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A Model for Early Prediction of Facial Nerve Recovery After Vestibular Schwannoma Surgery

*Alejandro Rivas, *Kofi D. Boahene, †Héctor Corrada Bravo, *Marietta Tan, ‡Rafael J. Tamargo, and *Howard W. Francis

**Department of Otolaryngology – Head and Neck Surgery, †Department of Biostatistics, Bloomberg School of Public Health, and ‡Department of Neurosurgery, Johns Hopkins University, Baltimore, Maryland, U.S.A.*

Objective: To identify early predictors of long-term facial nerve function after vestibular schwannoma resection.
Study Design: Retrospective chart review.
Setting: Tertiary referral center.
Patients: Subjects with facial nerve weakness despite anatomic preservation of the nerve after removal of vestibular schwannoma.
Intervention: Surgical resection of vestibular schwannoma.
Main Outcome Measure: Facial function after 1 postoperative year. Independent variables included patient demographics, presenting symptoms, tumor size and location, and serial postoperative function within the first year.
Results: Among 281 patients with postoperative facial weakness, 81% improved to a House-Brackmann (HB) III or better (good outcome) after 12 months of recovery, whereas 12% remained HB IV or worse (poor outcome). For patients starting with HB V or VI function, recovery rate was the most reliable predictor of poor outcome after 1 year. The resulting predictive model using rate of functional improvement as the independent variable was found to anticipate poor outcome before 1 year in more than 50% of cases with 97% sensitivity and 97% specificity. Although associated with facial nerve outcome, tumor size, tumor vascularity, preoperative facial function, age at surgery, and ability to stimulate the nerve intraoperatively did not contribute significantly to the predictive model.
Conclusion: The rate of recovery within the first postoperative year serves as a useful early predictor of long-term facial nerve function. We present a novel predictive model using rate of recovery that can be used to select candidates for reanimation surgery sooner than the traditional waiting period of 1 year, potentially improving the outcome of this intervention.
Key Words: Acoustic neuroma—Cranial base—Facial nerve—Facial paralysis—Facial reanimation—Outcome—Prediction—Vestibular schwannoma.

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The goals of vestibular schwannoma (acoustic neuroma) surgery have changed during the last century. The focus on reducing surgical mortality during the first half of the 20th century has now shifted to minimizing cranial neuropathies, such as hearing loss and facial nerve (FN) deficits. The FN was invariably sacrificed during vestibular schwannoma resection until 1931, when Caims (1) reported the first functionally intact FN after surgery. With the introduction of the operating microscope in 1961 and intraoperative electrophysiological monitoring in 1979, rates of FN preservation improved dramatically (2). Rates of anatomic preservation are now routinely greater than 90% (3–5), with a rate of 97.5% at our institution (6). However, even with anatomic preservation of the nerve, functional deficits may still occur (5,6). Such deficits may have significant psychosocial effects and adversely affect patient-perceived quality of life. Many patients feel significantly affected by facial weakness and consider it one of the most difficult aspects of recovery (7,8).

In the absence of spontaneous recovery, patients have several options for FN reanimation, such as hypoglossal FN anastomosis. In recent studies, rates of success after hypoglossal FN anastomosis range from 65% to 78% of patients improving to a House-Brackmann (HB) Grade III or better (5,9–11). Reanimation procedures are typically indicated when spontaneous recovery fails to achieve functional recovery to HB III or better after a postoperative interval of 12 months. Early anastomosis, however, is thought to yield better results by limiting the degenerative effects of denervation (11–14) and by enhancing accelerated regeneration of motoneurons (15). Clinicians are therefore faced with the dilemma of

Address correspondence and reprint requests to Howard W. Francis, M.D., 601 N. Caroline St., JHOC 6223, Baltimore, MD 21287, U.S.A.; E-mail: hfrancis@jhmi.edu
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whether to wait for spontaneous recovery but risk increased degeneration and decreased success of the reanimation procedure or to proceed with early reanimation at the risk of harming a recovering nerve.

In this study, we review the patterns of FN recovery after vestibular schwannoma resection at the Johns Hopkins Hospital. We sought to identify predictors of FN outcome after resection of vestibular schwannoma in patients with anatomically intact FNs. We also sought to evaluate the accuracy with which a clinical decision model using these predictors could guide reanimation surgery sooner than the current standard of 12 months. We hypothesized that a poor functional outcome after 12 months can be predicted several months earlier by the initial postoperative function, tumor size, and the rate of functional recovery.

MATERIALS AND METHODS

A retrospective chart review of patients who developed FN weakness, despite anatomic preservation of the nerve during surgical resection of vestibular schwannoma at the Johns Hopkins Hospital between 1997 and 2007, was conducted. This study was approved by the institutional review board, and established international research codes of ethics were observed (16).

Medical records were reviewed for extraction of demographic information, presenting symptoms and preexisting medical comorbidities. Magnetic resonance imaging (MRI) reports were evaluated for tumor size and location. Operative reports were reviewed for tumor, dissection, and stimulation characteristics.

Facial nerve function was assessed and documented using the HB grading system (17). Facial nerve function was evaluated in the preoperative period, immediately after surgery, and at subsequent intervals of 2 to 6 months, 6 to 12 months, and more than 12 months. Patients were included in the study if they had HB Grade II to VI immediately after surgery. Exclusion criteria included nerve of origin other than the vestibular nerve or pathologic finding other than schwannoma neurofibromatosis Type II, previous surgical history or radiation treatment of the tumor, or normal postoperative FN function.

The major study outcome was facial function after 12 postoperative months. This outcome was categorized as ''good'' for HB Grades I, II, and III and ''poor'' for HB Grades IV, V, and VI. A poor outcome with HB Grade V or VI at 1 year was considered an indication for surgical reanimation surgery.

Statistical comparisons were made using a χ^2 statistic, multivariate logistic regression, unpaired *t* test, and Wilcoxon rank-sum test. Statistical significance was accepted at $p < 0.05$. A linear logistic regression model was used to measure the dependence of functional outcome on tumor size. The rate of functional recovery was determined for subjects with initial postoperative HB Grades V and VI. A cross-validation procedure was used to test the accuracy of a predictive model based on FN rate of recovery (see Text, Supplemental Digital Content 1, Additional Materials and Methods, available at http://links.lww.com/MAO/A63).

RESULTS

Subject Characteristics

Two hundred eighty-one patients, who developed varying degrees of FN weakness after vestibular schwannoma resection, were included in this study. In all cases, anatomic integrity of the FN was preserved. As presented in Table 1, the study cohort had equal sex distribution and an age range of 10 to 82 years (mean, 50.1 yr). Tumor size, measured as the largest dimension on preoperative gadolinium-enhanced T1-weighted MR images, ranged from 3 to 65 mm (mean, 24 mm; median, 21 mm). Two hundred and sixty-five (94%) subjects underwent resection via the retrosigmoid approach, whereas 11 (4%) and 5 (2%) had translabyrinthine and middle fossa procedures, respectively. At a mean postoperative period of 0.8 months, 145 patients were documented to have FN weakness with HB Grade II or III, whereas 130 patients had a higher degree of weakness, of which 21% had HB VI (Table 1). Surgical approach (retrosigmoid versus other approaches) had no effect on early FN outcomes ($\chi^2 = 4.3$, $p > 0.05$).

Patterns of FN Recovery

After a year of recovery, functional grade recorded at a mean postresection interval of 17.8 months was HB Grade I to III (good) for 227 subjects (81%), HB Grade IV to VI (poor) for 35 subjects (12%) (Table 2). The incidence of poor outcome was further halved after 2 years of recovery, resulting in an overall incidence of 7% between 1997 and 2007. There was no effect of surgical approach on FN outcomes at 1 or 2 years after tumor resection.

TABLE 1. *Subject baseline characteristics*

Age at surgery, n (%), yr	
10–20	2 (0.7)
20–30	10 (3.6)
30–40	41 (14.6)
40–50	78 (27.8)
50–60	94 (33.4)
60–70	44 (15.7)
70–80	11 (3.9)
80–90	1 (0.4)
Mean (SD)	50 (11.7)
Sex, n (%)	
Male	143 (51)
Female	138 (49)
Surgical approach, n (%)	
Suboccipital	265 (94)
Translabyrinthine	11 (4)
Middle fossa	5 (2)
Tumor size by MRI, n (%), mm	
<10	18 (7)
11–20	81 (30)
21–30	84 (31)
31–40	49 (18)
41–50	29 (11)
51–60	6 (2)
61–70	2 (0.7)
Mean (SD)	24 (11.4)
Initial postoperative HB score (0–2 mo), n (%)	
II	89 (32)
III	56 (20)
IV	33 (12)
V	39 (14)
VI	58 (21)
Unknown	6 (2)
Mean postoperative time (SD), mo	0.8 (0.5)

TABLE 2. *Facial nerve recovery as a function of postoperative time*

Outcome	6 mo postoperatively, n (%)	12 mo postoperatively, n (%)	>24 mo postoperatively, n (%)
Good (HB I–III)	192 (68)	227 (81)	235 (84)
Poor (HB IV–VI)	89 (32)	35 (12)	19 (7)
Unknown	0 (0)	19 (7)	27 (10)

The extent and speed of functional recovery were related to the initial HB grade (Figs. 1 and 2). Ninety percent of subjects starting with an HB Grade II, for example, improved to a Grade I within a mean interval of 9 months and all were fully recovered by 19 months. Among patients who started with an initial postoperative Grade III, 74% improved to a Grade I, 24% to a Grade II, and 2% maintained their original function at a mean time interval of 17.5 months. At a mean time interval of 39 months, all patients with initial HB Grade III improved to HB Grade II or better, and 36%, 52%, and 12% of patients with initial HB Grade IV recovered to HB Grades I, II, and III, respectively. It is therefore evident that an initial postoperative HB Grade IV or better is a favorable predictor of complete or near complete functional recovery.

Slower and incomplete recovery, however, was more likely among patients with initial postoperative FN function of HB Grade V or VI. Whereas 79% of patients with an initial HB Grade V improved to HB Grade III or better within a mean time interval of 15.7 months, this was only true for 54% of patients with initial HB Grade VI. Large differences in the increments of functional improvement ($p < 0.05$) were evident between subjects with good versus poor function in the early postoperative period (Fig. 2). Rate of recovery was therefore examined for its ability to predict 12 to 24 months of FN outcomes at earlier time points.

Predictors of Recovery

Whereas some tumor- and patient-specific variables were associated with FN outcome for subjects with initial

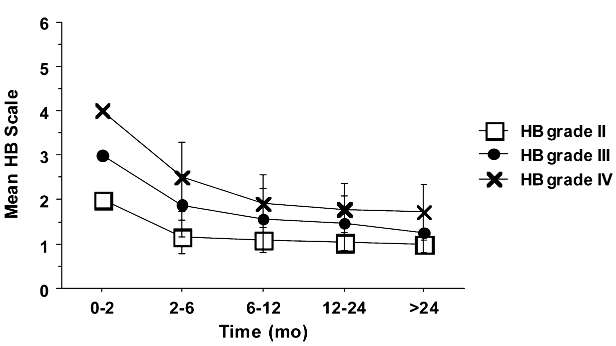

FIG. 1. Mean recovery of FN function for patients with initial HB Grades II to IV. Notice that all patients improve to an HB Grade II or better by a mean time of 8.5 months (mo).

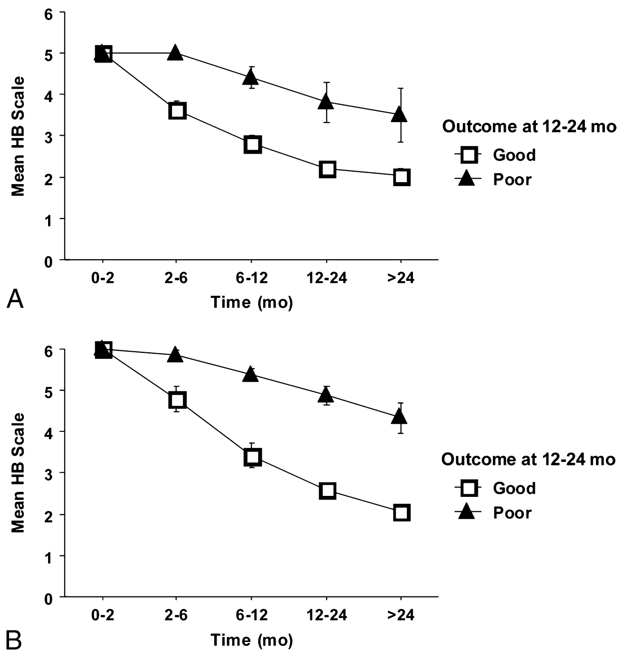

FIG. 2. Mean recovery of FN function for patients with initial HB V (*A*) and HB VI (*B*). There is a statistically significant difference (Wilcoxon rank-sum test, $p < 0.01$) in time course between patients with good (HB I–III) and poor (HB IV–VI) outcomes as determined at 12 to 24 months after tumor resection.

HB Grades V and VI, recovery rate was found to be the most reliable predictor of poor outcome.

Recovery Rate

To determine how quickly HB measurements improve after operation, we used 190 observations for 54 patients with initial HB Grades V and VI. We eliminated 1 patient each who underwent translabyrinthine and middle fossa approaches, limiting this analysis to patients for whom the retrosigmoid approach was used, to remove any variability imposed by surgical approach. We found a significant difference in the mean rate of recovery for the 2 outcome groups (Wilcoxon rank-sum test, $p = 1.62e^{-07}$). In general, subjects with poor outcome show a slower rate of recovery than subjects with good outcome when examined for up to 15 postoperative months (Fig. 3). When using a linear logistic regression model of outcome to determine the probability (p_i) of a poor outcome for a given subject (i), we can ask questions such as the following: *If the first HB measurement after operation is VI, how quickly must a measurement of V be seen so that the probability of a poor outcome is less than 80%.* Figure 4 can be used to answer this question. The upper curve corresponds to subjects that start with HB Grade VI, and plots the probability of a poor outcome as a function of the time until HB Grade V is observed. Improvement to HB Grade V after 7 months renders the probability of a poor outcome approximately 90%. The lowest line refers to recovery from HB Grade VI to IV. We see that an HB Grade IV any time before 10 months makes a poor outcome very

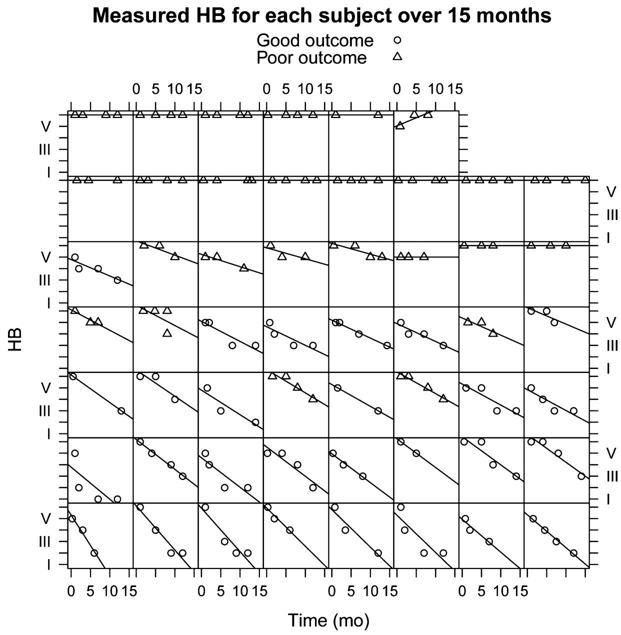

FIG. 3. Time trend of HB measurements in retrosigmoid cases. Each subject's functional grade is plotted in its own panel. Outcome at 12 to 24 months is defined as good (HB I–III) or poor (HB IV–VI) and is indicated by a *circle* or a *triangle*, respectively. The *line* is the least squares linear estimate of HB as a function of measurement time. The *slope* of this linear estimate is the rate of recovery. The *panels* are sorted by decreasing rate of recovery. Notice that, in general, subjects with poor outcome show a slower rate of recovery than those with good outcome.

unlikely. The middle line corresponds to recovery from an initial HB Grade V to an HB Grade IV. Note that unless the rate of recovery is enough so that an HB Grade IV is observed by 10 months, the probability of a poor outcome is greater than 80%.

Evaluation of Predictive Model On the Basis of Recovery Rate

In general, the model presented in Figure 4 can be used to determine cases where the probability of a poor outcome is high, based on functional assessments made earlier than the standard 12 months. To test the accuracy of this model in predicting patient outcome, using their FN rate of recovery, we performed a cross-validation procedure (see Materials and Methods). We tested the rate-of-recovery model under 3 prediction regimens: (*a*) using all HB measurements made up to 15 months postoperatively, (*b*) using HB measurements made up to 12 months postoperatively, and (*c*) using an adaptive strategy where functional assessments made after 6 months are used only up to the point where the probability of poor outcome is higher than 80%, based on the rate-of-recovery model. The adaptive strategy was evaluated as a clinical approach that may provide an early opportunity for intervention before the traditional 1-year waiting period. We show the resulting receiver operating characteristic curves and their area under the curve in Figure 5. When we use all of the measurements available for each subject to predict their outcome (regimen a), we see that this model is extremely accurate. If we use measurements made before 12 months to predict a subject's outcome (regimen b), we see that predictive performance drops significantly. This means that the standard use of recovery assessments made before 12 months is an inaccurate strategy for the prediction of longer-term FN function. By comparison, the adaptive strategy (regimen c), where measurements made 6 months or later are used up to the time where the model gives an 80% probability of a poor outcome, is very accurate—giving almost the same predictive performance as when all measurements are used (regimen a). Only 1 false positive was detected using the adaptive strategy. Importantly, for some cases, an accurate prediction of functional outcome between 12 and 24 months could be made sooner, ranging from 1 to 5 months earlier than the typical 12-month waiting period. Using the adaptive predictive strategy with a probability threshold of 80%, 14 of the 26 subjects accurately predicted to have a poor outcome were detected using functional assessments made between 6 and 12 months after tumor resection.

In summary, using an adaptive strategy at a probability threshold of 80%, the rate-of-recovery model depicted in Figure 4 can accurately predict poor outcome in patients with initial HB Grades V and VI as a function of rate of improvement. This prediction can be made with 97%

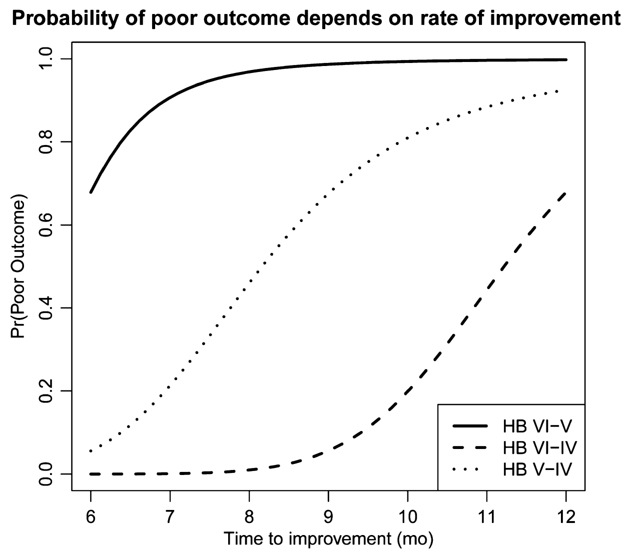

FIG. 4. Predictive model for functional outcome in patients with initial postoperative scores of HB Grades V and VI based on rate of recovery. The analysis is limited to retrosigmoid cases. Using an adaptive strategy, this model provides the probability of poor outcome as a function of time to an improved HB grade. The top curve (*solid*) corresponds to subjects that have an initial HB Grade VI and plots the probability of a poor outcome as a function of the time to an improved measurement of HB Grade V. The *dashed line* is similar, but plots probability of a poor outcome as a function of time to an improved measurement of HB Grade IV. The *dotted line* assumes an initial measurement of HB Grade V and an improved measurement of HB Grade IV.

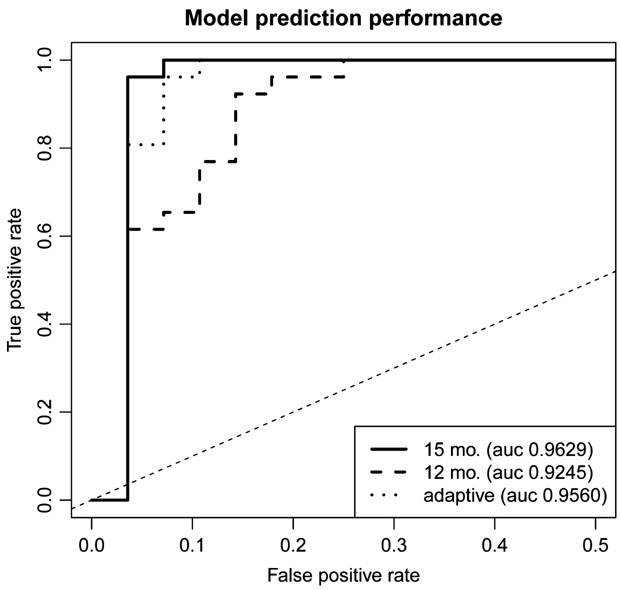

FIG. 5. Accuracy curve of the adaptive strategy model for patients with initial HB Grades V and VI whose tumors were resected using the retrosigmoid approach. The *solid line* uses all of the measurements available for each subject to predict their outcome. This model is extremely accurate reflecting a strong correlation between the rate-of-recovery and outcome. The *dashed line* uses measurements made up to 12 months to predict a subject's outcome. Note that predictive performance drops significantly, suggesting that a prediction before 12 months is not a good strategy when applied to all subjects. The *dotted line* is the adaptive strategy in which functional assessments are made serially after 6 months up to the time where the model gives an 80% probability of a poor outcome. This strategy gives almost the same predictive performance as the strategy using a full complement of assessments presented in the first model. AUC indicates area under the curve.

sensitivity and 97% specificity, as determined by the axes of the receiver operating characteristic curves (sensitivity versus 1 − specificity; Fig. 5). In some cases, this model can accurately predict functional outcome as much as 5 months sooner than the standard 12-month postoperative interval.

Tumor Characteristics

Surgical report of tumor consistency or its adherence to the FN was not correlated to FN outcome 12 months postoperatively. Thirty-three patients (12%) had tumors that subjectively seemed to have increased vascularity and large-caliber blood supply. Significant tumor vascularity was predictive of poor FN function ($\chi^2 = 5.1$, $p < 0.05$). However, tumor size may be linked to FN outcomes because vascular tumors were larger on average (32.0 mm; SD, 9.0) than those that were not (22.7 mm; SD, 11.3; Mann-Whitney, $p < 0.0001$). Taking size into consideration, increased vascularity had no significant relationship to functional outcome ($\chi^2 = 0.6$, $p > 0.05$).

Tumor size, measured as the largest diameter on preoperative MRI, was significantly correlated to FN outcome after 12 months of recovery. Patients with poor facial function at 12 months after surgery had larger tumors on average (34.1 mm; SD, 11.7) than those with good outcomes (21.6 mm; SD, 10.2; Wilcoxon rank-sum test, $p < 0.01$) (Fig. 6). All but 2 patients with poor outcome had tumors larger than 2 cm. The maximum likelihood estimate of the tumor size effect β_1 was 1.0987, meaning that the odds of a poor outcome roughly doubles for each increase in tumor size of 1 SD (SD = 11.443 mm). The effect is statistically significant with a p value of $1.1411e^{-07}$. The effect of size on FN outcome is slightly greater when only retrosigmoid cases are analyzed ($\beta_1 = 1.1886$; SD = 11.253 mm; $p = 7.7558e^{-08}$). Figure 7 plots the fitted mean probability curve of poor outcome as a function of tumor size in retrosigmoid cases, along with 1 SE curve; the negative effect of tumor growth on FN outcome increases as tumor diameter exceeds 2 cm.

A small group of patients (17%) had tumors confined to the internal auditory canal (IAC), whereas the rest involved both the cerebellopontine angle (CPA) and the IAC. A strong association between intracanalicular tumors and good FN prognosis was found (Wilcoxon rank-sum test, $p < 0.01$). Only 1 patient (2%) of those with tumors confined to the IAC and immediate postoperative weakness had a poor long-term outcome compared with 15% with tumors extending into the CPA. None of the 34 intracanalicular tumors removed using the retrosigmoid approach had a poor outcome, whereas 15.6% extending to the CPA did.

Adding size to the rate-of-recovery model did not improve the predictive accuracy of the adaptive strategy or its ability to predict the outcome earlier. However, we found indications that the study of a larger sample size may make this possible in the future.

Electromyographic Characteristics

Electromyographic FN stimulus amplitudes measured at the brainstem after tumor resection were absent in 23 patients (9%). Lack of stimulation had a strong correlation with poor FN functional outcome ($\chi^2 = 19.7$,

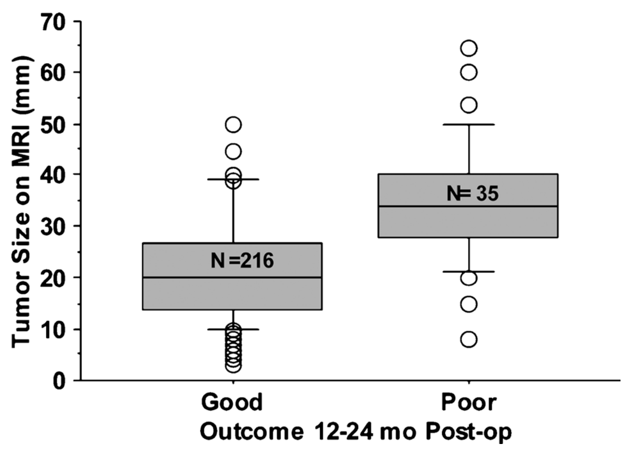

FIG. 6. Tumor size is correlated to the outcome of FN recovery. Patients with poor FN outcomes 12 months after surgery had bigger tumors compared with patients with better outcomes.

$p < 0.05$). However, when present, the nerve stimulation threshold failed to correlate with facial nerve function ($p > 0.05$). When limited to retrosigmoid cases, a stronger correlation between 1-year outcome and the presence or absence of stimulation ($\chi^2 = 29.8$, $p < 0.0001$) was found, and an association between stimulation threshold and outcome approached statistical significance (Table 3).

Patient Characteristics

When taking tumor size and surgical approach into consideration, covariate analysis revealed a trend toward worse FN outcome after 12 months in older patients (age, $\chi^2 = 3.6$, $p = 0.06$; tumor size, $\chi^2 = 31.0$, $p < 0.0001$). Presenting symptoms in order of frequency included hearing loss (95%), tinnitus (73%), dizziness (37%), facial dysesthesia (29%), fasciculations (17%), facial weakness (7%), and other cranial nerve deficits (1%). Preoperative facial weakness was associated with worse FN functional prognosis ($\chi^2 = 4.2$, $p < 0.05$), whereas other symptoms did not predict FN outcome. The most prevalent comorbidities including hypertension (21%), hypothyroidism (6%), diabetes (5%), coronary heart disease (4%), and cerebrovascular disease (4%) were not found to be predictors of postoperative facial function.

DISCUSSION

This study provides strong evidence that candidacy for facial reanimation surgery after vestibular schwannoma resection need not always rely on the 1-year functional

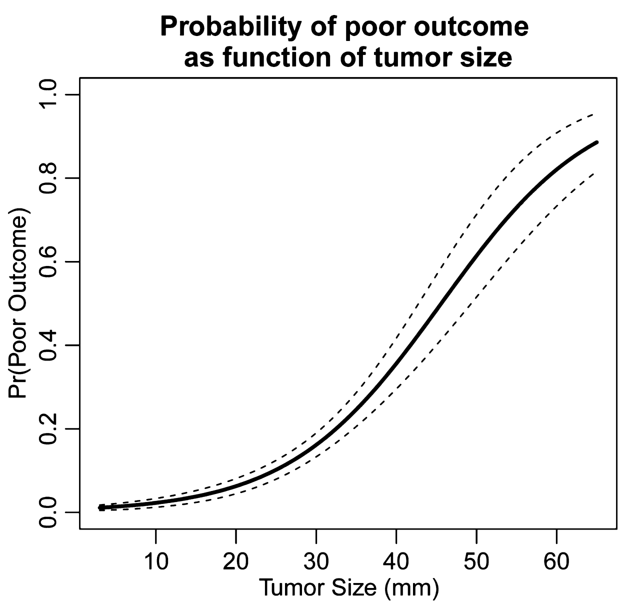

FIG. 7. Probability of poor outcome as function of tumor size in retrosigmoid cases. This curve plots the fitted mean probability of poor outcome as a function of tumor size, along with 1 SE curve. The odds of a poor outcome increase by a factor of 2.2 for each increase in tumor size of 1 SD (11.3 mm). Incremental growth poses an increasing threat to FN outcome after surgery for tumors larger than 2 cm. Pr indicates probability.

TABLE 3. *Results of proximal FN stimulation in retrosigmoid cases relative to 1-year FN outcomes*

	Good outcome	Poor outcome
Postresection FN stimulation at brainstem, n (%)		
Present	190 (92)	16 (8)
Absent	9 (50)	9 (50)
FN stimulus threshold, mA		
0.1	60	1
0.2	24	1
0.3	3	1
0.4	1	1
≥0.5	2	0
Mean (SD)[a]	0.15 (0.12)	0.25 (0.13)

[a]Mann-Whitney, $p = 0.08$.

outcome. Rate of recovery during that time is a predictor of outcome beyond 1 year. The resulting functional recovery model (Fig. 4) may predict poor recovery with high certainty months earlier than the traditional 1-year endpoint. Early selection of candidates for facial reanimation surgery has significant implications for long-term functional results because anastomosis sooner than 12 months is thought to enhance and accelerate regeneration of motoneurons (15).

An adaptive strategy is required for early candidate selection using the recovery model. At a probability threshold of 80%, the recovery curve in Figure 4 is selected, based on the baseline postoperative HB grade, and facial function is reevaluated and plotted at 1- to 2-month intervals starting at 6 months. Failure of HB Grade VI to improve to V by 6 months, for example, should prompt a reevaluation in 1 month. Persistent HB VI is associated with a greater-than 80% chance of poor long-term function, suggesting that early reanimation surgery may be indicated. Initial functional HB Grade V, by comparison, would prompt early surgical intervention if there was no improvement to Grade IV by approximately 10 months. When used with an adaptive strategy, our recovery model predicts poor outcome in patients with initial HB Grades V and VI with 97% sensitivity and 97% specificity. This approach predicted functional outcome as soon as 7 months after surgery in more than 50% of patients whose tumors were removed via a retrosigmoid approach.

Although there are associations of long-term FN recovery, none have provided sufficient accuracy to be trustworthy in selecting candidates for early reanimation surgery. Multiple studies have suggested that immediate FN function is a reliable predictor of facial function (18–20). Although prognosis is favorable for cases with initial HB IV or better, recovery of patients presenting with early HB V-VI is likely to be poor and difficult to predict. Isaacson et al. created a mathematical model using the amplitude ratio of proximal-to-distal evoked FN potentials and stimulus thresholds measured during intraoperative monitoring to predict FN recovery. Despite a favorable positive predictive value of 95%, this approach resulted in a negative predictive value of 67% (20). Others have shown that a response of 240 μV or greater using an electromyographic stimulus threshold of 0.05 mA or less can predict an HB Grade I or II outcome with a 98% probability; however, Grade III to VI patients also met this standard, which gives false-positive results (21). We observed that the lack of stimulation had a strong correlation with poor functional outcome and the response threshold was much less predictive.

Our results are also consistent with reports that tumor size is a strong predictor of poor FN outcome (6,20,22–24), particularly for tumors larger than 2.5 cm. We have found in our study cohort that the odds of a poor functional outcome was more than doubled for each 11-mm increase in the diameter of tumors removed using the retrosigmoid approach (Fig. 7). However, the predictive value of tumor size measured in this study did not contribute significantly to the rate of functional recovery and was therefore not included in our predictive model. Nevertheless, these trends are worth considering when weighing the pros and cons of monitoring a tumor by serial imaging. Although growth increments are likely to have a small effect on FN prognosis for tumors smaller than 2 cm in diameter, the risk rapidly increases for larger tumors.

The strong relationship between tumor size and vascularity in our study raises the possibility that other factors, in addition to mass effect, may contribute to poor nerve recovery after tumor dissection. Anecdotal reports of factors contributing to challenging dissections have included vascularity and tumor adherence, whereas better results have been achieved in moderately firm and avascular tumors (25). Likewise, in tumors resected after stereotactic radiation, worse FN prognosis and longer operative time (26,27) are associated with extensive fibrosis adjacent to the FN and increased vascularity. Shamji et al. (28) noticed a slight correlation between tumor adherence and FN outcomes. The ability to score tumor adherence and vascularity may increase the predictive power of tumor size for long-term functional recovery, although variations in surgeon technique may confound its clinical usefulness.

There was a strong trend toward worse FN outcome in older patients when tumor size and surgical approach were taken into consideration. Its relative contribution to FN outcome is small, however, compared with the rate of functional recovery. Other studies have described opposing results regarding age as a predictive factor of FN outcome (29,30); however, none have taken tumor size into account. Although not included in the rate-of-recovery predictive model, older age and larger tumor size may increase one's confidence in an early prediction of poor outcome.

There are limitations related to the retrospective nature of the study design. There could also be variability in the dimension selected for the measurement of tumor size and in the method used. Tumor volume estimation would be desirable because it has been shown to be a strong predictor of functional outcomes (29) and a more sensitive measure of tumor growth (31). Inaccuracies associated with the retrospective nature of the study are likely to be random in nature. The predominance of the retrosigmoid approach in this cohort may limit the relevance of findings in this study for patients who undergo the middle fossa or translabyrinthine approaches. Diverse mechanisms of FN injury between these approaches require further study of FN recovery in other surgical cohorts.

In the present study, the approximate incidence of poor outcome (HB Grades IV, V, and VI) 2 years after resection of unilateral vestibular schwannoma, between 1997 and 2007, was 7%. This is similar to that described in the world literature, which varies between 4% and 41% (29,32–34). The apparent increase in institutional prevalence of HB Grades V to VI outcome, from 1.3% between 1973 and 1994 (6) to 3.9% between 1997 and 2007, is a reflection of changing practice trends in our group, where smaller tumors are now likely to be either monitored conservatively or treated radiosurgically, and thus, surgically resected tumors are now likely to be larger (35,36).

CONCLUSION

The rate of recovery of facial function within the first postoperative year after vestibular schwannoma resection serves as a useful early predictor of long-term FN function. A resulting functional recovery model may serve as a valuable tool with which poor recovery can be predicted with 97% sensitivity and 97% specificity. This adaptive approach can be used to select candidates for reanimation surgery as much as 5 months earlier than the standard 12-month postoperative interval, potentially improving the outcome of this intervention.

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