pre-and-post op versus only post-op		.62 (.14–2.76)	.53	.59 (.12–2.57)	.46
Hearing Preservation: Yes vs No	93	1.04 (.46–2.33)	.93		
CSF Leak: Yes vs No	362	1.05 (.53–2.10)	.88		
House–Brackmann: Score 3–6 versus Score 1–2	357	.74 (.40–1.37)	.34		
Size (per 1 cm increase)	364	.96 (.80–1.16)	.68		

N = The number of patients used for the estimates. The sample size for the adjusted estimates = 359. The PANQOL pain item asks participants to respond to the following item using a five-point ordinal scale (1 = Strong disagree to 5 = Strongly agree): "I have problems with head pain on the side of my acoustic neuroma tumor".

3.3.5. Anxiety

The mean score in the anxiety domain was 80/100 (SD 25). Patients with a postoperative headache reported lower QOL in the PANQOL anxiety domain (μdiff = −14.68, 95% CI: −26.98 to −2.37; $p = 0.01$). Otherwise, PANQOL anxiety domain scores were not associated with remaining patient characteristics in this sample of data (Supplemental Table 3).

3.3.6. Energy

The mean score in the energy domain was 68/100 (SD 26). Patients with a postoperative headache reported lower QOL in the PANQOL energy domain (μdiff = −15.31, 95% CI: −28.33 to −2.29; $p = 0.02$). Conversely, males reported higher PANQOL energy scores (μdiff = 5.60, 95% CI: .17 to 11.02; $p = 0.04$). Otherwise, PANQOL energy domain

Table 5
PANQOL health scores as a function of patient characteristics.

	N	Unadjusted		Adjusted	
		β (95% CI)	*p*	β (95% CI)	*p*
Age (per 1-year increase)	366	−.34 (−.51 to −.16)	<.001		
Sex: Male vs Female	366	−.61 (−5.12 to 3.89)	.79		
Months since symptoms (per 1-month increase)	366	−.01 (−.04 to .01)	.27		
Residual: Yes vs No	365	2.27 (−3.90 to 8.44)	.47	1.76 (−4.92 to 8.44)	.60
Retreatment: Yes vs No	261	−8.98 (−18.55 to .59)	.07	−9.22 (−19.07 to .64)	.07
Tinnitus	363		.69		
Only post-op versus no post-op		3.53 (−10.52 to 17.58)	.82		
Pre-and-post op versus no post-op		−1.95 (−9.87 to 5.96)	.83		
Pre-and-post op versus only post-op		−5.48 (−21.06 to 10.09)	.69		
Balance	253		.82		
Only post-op versus no post-op		.16 (−9.07 to 9.39)	.99		
Pre-and-post op versus no post-op		2.96 (−8.00 to 13.91)	.80		
Pre-and-post op versus only post-op		2.80 (−10.62 to 16.21)	.88		
Headache	360		.001		.02
Only post-op versus no post-op		−9.90 (−20.59 to .80)	.08	1.58 (−10.45 to 13.61)	.93
Pre-and-post op versus no post-op		−25.15 (−44.47 to −5.83)	.01	−23.52 (−42.99 to −4.06)	.01
Pre-and-post op versus only post-op		−15.25 (−36.98 to 6.48)	.23	−25.10 (−47.13 to −3.07)	.02
Hearing Preservation: Yes vs No	93	2.98 (−6.10 to 12.06)	.52		
CSF Leak: Yes vs No	363	−1.08 (−9.39 to 7.23)	.80		
House–Brackmann: Score 3–6 versus Score 1–2	358	−2.85 (−10.05 to 4.34)	.44	−7.78 (−16.26 to .70)	.07
Size (per 1 cm increase)	365	.83 (−1.36 to 3.03)	.45	2.44 (−.41 to 5.29)	.09

N = The number of patients used for the estimates. The sample size for the adjusted estimates = 259. PANQOL health ranges from 0 to 100 with higher scores indicating greater QOL.

scores were not associated with remaining patient characteristics in this sample of data (Supplemental Table 4).

3.3.7. Pain

26.8% (365) of patients that responded to the pain domain question indicated that they experienced residual pain on the surgical side. Controlling for residual status, tinnitus, and months since symptoms began, patients with solely a postoperative headache were 2.8 times more likely to report higher agreement with the PANQOL pain domain (95% CI: 1.32 to 6.14; $p = 0.01$). Controlling for all other variables in the model, patients with solely postoperative tinnitus were 3.3 times more likely to report higher agreement with the PANQOL pain item (95% CI: 1.23 to 8.90; $p = 0.02$) (Table 4).

3.3.8. Health

The mean score in the health domain was 69/100 (SD 22). Controlling for all other variables in the model, patients with both a pre- and postoperative headache reported lower PANQOL health QOL scores than those with no postoperative headache (μdiff = −23.52, 95% CI: −42.99 to −4.06; $p = 0.01$) and those with solely a postoperative headache (μdiff = −25.10, 95% CI: −47.13 to −3.07; $p = 0.02$). There was no significant difference in reported scores between patients with postoperative headaches and those with no postoperative headaches (μdiff = 1.58, 95% CI: −10.45 to 13.61) (Table 5).

3.4. PANQOL scores by House-Brackmann grade

There was significant variability in the PANQOL face and total scores when analyzed by HB grade. For the face domain, patients with HB grade I had a higher QOL (median = 100, IQR: 75–100) than patients with HB grade II (median = 58, IQR: 38–75), HB grade III (median = 42, IQR: 33–58; $p < .001$), and HB grade IV-VI (median = 42, IQR: 25–58; $p < .001$). No other pairwise comparisons were statistically significant. While there was overall variability among the four HB groups in the PANQOL total score (overall $p = 0.02$), no post-hoc pairwise comparison was statistically significant after adjusting for inflated Type 1 error (all $p > 0.05$) (Table 6).

3.5. PANQOL scores by extent of resection

Ninety-one percent of patients received GTR (n = 334), the remaining receiving less than GTR for purpose of neurologic preservation in the setting of closely adherent tissue. Extent of resection was not associated with PANQOL total score (μdiff = −1.91, 95% CI: −7.45 to 3.63, $p = 0.50$), hearing score (μdiff = −1.74, 95% CI: −8.55 to 5.07, $p = 0.62$), balance score (μdiff = −3.05, 95% CI: −10.48 to 4.38, $p = 0.42$), face score (μdiff = −.23, 95% CI: −6.68 to 6.21, $p = 0.94$), anxiety score (μdiff = −3.79, 95% CI: −10.85 to 3.28, $p = 0.29$), energy score (μdiff = −5.77, 95% CI: −13.24 to 1.69, $p = 0.13$), pain score (μdiff = 1.42, 95% CI: .82 to 2.44, $p = 0.06$), or health score (μdiff = 1.76, 95% CI: −4.92 to

Table 6
PANQOL scores by House Brackmann groups.

	House-Brackmann (recoded)																Overall *p*
	Score 1				Score 2				Score 3				Scores 4 - 6				
	N	Mdn	25%	75%	N	Mdn	25%	75%	N	Mdn	25%	75%	N	Mdn	25%	75%	
PANQOL Hearing	273	56	38	75	46	59	31	75	30	56	44	75	10	50	31	75	.91
PANQOL Balance	273	71	50	96	46	71	42	88	30	75	50	96	10	63	42	79	.58
PANQOL Face	273	100	75	100	46	58	38	75	30	42	33	58	10	42	25	58	<.001
PANQOL Anxiety	273	94	69	100	46	94	69	100	30	84	56	100	10	75	50	75	.24
PANQOL Energy	273	75	50	96	46	67	50	79	30	69	50	83	10	52	42	71	.28
PANQOL Pain	271	75	25	100	46	75	25	100	30	75	50	100	10	75	75	100	.63
PANQOL Health	272	75	50	88	46	63	50	75	30	75	50	88	10	63	50	75	.44
PANQOL Total	273	74	59	86	46	69	57	76	30	66	57	79	10	61	51	65	.02

Note: Mdn = Median. 25% & 75% = Interquartile Range (IQR).

8.44, $p = 0.60$).

3.6. PANQOL scores by retreatment

5.4% of patients required retreatment of their tumor (n = 20). Retreatment was significantly associated with decrease in PANQOL total score (μdiff = −10.11, 95% CI: −19.48 to −.74, p =0.03) and face score (μdiff = −20.34, 95% CI: −29.78 to −10.91, $p < 0.001$). Retreatment was not associated with hearing score (μdiff = −3.95, 95% CI: −14.86 to 6.97, p =0.48), balance score (μdiff = −9.76, 95% CI: −21.69 to 2.17, p =0.11), anxiety score (μdiff = −5.75, 95% CI: −17.14 to 5.63, p =0.32), energy score (μdiff = −7.89, 95% CI: −19.67 to 3.89, p =0.19), pain score (μdiff = 1.14, 95% CI: .50 to 2.59, p =0.76), or health score (μdiff = −9.22, 95% CI: −19.07 to .64, $p = 0.07$).

3.7. PANQOL scores by year of operation

From 1989 to 2004 (n = 133), the mean PANQOL score was 75.88. From 2005 to 2009 (n = 82) and 2010–2018 (n = 152), the mean PANQOL scores were 81.50 and 78.95, respectively.

4. Discussion

While most studies utilizing PANQOL have assessed how treatment modality impacts QOL in patients with VS,[13–21] we sought to determine the specific baseline characteristics and surgical outcomes that influence the QOL of patients who undergo microsurgical resection. Expectedly, we identified that functional outcomes, such as hearing preservation and HB grade, had a significant impact on self-reported scores within the hearing and facial domains. Also as expected, scores within the facial domain between 1988 and 2004 were, on average, lower than the facial domain scores between both 2005–2009 and 2010–2018, given that the chance of a patient having a postoperative HB I score was higher during those times.[24] In concordance with prior literature, postoperative headache was associated with lower QOL scores in the anxiety, energy, pain, and health domains.[15] Total PANQOL scores were negatively influenced by poor HB grade, retreatment status, and female sex.

Our results demonstrate that extent of resection had no significant impact on PANQOL domain or overall scores in our patient population, which differs from a pivotal study by Link et al who showed that greater extent of resection is associated with improved self-reported QOL. Their study analyzed long term QOL between 143 patients who received either GTR (85%) or less than GTR (15%) from microsurgical removal of VS, demonstrating that those receiving GTR reported better facial, energy, health, and total PANQOL scores than those receiving less than GTR.[28] While Link et al reported on extent of resection, the effect of the need for retreatment on QOL was not evaluated.

Significantly, we found that when controlling for extent of resection and HB grade, retreatment was significantly associated with lower face domain and total PANQOL scores. Thus, we suggest that retreatment impacts QOL while extent of resection does not. This idea builds upon suggestions by Link et al that there is a psychological component to overall QOL outcomes among patients undergoing microsurgery, and there may be an interplay between preoperative expectations, patient perception of residual tumor, and requirement of retreatment influencing satisfaction and QOL despite functional outcomes.[28] Although Link et al demonstrated that extent of resection was positively associated with improved QOL, differences in study design may explain our varying results. Our present study consisted of a larger patient population (367 patients vs. 143 patients) and longer mean period between surgery and PANQOL survey (11.4 years vs. 7.7 years), which may elucidate trends in patient perception of importance of extent of resection on QOL over time.

The approach to VS resection remains variable among the neurosurgical and otolaryngologic communities. Some surgeons approach VS management with tumor debulking followed by planned stereotactic radiosurgery, and others plan for complete resection with willingness to sacrifice neurological function.[10] Our previous study looking specifically at surgical approach and PANQOL scores showed that patients who had the retrosigmoid approach have higher PANQOL scores than those who underwent the translabyrinthine approach.[29] The two senior authors (DEA and JPL) aim for GTR while recognizing that a small amount of residual tumor as a means of functional preservation is acceptable. Inclusion of various tumor sizes in this analysis highlights a potential difference in expectations between patients with small and large tumors; patients with larger tumors have a trend towards reporting improved PANQOL health and face scores, although these were not statistically significant. Reasonably, we agree with Link et al in their proposition that patients who elect to have microsurgery for VS less than 3 cm may be psychologically biased to expect to have their tumors completely removed, thus are less satisfied when discovering residual tumor was left.[27]

Limitations of this study include the retrospective nature of chart review, in addition to self-report bias on PANQOL. Additionally, this study was performed at a single center by one interdisciplinary team, which may limit generalizability. Our response rate was 52%, with a lower response rate in earlier years, which may contribute significant response bias, and was a notably lower response rate than other PANQOL studies.[15,28] Some patients included comments on their surveys indicating that they were unsure whether problems indicated by the survey were due to their VS or due to aging and other health conditions. Furthermore, due to the wide time range of this study, there were minor differences in reporting and data collection between patients with paper versus electronic medical records. It is also important to note that there have been advancements in technology, intraoperative monitoring, and surgical techniques over the time range of this study; however, there are numerous studies examining the effect of these advancements on the variables measured in our study, such as facial and hearing preservation and extent of resection. Therefore, one can draw obvious conclusions about the effect of these advancements on our results.

5. Conclusion

Our results demonstrate that patients who undergo surgical retreatment of VS following initial microsurgical intervention have lower patient reported QOL than those who do not. In contrast to previously reported studies, we found that extent of resection does not impact QOL. Additionally, poor HB grade and female sex were negatively associated with total PANQOL scores, while postoperative headache was negatively associated with anxiety, energy, pain, and health domain scores. These results suggest that technological advancements should continue to focus on maximizing facial and cochlear nerve preservation and minimizing the chances of reoperation and postoperative headache. Furthermore, stratification of HB grades revealed a significant decrease in PANQOL face domain scores between HB grade I, II, and III, suggesting that favorable facial function outcomes definitions should be revisited.

CRediT authorship contribution statement

Loren N. Riedy: Conceptualization, Data curation, Writing – original draft. **Rachyl M. Shanker:** Conceptualization, Writing – original draft. **Dayna C. Sloane:** Writing – review & editing. **Daniel M. Heiferman:** Conceptualization, Writing – review & editing. **Elhaum G. Rezaii:** Data curation, Writing – review & editing. **Sarah E. Finucane:** Data curation. **Perry Veras:** Data curation. **John P. Leonetti:** Supervision. **Douglas E. Anderson:** Conceptualization, Supervision.

Declaration of competing interest

The authors do not have any disclosures.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.wnsx.2024.100294.

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Abbreviation List

AIC: Akaike's Information Criterion
GR: Gardner-Robertson hearing scale
GTR: gross total resection
HB: House-Brackmann
IQR: interquartile range
PANQOL: Penn Acoustic Neuroma Quality of Life
PTA: pure tone average
QOL:: quality of life
VS: vestibular schwannoma