Surgery versus radiosurgery for facial nerve schwannoma: a systematic review and meta-analysis of facial nerve function, postoperative complications, and progression

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OBJECTIVE Intracranial facial nerve schwannomas (FNS) requiring treatment are frequently recommended for surgery or stereotactic radiosurgery (SRS). The objective of this study was to compare facial nerve function outcomes between these two interventions for FNS via a systematic review and meta-analysis.

METHODS A search of the Ovid EMBASE, PubMed, SCOPUS, and Cochrane databases from inception to July 2019 was conducted following PRISMA guidelines. Articles were screened against prespecified criteria. Facial nerve outcomes were classified as improved, stabilized, or worsened by last follow-up. Incidence was pooled by random-effects meta-analysis of proportions.

RESULTS Thirty-three articles with a pooled cohort of 519 patients with FNS satisfied all criteria. Twenty-five articles described operative outcomes in 407 (78%) patients; 10 articles reported SRS outcomes in 112 (22%). In the surgical cohort, facial nerve function improved in 23% (95% CI 15%–32%), stabilized in 41% (95% CI 32%–50%), and worsened in 30% (95% CI 21%–40%). In the SRS cohort, facial nerve function was improved in 20% (95% CI 9%–34%), stable in 66% (95% CI 54%–78%), and worsened in 9% (95% CI 3%–16%). Compared with SRS, microsurgery was associated with a significantly lower incidence of stable facial nerve function ($p < 0.01$) and a significantly higher incidence of worsened facial nerve function ($p < 0.01$). Tumor progression and complication rates were comparable. Outcome certainty assessments were very low to moderate for all parameters.

CONCLUSIONS Unfavorable facial nerve function outcomes are associated with surgical treatment of intracranial FNS, whereas stable facial nerve function outcomes are associated with SRS. Therefore, SRS should be recommended to patients with FNS who require treatment, and surgery should be reserved for patients with another indication, such as decompression of the brainstem. Further study is required to definitively optimize and validate management strategies for these rare skull base tumors.

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KEYWORDS facial nerve schwannoma; seventh cranial nerve; surgery; resection; stripping; stereotactic radiosurgery; Gamma Knife; skull base

INTRACRANIAL facial nerve schwannomas (FNS) are slow-growing, rare, benign tumors that arise from the myelin-producing Schwann cells of the facial nerve (cranial nerve [CN] VII). Although common presenting symptoms include asymmetrical hearing loss and facial weakness, patients with cerebellopontine angle FNS also frequently present with hemifacial spasm, headache, mass effect, hydrocephalus, or nonspecific symptoms.^{1–3}

Given their slow rate of growth and increased potential for treatment morbidity as compared with vestibular schwannomas (VSs), FNS are often observed initially, with

treatment reserved for tumors demonstrating progressive growth or worsening symptoms.^{1,4} Although resection was the historical standard of care, over the past 3 decades stereotactic radiosurgery (SRS) has been established as a safe and effective alternative treatment, which offers excellent tumor control and very low risk of treatment-associated facial nerve morbidity.^{5–7} Although numerous studies have compared surgery and SRS for FNS, the contemporary standard of care for tumors with an indication for treatment remains controversial. Correspondingly, this study compared outcomes of patients with FNS who underwent

ABBREVIATIONS CN = cranial nerve; ES = effect size; FNS = facial nerve schwannomas; GRADE = Grading of Recommendations, Assessment, Development and Evaluations; HB = House-Brackmann; PICOS = Population, Intervention, Comparator, Outcome, Study type; SRS = stereotactic radiosurgery; VS = vestibular schwannoma.

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the reported surgical strategies for this tumor, including surgical removal with grafting, surgical removal without grafting, and canal decompression, with those treated with Gamma Knife SRS. To the best of our knowledge, this represents the first systematic review and meta-analysis of observational studies reporting facial nerve outcomes after either surgery or SRS treatment of intracranial FNS, and we conducted it in order to better inform future treatment decision-making and patient counseling when discussing surgery and SRS as treatment options.

Methods

Search Strategy

The search strategy was designed using the PICOS format: among patients with intracranial FNS (Population) treated with surgery (Intervention) compared with SRS (Comparator), what are the postoperative facial nerve function outcomes (Outcome), based on observational studies (Study type)? The literature review was conducted according to the PRISMA guidelines and recommendations.⁸ Electronic searches were performed using the Ovid EMBASE, PubMed, SCOPUS, and Cochrane databases from inception to July 2019 (Appendix). The literature was searched independently by two investigators (J.R., V.M.L.) using the following string of terms: (facial schwannoma) OR (facial nerve schwannoma) OR (facial neuroma) OR (facial nerve neuroma) AND (surgery OR radiosurgery OR SRS).

Selection Criteria

The included articles reported patients with the following characteristics: 1) diagnosed with intracranial FNS and verified based on neuroanatomical location; 2) undergoing primary treatment via surgery or SRS; 3) with postoperative facial nerve function reported; and 4) aged > 18 years. Studies inclusive of both sporadic and syndromic patients without parsed data were excluded. All surgical approaches, including gross-total resection or partial decompression with or without nerve graft, were considered eligible for inclusion, and SRS by Gamma Knife therapy was the only SRS modality considered. Exclusion criteria were as follows: 1) schwannomas arising from other cranial nerves; 2) lesions arising in the setting of neurofibromatosis type 2 or other genetic tumor syndromes; 3) extracranial lesions including parotid locations; and 4) publications reporting on < 3 patients, to reduce the risk of selection bias. For institutions publishing serial overlapping cohorts, only the most complete reports were included for quantitative assessment at each time interval. Publications were limited to those written in the English language.

Data and Extraction

Outcomes were abstracted directly from article texts, tables, and figures independently by two investigators (J.R., V.M.L.). The primary endpoint was facial nerve function as measured by changes in House-Brackmann (HB) grade from time of treatment to last follow-up, using a 3-tier Likert scale (e.g., facial nerve function was improved, unchanged, worsened). Secondary endpoints

included postoperative complications and tumor progression, when reported. Postoperative complications were defined as adverse events that occurred as a result of surgical or radiosurgical intervention. Tumor progression was defined as radiographic or symptomatic evidence of residual growth or new recurrence.

Meta-Analysis

The incidence rate was the primary summary statistics of this study. Incidence was calculated with initial variance by Fisher's exact test for binomial data and then transformed by Freeman-Tukey transformation to stabilize the variances.⁹ All statistics were pooled by meta-analysis of proportions in which the random-effects model described by DerSimonian and Laird¹⁰ was used to provide the overall incidence statistic. Data are presented as forest plots, where the effect size (ES) of incidence, its 95% confidence interval (CI), and the relative weightings are represented by the middle of the square, the horizontal line, and the relative size of the square, respectively. Pooled incidence estimates of each functional outcome category were calculated independently and were therefore not necessarily expected to sum to a total of 100%. A random-effects meta-regression using aggregate-level data was used to identify possible trends across the meta-analysis results by time of study publication. Heterogeneity was assessed using I^2 for random-effects modeling, with values > 50% indicating substantial heterogeneity.¹¹ Meta-analytical data were presented as forest plots. All p values were two-sided, and significance was defined using the alpha threshold 0.05. All statistical analyses were conducted with Stata 14.1 (StataCorp).

Quality and Bias Assessment

The certainty of each outcome was evaluated using the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) criteria and presented as a summary of findings to identify the certainty of all pooled outcomes.¹² The quality of evidence for each study was then evaluated using a modified Newcastle-Ottawa Scale (NOS)¹³ for assessment of single-arm cohort studies.¹⁴ Overall methodological quality was then summarized based on the quality trends observed. In terms of bias for each outcome, when there were ≥ 10 studies, publication bias was assessed using funnel plots, and small-study biases were evaluated using Egger's linear regression test and Begg's correlation test.^{15,16}

Results

Search Strategy

The initial search identified 563 references, representing 317 unique studies (Fig. 1). Screening against all selection criteria yielded 74 candidate studies, which underwent full-text analysis. Overall, 33 surgical^{1,4,17–37} and radiosurgical^{1,5–7,19,38–42} studies satisfied inclusion criteria into this study.

Demographics and Clinical Features

Facial nerve outcomes were reported for 519 patients

FIG. 1. Results of the PRISMA search strategy. Figure is available in color online only.

with FNS, for whom surgery was the primary treatment in 407 (78%) versus SRS in 112 (22%) (Table 1).

In the surgical cohorts, the median proportion of females was 55% (range 33%–100%), the median age was 42 years (range 34–63 years), and the median follow-up was 49 months (range 6–122 months) (Table 1). Attempted gross-total resection of the lesion was the most common surgical strategy for FNS (23 studies), whereas other reports included biopsy, decompression, stripping, and nerve root sleeve resection (Table 2). The most common nerves for grafting were the greater auricular and sural nerves, reported in 18 and 17 studies, respectively, with infrequently described graft donor nerves including the hypoglossal and occipital major. The most common coaptation was CN VII–CN XII ($n = 11$ studies), with other reported procedures including CN VII–CN VII and CN VII–CN XI.

In the SRS cohorts, the median proportion of females was 64% (range 33%–79%), the median age was 39 years (range 35–50 years), and the median follow-up was 45 months (range 12–81 months) (Table 1).

Facial Nerve Function

Based on 24 studies, facial nerve function improved following surgical intervention in 23% (95% CI 15%–32%, $I^2 = 71\%$; P-heterogeneity < 0.01); stabilized in 41% (95% CI 32%–50%, $I^2 = 61\%$; P-heterogeneity < 0.01); and worsened in 30% (95% CI 21%–40%, $I^2 = 70\%$; P-heterogeneity < 0.01) (Fig. 2). In surgical patients with improved postoperative facial nerve function, 73 (74%) had active

facial reanimation during their tumor resection. Based on 10 studies, following SRS intervention facial nerve function improved in 20% (95% CI 9%–34%, $I^2 = 44\%$; P-heterogeneity = 0.07); stabilized in 66% (95% CI 54%–78%, $I^2 = 23\%$; P-heterogeneity = 0.23); and worsened in 9% (95% CI 3%–16%, $I^2 = 0\%$; P-heterogeneity = 0.79) (Fig. 3). Overall, SRS resulted in statistically greater incidence of stable posttreatment facial nerve function (P-interaction < 0.01) and a statistically lower incidence of worsened function (P-interaction < 0.01) compared with resection. There was no statistical difference in improved function incidences between interventions (P-interaction = 0.87).

Postoperative Complications

Surgical complications were reported by 10 studies, with an overall incidence of 7% (95% CI 1%–15%, $I^2 = 48\%$; P-heterogeneity = 0.05), as compared with 4% (95% CI 0%–12%, $I^2 = 0\%$; P-heterogeneity = 0.43) in 4 studies reporting SRS outcomes (Fig. 4). There was no statistical difference in postoperative complication incidences between interventions (P-interaction = 0.65).

Progression

Posttreatment disease progression was reported in 19 operative studies at an incidence of 2% (95% CI 0%–5%, $I^2 = 10\%$; P-heterogeneity = 0.33), and in 8 SRS studies at an incidence of 3% (95% CI 0%–11%, $I^2 = 39\%$; P-heterogeneity = 0.12) (Fig. 5). There was no statistical difference in progression incidences between interventions (P-interaction = 0.58).

TABLE 1. Design and demographic characteristics of included studies

Authors & Year	Country	Study Period	Design*	Cohort†			Mean Follow-Up (mos)
				Size (no.)	Females (%)	Mean Age (yrs)	
Surgery treatment							
Bacciu et al., 2014 ¹⁷	Italy	1991–2012	R OCS (3)	23	65	45	18
Carlson et al., 2016 ¹	US	1990–2015	R OCS (1)	34	NR	45	50
Chung et al., 2004 ¹⁸	Korea	1993–2001	R OCS (1)	8	75	42	39
Doshi et al., 2015 ¹⁹	UK	1994–2013	R OCS (1)	16	NR	43	NR
Eshraghi et al., 2019 ²	US	1996–2017	R OCS (2)	27	NR	NR	NR
Günther et al., 2010 ²⁰	Sweden	1971–2006	R OCS (1)	26	50	36	122
Kim & Suh, 2007 ²¹	Korea	1982–2006	R OCS (1)	25	72	36	76
Kohmura et al., 2007 ²²	Japan	1988–2004	R OCS (1)	6	33	52	NR
Lahlou et al., 2016 ²³	France	1988–2013	R OCS (1)	19	NR	NR	50
Lee et al., 2007 ²⁴	Korea	1996–2005	R OCS (1)	6	33	34	53
Li & Dai, 2017 ²⁵	China	1988–2008	R OCS (1)	15	53	34	84
Liu & Fagan, 2001 ²⁶	Australia	1982–2000	R OCS (1)	12	50	42	31
Lu et al., 2015 ²⁷	China	NR	R OCS (1)	17	53	36	44
McMonagle et al., 2008 ²⁸	Australia	1985–2005	R OCS (2)	33	33	47	NR
Minovi et al., 2004 ²⁹	Germany	1989–2004	R OCS (1)	11	NR	53	34
Mowry et al., 2012 ³⁰	US	1998–2010	R OCS (1)	14	71	50	12
Nadeau & Sataloff, 2003 ³¹	US	1983–1996	R OCS (1)	7	71	49	82
Park et al., 2014 ³²	Korea	1995–2013	R OCS (1)	28	50	42	60
Perez et al., 2005 ⁴	Canada	1979–2004	R OCS (1)	11	45	38	99
Sherman et al., 2002 ³³	US	1991–1997	R OCS (1)	10	60	47	33
Shirazi et al., 2007 ³⁴	US	1990–2006	R OCS (1)	16	56	46	36
Sun et al., 2015 ³⁵	China	2000–2009	R OCS (1)	18	56	36	70
West et al., 2018 ³⁶	Denmark	NR	R OCS (1)	3	100	63	6
Xiang et al., 2015 ³⁷	China	NR	R OCS (1)	19	58	36	86
Radiosurgery treatment							
Carlson et al., 2016 ¹	US	1990–2015	R OCS (1)	13	NR	NR	NR
Comps et al., 2018 ³⁸	Switzerland	2010–2017	R OCS (1)	4	75	44	39
Eshraghi et al., 2019 ²	US	1996–2017	R OCS (2)	9	NR	NR	NR
Fezeu et al., 2015 ⁷	US	2005–2013	R OCS (1)	5	40	35	12
Hasegawa, 2013 ³⁹	Japan	1991–2013	R OCS (10)	42	79	50	48
Litre et al., 2007 ⁶	France	1992–2003	P OCS (1)	11	64	46	39
Madhok et al., 2009 ⁴⁰	US	NR	R OCS (1)	6	33	39	47
McRackan et al., 2015 ⁴¹	US	1995–2014	R OCS (1)	7	NR	NR	57
Moon et al., 2014 ⁵	Korea	2000–2012	R OCS (1)	14	57	37	81
Shi et al., 2016 ⁴²	US	1998–2011	R OCS (1)	8	75	39	43

NR = not reported; OCS = observational cohort study; P = prospective; R = retrospective.

* The number of institutions is in parentheses.

† These numbers reflect cohorts that were treated by the listed modality. Many studies reported a conservative management arm in their cohorts, which were not included in this analysis.

Quality and Certainty Assessment

On GRADE criteria, the certainty of all outcomes ranged from very low to moderate (Table 3). In the surgical intervention group, stable facial nerve function was rated low certainty, whereas all other outcomes were rated very low certainty. In the SRS group, stable facial nerve function was rated moderate certainty, with the remaining outcomes rated low certainty. According to Meta-Analysis of Observational Studies in Epidemiology (MOOSE) cri-

teria, all included studies were deemed to be of good quality to answer our targeted PICOS question (Supplemental Table 1).

Bias Assessment

Funnel plots generated for outcomes with ≥ 10 studies did not demonstrate significant asymmetry, indicating low likelihood of publication bias in our outcomes. Linear regression by Begg's and Egger's tests for outcomes with

TABLE 2. Clinical features and outcomes of all included studies

Authors & Year	Operative Data		Mean HB Scores		Postop Course	
	Surgical Approach(es)	Graft(s)/ Anastomoses Used	Preop	Postop	No. of Complications (breakdown, description)	Recurrence (no.)
Surgery treatment						
Bacciu et al., 2014 ¹⁷	Resection, decompression	Sural, GAN/CN VII–XII	1.6	2.2	NR	NR
Carlson et al., 2016 ¹	Resection, decompression	Sural, GAN/CN VII–XII, CN VII–XI, CN VII–V	1.9	2.7	NR	15
Chung et al., 2004 ¹⁸	Resection, parotidectomy	Sural, GAN/CN VII–XII	4.0	3.8	3 (2 wounds, 1 nerve damage)	0
Doshi et al., 2015 ¹⁹	NR	Sural, GAN/CN VII–XII	2.0	1.9	4 (4 CSF leaks)	0
Eshraghi et al., 2019 ²	Resection	NR	2.3	3.3	NR	NR
Günther et al., 2010 ²⁰	Resection	Sural, GAN/CN VII–XI	3.2	3.5	3 (1 CSF leak, 1 infection, 1 nerve damage)	8
Kim & Suh, 2007 ²¹	NR	Sural, GAN/CN VII–XII			NR	0
Kohmura et al., 2007 ²²	Resection	Sural	2.0	2.8	NR	NR
Lahlou et al., 2016 ²³	Resection	Sural, GAN/CN VII–VII	3.0	3.0	1 (1 hematoma)	5
Lee et al., 2007 ²⁴	Resection, decompression	None	1.3	1.7	NR	0
Li & Dai, 2017 ²⁵	Resection	None	1.9	1.7	NR	27
Liu & Fagan, 2001 ²⁶	Resection, decompression, biopsy	Sural, GAN/CN VII–XII	4.2	4.0	NR	0
Lu et al., 2015 ²⁷	Stripping, resection	Sural, GAN	5.5	3.9	NR	0
McMonagle et al., 2008 ²⁸	Resection, decompression, biopsy	Sural, GAN/CN VII–XII, CN VII–VII	2.6	3.0	6 (1 infection, 1 CSF leak, 1 HA/tinnitus, 1 vertigo, 1 tongue atrophy, 1 EAC stenosis)	6
Minovi et al., 2004 ²⁹	Resection	Sural, GAN/CN VII–XII	2.4	3.3	0	0
Mowry et al., 2012 ³⁰	Resection, decompression	NR	1.0	1.4	NR	7
Nadeau & Sataloff, 2003 ³¹	Resection	GAN/CN VII–VIII	1.3	3.1	NR	0
Park et al., 2014 ³²	Stripping, resection	Sural, GAN/CN VII–XII, CN VII–VII	2.5	2.8	NR	0
Perez et al., 2005 ⁴	Resection	Sural, GAN/CN VII–XII, CN VII–VII	3.6	2.9	NR	0
Sherman et al., 2002 ³³	Resection	Sural, GAN	3.0	2.3	0	0
Shirazi et al., 2007 ³⁴	Resection, decompression	Sural, GAN/CN VII–XII	3.6	3.0	0	0
Sun et al., 2015 ³⁵	Stripping, decompression	NR	2.3	2.2	NR	0
West et al., 2018 ³⁶	Resection	None	2.0	2.7	0	0
Xiang et al., 2015 ³⁷	Resection	Sural, GAN	2.2	2.3	0	0
Radisurgery treatment						
Carlson et al., 2016 ¹		NA	1.3	1.5	NR	31
Comps et al., 2018 ³⁸		NA	3.0	2.6	0	NR
Eshraghi et al., 2019 ²		NA	2.3	1.7	NR	NR
Fezeu et al., 2015 ⁷		NA	3.2	2.6	NR	0
Hasegawa, 2013 ³⁹		NA	2.7	2.6	5 (3 nerve palsies, 1 HA/tinnitus, 1 vertigo)	2
Litre et al., 2007 ⁶		NA	2.0	2.5	NR	9
Madhok et al., 2009 ⁴⁰		NA	2.7	2.5	0	0
McRackan et al., 2015 ⁴¹		NA	NA	NA	NR	NR
Moon et al., 2014 ⁵		NA	2.6	2.5	0	0
Shi et al., 2016 ⁴²		NA	2.3	1.8	NR	0

EAC = external auricular canal; GAN = great auricular nerve; HA = headache; NA = not applicable.

FIG. 2. Forest plot of incidence of facial nerve function (ES) following surgical intervention. Figure is available in color online only.

FIG. 3. Forest plot of incidence of facial nerve function (ES) following radiosurgical intervention. Figure is available in color online only.

≥ 10 studies did not yield statistically significant results, indicating a low likelihood of small-study bias.

Trends Over Time

There were no linear trends related to time concerning the pretreatment HB score for either the surgical cohort (slope = -0.02 , $p = 0.58$) or the radiosurgery cohort (slope = 0.01 , $p = 0.83$). Furthermore, meta-regression did not identify any statistically significant trends across time for any of the tiers of facial nerve function outcome for the surgery or radiosurgery cohorts (Supplemental Table 2).

Discussion

We report the first systematic review and meta-analysis comparing facial nerve outcomes after resection or SRS for patients with FNS; this study was conducted in order to better inform treatment recommendations and decision-making. Based on the current study, significantly more patients appear to have stable facial nerve function after SRS, whereas unfavorable facial nerve outcomes are significantly associated with surgical treatment. These findings will assist clinicians and patients alike in assessing the risks and benefits of treatment for FNS.

Across all studies and independent of treatment strategy,

the estimated summary effects in the current study suggest that approximately 1 in 5 patients will experience improved facial nerve function (i.e., reduced HB scores) after treatment, although the consistency between studies did vary significantly.^{2,7,27} It is important to note that improvements after surgery are probably attributable to reanimation instead of direct changes to or decompression of the facial nerve, and the degree to which this occurs probably varies intrinsically within each study. Although our findings provide some limited encouragement for those patients presenting with marked facial weakness at baseline, it is likely to be less pertinent to the majority of patients, for whom the threat of losing normal or near-normal facial nerve function is far more salient than the potential for recovery. Correspondingly, we anticipate that qualitative, directional approximations of facial nerve outcome will be more useful in the patient education and counseling setting.

In the setting of FNS, many surgeons would recommend watchful waiting to patients with minimal degradation in facial function; radiosurgery for moderate reduction in facial function; and surgery for poor facial function (HB IV or worse) or for significant mass effect. Stratifying patients based on clinical symptoms may result in underlying tumor-specific differences and biases among the co-

FIG. 4. Forest plot of incidence of postoperative complications (ES) following surgical versus radiosurgical intervention. Figure is available in color online only.

hort outcomes that could account for posttreatment facial function trends. We do recognize that, because radiosurgery and watchful waiting are relatively newer therapeutic strategies, the earlier surgical cohorts probably included patients who would have otherwise undergone a different treatment modality. Still, our meta-regression did not detect a significant trend toward bias with time of study publication, which is encouraging for the interpretability of our results.

Based on our findings and the preceding literature, SRS appears to be significantly associated with a larger proportion of patients emerging from treatment with stable facial nerve function, as compared with those undergoing surgery.^{1,43} Put another way, the current study empowers clinicians to relate one of the most potentially meaningful treatment parameters—facial nerve stability—to patients and colleagues with the highest degree of certainty, based on the presently available literature. By the same token, the companion risk of worsened facial nerve function is also highly salient to patients, which we noted to be significantly associated with surgery.⁴⁴ Candidly, given that most studies of SRS reported essentially a zero incidence of degraded facial function, the differences observed in outcome may be predominantly driven by unfavorable outcomes following surgery, rather than favorable outcomes following SRS.^{5,6,38,40}

We did not identify a statistically significant difference in the incidence of complications, which ranged from 4% to 7%, or risk of progression, which ranged from 2% to 3% across all included studies, although the certainty of these findings is low. With respect to complications, we do note that, looking more broadly at the literature comparing out-

comes after SRS and surgery, treatment-related morbidity and complications are almost universally lower following radiosurgery.^{45–50} Indeed, due to probable underreporting, it would be difficult to conclude with a high degree of certainty that there was no difference in complication rates after surgery or SRS, and this finding should be interpreted with caution when discussing with patients.

Although it is possible that the present study is insufficiently powered to detect a true difference in the risk of progression between surgery and SRS for FNS, other factors are likely to be more clinically relevant when counseling patients regarding treatment decision-making. Accordingly, we recommend de-emphasizing efficacy, or risk of tumor progression, when counseling patients with FNS, in order to focus on the well-described differences in risk profiles between the treatment options. Of particular interest, the majority of the postsurgical recurrences observed did arise following partial resection or biopsy, a finding that accords with the VS literature.^{51,52} However, given the low estimated absolute incidence rate of treatment failure and the significant increase in risk of an adverse facial nerve outcome following gross-total resection of FNS, we do not explicitly advocate for aggressive resection, but individualize treatment planning and patient counseling with regard to the individual anatomy, goals, and risk tolerance, with consideration given to primary SRS or adjuvant SRS following subtotal resection, as well as the rare pursuit of gross-total resection in carefully selected individuals.^{32,53}

Several unanswered questions anticipate future research. With respect to clinical practice, although watchful waiting often precedes treatment of FNS at initial

FIG. 5. Forest plot of incidence of progression (ES) following surgical versus radiosurgical intervention. Figure is available in color online only.

detection, optimal treatment timing has not yet been established. Because SRS confers the highest incidence of stable facial nerve function, with excellent tumor control and a very low incidence of complications, the current study results would support consideration of SRS as the predominant first-line treatment for symptomatic FNS. Furthermore, given the potential for successful long-term treatment of small FNS via SRS, one could advocate for consideration of earlier and more aggressive treatment of asymptomatic or minimally symptomatic FNS via SRS, in hopes of reducing the incidence of patients developing either more severe symptoms or sufficient tumor growth that resection would be mandatory.

Strength and Limitations

By adhering to PRISMA guidelines and using a robust search strategy, the literature search completed within the current study was comprehensive and reproducible. The PRISMA checklist served as an internal assessment tool to optimize conclusion quality and minimize bias. Using a random-effects model will have somewhat reduced the interstudy heterogeneity, improving the robustness of our findings.

There are limitations to be addressed by future studies. Outside the standard call for increased cohort size and

statistical power, we note that all studies were retrospective, save for the prospective study by Litre et al.⁶ Due to inherent clinical heterogeneity that is difficult to ascertain in retrospect, unanalyzed clinical and patient factors that guided treatment timing, strategy, technique, and need for additional management may have confounded our results. The current literature is limited by a lack of granularity with respect to tumor diagnosis methods; therefore, it is possible that we included misclassified VS or hemangioma cases, and excluded patients with unreported, misdiagnosed FNS. Other insights into managing this and other clinically meaningful nuances, such as the decision to use specific surgical approaches for resection, and detailed SRS parameters, such as biological effective dose, are also precluded by this type of analysis.^{32,54–56} A more detailed comparison of individual surgical techniques was not possible due to the limitations of the available data and associated implications for statistical power. The comparably low incidences of complication may be more attributable to the lack of reported complications rather than to a nonstatistically significant difference between the complication incidences of the two cohorts. Furthermore, this analysis does not account for differences in complication type—surgical patients, unlike SRS patients, are at increased risk for infection, clots, and focal

TABLE 3. GRADE assessment for reported outcomes

Outcome	Pooled Incidence (95% CI)	No. of Cohorts (studies)	Certainty Assessment					Overall Quality	Certainty
			Type of Evidence	Quality	Consistency	Directness	ES		
Surgical intervention									
Facial nerve function									
Improved	23% (15–32%)	24	+2	–1	0	0	0	+1	Very low
Stable	41% (32–50%)	24	+2	–1	0	0	+1	+2	Low
Worsened	30% (21–40%)	24	+2	–1	0	0	0	+1	Very low
Postop complications	7% (1–15%)	10	+2	–1	–1	0	+1	+1	Very low
Progression	2% (0–5%)	19	+2	–1	0	0	0	+1	Very low
Radiosurgical intervention									
Facial nerve function									
Improved	20% (9–34%)	10	+2	–1	0	0	+1	+2	Low
Stable	66% (54–78%)	10	+2	–1	0	0	+2	+3	Moderate
Worsened	9% (3–16%)	10	+2	–1	0	0	+1	+2	Low
Postop complications	4% (0–12%)	4	+2	–1	0	0	+1	+2	Low
Progression	3% (0–11%)	8	+2	–1	0	0	+1	+2	Low

The overall quality score is determined based on the sum of the included domains. Type of evidence is based on the design of the included studies (range +2 to +4). The study quality reflects the blinding and allocation, follow-up and withdrawals, sparsity of data, and methodological concerns (range –3 to 0). Consistency is graded based on the heterogeneity of the included population and study endpoints with respect to one another (range –1 to +1). Directness is graded based on the generalizability of the included results (range –2 to 0). Effect size is graded based on the overlap of the 95% CI estimates within 10% of either 0% or 100% incidence (range 0 to 2). The overall quality of results for each outcome can be considered high (≥ 4 points), moderate (3 points), low (2 points), or very low (≤ 1 point).

neurological deficits; even within the surgical cohort, each surgical strategy carries a unique risk for specific complications.

Additionally, although the HB scoring system is a relatively standardized metric, the inconsistencies in interrater reliability, which are well described, compromise an idealized analysis of facial nerve function outcomes.⁵⁷ Therefore, given the heterogeneous nature of the studies and centers represented by the present meta-analysis, we collapsed the subjectively assigned numeric HB values, which are more vulnerable to bias, into more reliable and clinically relevant categories of worsened, stabilized, or improved. Additionally, because the HB scores do not fully communicate the nuances of degraded facial function, Fattah et al. recommended the widespread adoption of the Sunnybrook Facial Grading Scale after comparing the convenience in clinical practice, reproducibility, variability, sensitivity, and several other factors of 19 facial nerve grading scales, including HB.^{58,59} Most facial grading scales lack the resolution necessary to report zonal changes in response to reanimation, which led to the development of computer applications like eFACE; however, these tools are neither convenient nor practical for widespread clinical use.⁵⁸

Finally, we recognize that facial nerve function is one of numerous outcomes that may influence individual clinician or patient decisions, including whether to pursue treatment at all, to say nothing of the determination between resection or SRS. The more favorable long-term prognosis of these tumors places a greater emphasis on optimizing patient outcomes, for which other parameters such as aesthetic outcome and recovery time may also significantly impact decision-making in a way that cannot be detected based on the available data. Unfortunately, com-

pared with quality-of-life data reported in VS, direct data reporting pertinent outcomes in FNS are very limited at present.^{45,60–62}

Conclusions

In this study we conducted a systematic, metadata-based analysis of the existing literature on facial nerve outcomes after surgery or SRS in patients with FNS. We report differences in stable and worsened facial function outcomes based on changes between preoperative and final postoperative HB scores. SRS appears to be associated with a significantly higher incidence of stable facial nerve function, as well as with the greatest certainty in the observed effect; in contrast, surgery appears to be associated with a higher incidence of worsened facial nerve function. These results suggest that SRS should be considered the front-line option in patients with FNS who require treatment in order to preserve their facial function. In contrast, resection should be reserved for patients who require treatment of their FNS and have a separate indication for surgery, such as decompression of the brainstem, establishment of a diagnosis, or treatment of hydrocephalus. Further research should investigate this possibility in a more robust and rigorous fashion, as well as the question of optimal treatment timing with respect to symptomatic onset.

Appendix

Query Translation

("facial nerve schwannoma"[All Fields] OR "facial schwannoma"[All Fields]) AND (("surgery"[Subheading] OR "surgery"[All Fields] OR "surgical procedures, operative"[MeSH Terms] OR ("surgical"[All Fields] AND "procedures"[All

Fields] AND “operative”[All Fields]) OR “operative surgical procedures”[All Fields] OR “surgery”[All Fields] OR “general surgery”[MeSH Terms] OR (“general”[All Fields] AND “surgery”[All Fields]) OR “general surgery”[All Fields] OR (“radiosurgery”[MeSH Terms] OR “radiosurgery”[All Fields])

MeSH Translations

Surgery

“surgery”[Subheading] OR “surgery”[All Fields] OR “surgical procedures, operative”[MeSH Terms] OR (“surgical”[All Fields] AND “procedures”[All Fields] AND “operative”[All Fields]) OR “operative surgical procedures”[All Fields] OR “surgery”[All Fields] OR “general surgery”[MeSH Terms] OR (“general”[All Fields] AND “surgery”[All Fields]) OR “general surgery”[All Fields]

Radiosurgery

“radiosurgery”[MeSH Terms] OR “radiosurgery”[All Fields]

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Lu, Graffeo, Perry. Acquisition of data: Rotter, Lu. Analysis and interpretation of data: Link, Rotter, Lu. Drafting the article: Link, Rotter, Lu, Perry. Critically revising the article: Link, Lu, Graffeo, Perry, Pollock. Reviewed submitted version of manuscript: Rotter, Graffeo, Perry, Driscoll. Approved the final version of the manuscript on behalf of all authors: Link. Statistical analysis: Lu. Administrative/technical/material support: Lu, Graffeo, Perry. Study supervision: Link, Lu, Graffeo, Perry, Driscoll, Pollock.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

Supplemental Tables 1 and 2. <https://thejns.org/doi/suppl/10.3171/2020.6.JNS201548>.

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