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Prospective comparison of long-term pain relief rates after first-time microvascular decompression and stereotactic radiosurgery for trigeminal neuralgia

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Objective Common surgical treatments for trigeminal neuralgia (TN) include microvascular decompression (MVD), stereotactic radiosurgery (SRS), and radiofrequency ablation (RFA). Although the efficacy of each procedure has been described, few studies have directly compared these treatment modalities on pain control for TN. Using a large prospective longitudinal database, this study aimed to 1) directly compare long-term pain control rates for first-time surgical treatments for idiopathic TN; and 2) identify predictors of pain control.

Methods The authors reviewed a prospectively collected database for all patients who underwent treatment for TN between 1997 and 2014 at the University of California San Francisco. Standardized collection of data on preoperative clinical characteristics, surgical procedure, and postoperative outcomes was performed. Data analyses were limited to those patients who received a first-time procedure for treatment of idiopathic TN with > 1 year of follow-up.

Results Of 764 surgical procedures performed at the University of California, San Francisco, for TN (364 SRS, 316 MVD, and 84 RFA), 340 patients underwent first-time treatment for idiopathic TN (164 MVD, 168 SRS, and 8 RFA) and had > 1 year of follow-up. The analysis was restricted to patients who underwent MVD or SRS. Patients who received MVD were younger than those who underwent SRS (median age 63 vs 72 years, respectively; $p < 0.001$). The mean follow-up was 59 ± 35 months for MVD and 59 ± 45 months for SRS. Approximately 38% of patients who underwent MVD or SRS had > 5 years of follow-up (60 of 164 and 64 of 168 patients, respectively). Immediate or short-term (< 3 months) postoperative pain-free rates (Barrow Neurological Institute Pain Intensity score of I) were 96% for MVD and 75% for SRS. Percentages of patients with Barrow Neurological Institute Pain Intensity score of I at 1, 5, and 10 years after MVD were 83%, 61%, and 44%, and the corresponding percentages after SRS were 71%, 47%, and 27%, respectively. The median time to pain recurrence was 94 months (25th–75th quartiles: 57–131 months) for MVD and 53 months (25th–75th quartiles: 37–69 months) for SRS ($p = 0.006$). A subset of patients who had MVD also underwent partial sensory rhizotomy, usually in the setting of insignificant vascular compression. Compared with MVD alone, those who underwent MVD plus partial sensory rhizotomy had shorter pain-free intervals (median 45 months vs no median reached; $p = 0.022$). Multivariable regression demonstrated that shorter preoperative symptom duration (HR 1.005, 95% CI 1.001–1.008; $p = 0.006$) was associated with favorable outcome for MVD and that post-SRS sensory changes (HR 0.392, 95% CI 0.213–0.723; $p = 0.003$) were associated with favorable outcome for SRS.

Conclusions In this longitudinal study, patients who received MVD had longer pain-free intervals compared with those who underwent SRS. For patients who received SRS, postoperative sensory change was predictive of favorable outcome. However, surgical decision making depends upon many factors. This information can help physicians counsel patients with idiopathic TN on treatment selection.

Key Words trigeminal neuralgia; microvascular decompression; Gamma Knife; stereotactic radiosurgery; radiofrequency ablation; surgical outcome; long term outcome; pain

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Abbreviations BNI = Barrow Neurological Institute; IQR = interquartile range; MVD = microvascular decompression; RFA = radiofrequency ablation; Rhiz = partial sensory rhizotomy; SRS = stereotactic radiosurgery; TN = trigeminal neuralgia; UCSF = University of California, San Francisco.

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TRIGEMINAL neuralgia (TN), also known as tic douloureux, is a syndrome characterized by paroxysmal facial pain in the somatosensory distribution of the trigeminal nerve. Common surgical treatments for TN include ablative procedures, such as stereotactic radiosurgery (SRS) and percutaneous rhizotomy, and nonablative surgical microvascular decompression (MVD). Ablative therapies are based on desensitizing or injuring the nerve to resolve the pain, whereas nondestructive surgical procedures aim to relieve the causative physical compression of the trigeminal nerve from adjacent vasculature.

There is a growing body of literature describing the efficacy for each of these procedures. For MVD, several large series with long-term follow-up have reported pain-free rates of 70%–80% in patients at 5–10 years.[2,37,43] The published rate of pain relief in patients who have undergone SRS is more variable, ranging from 35%–65% at 5 years to 20%–45% at 10 years.[11,17,20,25,32,33] Despite the large body of literature describing surgical outcomes for single procedures, there have been relatively few studies that directly compare efficacies between the procedures while controlling for potential confounding patient variables.[5,20,30,31,36,42–44] Most have included patients with recurrent or atypical trigeminal pain. In addition, SRS for TN treatment was popularized in the late 1990s, and there are few reports with large patient cohorts with long-term follow-up to capture pain-recurrence rates.[11,17,32] Given the variable reported outcomes, a direct comparison of outcomes for these common surgical procedures would be valuable in guiding management and counseling patients.

We report our institution’s longitudinal experience in the surgical treatment of idiopathic TN from a prospectively collected database. With standardized data collection and long-term follow-up, we performed a direct comparison of pain control rates following MVD and SRS in a relatively homogeneous population of patients with idiopathic TN undergoing first-time surgical treatment. By finding the relative efficacies for these first-time procedures and identifying predictors of pain-free outcome, we aim to provide valuable information in guiding treatment selection in this patient population.

Methods

Patient Selection

Clinical data for all consecutive patients who underwent evaluation for surgical treatment for TN at University of California, San Francisco (UCSF), were prospectively collected since 1997. Because of the relatively low number of patients who underwent radiofrequency ablation (RFA), this study is an analysis of all patients who underwent MVD or SRS treatment between 1997 and 2014 by 2 surgeons (N.M.B. and E.F.C.). During the study period, 680 surgical procedures, including 364 SRSs and 316 MVDs, were performed. Inclusion criteria are as follows: idiopathic TN without mass lesions or multiple sclerosis; classic Type 1 trigeminal pain;[7,8,12] first-time surgical treatment for TN; > 1 year of follow-up; and sufficient preoperative and follow-up data.

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We identified 332 patients who met inclusion criteria for analysis: 164 who underwent MVD and 168 who had SRS (Fig. 1). All research protocols were approved by the UCSF IRB for human research (Committee for Human Research).

Data Collection and Outcome Measures

Clinical information was prospectively collected when patients underwent evaluation for TN surgery at UCSF. Variables that were prospectively recorded during the initial clinical visit included patient demographic data; symptom duration, location, and features; TN medications; relevant family and medical history; baseline physical examination findings; and imaging findings. Subsequent postsurgical follow-up visits were usually scheduled at 4–8 weeks, 4–6 months, and 12 months. Additional visits were scheduled on an as-needed basis. Variables collected at follow-up visits included treatments received, medications, TN pain description, sensory disturbances, as well as examination findings. If patients did not undergo regular follow-up, telephone calls were placed and the same variables (except for physical examination findings) were recorded. Of note, the reporting period began before the availability of high-resolution, fine-cut MRI with gradient echo sequences.

Outcome measurements included Barrow Neurological Institute (BNI) Pain Intensity scores[34] at last follow-up (primary), surgical complications, and sensory changes. Patients were designated as free of pain if they did not have trigeminal pain when not taking medication (BNI score of I). Patients were designated as having favorable outcomes if they had BNI scores of I or II (occasional pain off medication). Patients who were not free of pain included all of those with residual pain (BNI score of IIIa: pain free on medication; IIIb: pain adequately controlled with medication; IV: pain not adequately controlled with medication; or V: no relief).

Treatment Protocols

Patients were not randomly assigned and were counseled on all 3 treatment modalities (MVD, SRS, and RFA). Selection of the procedure was guided by the following general considerations. For younger (in general < 75 years old) and healthy patients, MVD was recommended. For those in this group who refused MVD, SRS or RFA was performed based on patient preference in treatment modality. For older patients with medical comorbidities, SRS or RFA was performed. RFA was not recommended for any patient with V_1 distribution pain. Ultimately, treatment selection followed the patient's decision, which was influenced by the perceived risks and benefits of each procedure.

Following any procedure, patients were typically instructed to taper their TN medication once they became free of pain. For patients who received MVD, if they were free of pain postoperatively at time of discharge, medications were tapered 1 at a time for 2–6 weeks, with the goal of being off medication at their first postoperative visit. For patients who underwent SRS, medications were tapered after 6 weeks of complete pain control. If breakthrough pain occurred during the tapering-off period, all patients were instructed to hold off on the medication tapering and restart it when able. However, in many cases, primary care physicians or outside neurologists helped with patients' medical management and therefore not all managements were standardized.

Operative Technique

Microvascular Decompression

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The general operative technique followed that of previously described standard procedures.[3,13,26] A small retrosigmoid craniectomy was made, and the trigeminal nerve was examined under the microscope for vascular compression along the root entry zone or its cisternal course. Any compressive arteries or veins were identified, dissected from the nerve, padded with Teflon felt, and secured with biological adhesive. Some compressive veins were coagulated and divided. For selected patients without obvious vascular compression intraoperatively, a partial sensory rhizotomy was performed by dividing the nerve. Intraoperative auditory brainstem evoked potential monitoring was used in all cases.

Stereotactic Radiosurgery

SRS was performed using a Gamma Knife apparatus. The Leksell stereotactic frame (Elekta Instruments, AB) was applied under local anesthesia. All patients underwent stereotactic MRI for target definition. High-resolution T2-weighted images or T2-type fast imaging employing steady-state acquisition (FIESTA) sequences (when available) and contrast-enhanced T1-weighted images were used for target planning. A single isocenter using a 4-mm collimator was used to target the trigeminal nerve root in the cisternal portion of the trigeminal nerve. The majority (79%) of patients received 80 Gy (range 70–85 Gy).

Statistical Analysis

All statistical analyses were performed using SPSS version 23 (IBM). All analyses compared the MVD and SRS cohorts only. Continuous predictor and outcome variables were compared between the cohorts using either the parametric Student t-test or the nonparametric Mann-Whitney U-test after assessing for normality with the Shapiro-Wilk test. Categorical variables were compared with Pearson's chi-square or Fisher's exact test, as appropriate. The duration of pain relief for the various surgical procedures was plotted using Kaplan-Meier survival analyses, and statistical significance was measured using the log-rank test. Univariate analysis was performed to find predictors of outcome for each procedure type. Multivariate analysis was performed using the Cox proportional hazards model to assess the contribution of other predictor variables in TN pain relief. Only variables with a p value < 0.2 from the univariate analysis were included in the multivariate regression model to avoid overfitting. The threshold for statistical significance was set at a p value of 0.05.

Results

Between 1997 and 2014, a total of 316 MVD, 364 Gamma Knife SRS, and 84 RFA procedures were performed at UCSF. After excluding patients who had received procedures for their TN, had mass lesions or multiple sclerosis causing their trigeminal pain, had atypical trigeminal pain, and had < 1 year of follow-up, a total of 164 MVD, 168 SRS, and 8 RFA patients were included in this study (Fig. 1). Given the small number of patients who underwent RFA, we performed all analyses on the MVD and SRS groups. Demographic data (Table 1) demonstrated that patients who received MVD were younger than those who received SRS (median age 63 years for MVD vs 72 years for SRS; $p < 0.001$), had shorter preoperative symptom duration (median 48 months for MVD vs 84 months for SRS; $p < 0.001$), and had fewer preoperative sensory disturbances such as hyperesthesia or numbness (2% for MVD vs 11% for SRS; $p = 0.003$). There were no differences in sex, laterality or distribution of pain, family history of TN, or length of follow-up.

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Eighty-two patients with idiopathic TN who had MVD and 22 who underwent SRS were lost to follow-up ($p < 0.001$). Results of univariate analysis comparing preoperative characteristics of patients lost to follow-up with those included in the analysis for each procedure are shown in Supplementary Table 1. All of the factors were similar between the groups, except we found that patients who were lost to follow-up in the SRS group were significantly older compared with those in SRS with > 1 year of follow-up ($p = 0.019$, Supplementary Table 1).

Survival Analysis of Pain Outcome

Patients who underwent MVD had longer pain-free intervals than those who received SRS. Almost all of the patients who underwent MVD (n = 157, 96%) reported being free of pain (BNI Pain Intensity score of I) postoperatively, whereas only 75% of patients who received SRS had a BNI score of I outcome following their procedure (n = 126; $p < 0.001$). At the last follow-up visit, 57% of patients who had undergone MVD had a BNI I score and 58% had a favorable outcome (BNI score of I or II), whereas 44% of patients who had undergone SRS had BNI score of I and 46% had a favorable outcome ($p = 0.038$). Fourteen patients who had undergone MVD (8%) and 12 who had undergone SRS (8%) had symptoms that were controlled with medication (BNI scores of IIIa and IIIb). Fifty-five patients who had undergone MVD (33%) and 78 who had undergone SRS (46%) had little to no relief after their procedure (BNI scores of IV and V). These outcomes are reported in Table 2.

To further assess the difference in outcomes between the MVD and SRS groups, a Kaplan-Meier survival analysis was performed. Survival functions depicting time until pain recurrence for patients in the cohorts showed divergent outcomes that were significantly different ($p = 0.006$, log-rank test). The median estimated pain-free duration was 94 months for the MVD group (interquartile range [IQR] 57–131 months) and 53 months for the SRS group (IQR 37–69 months; $p = 0.006$). The estimated percentages of patients with a BNI score of I at 1, 5, and 10 years after MVD were 83%, 61%, and 44%, respectively. The corresponding estimated percentages for patients in the SRS group were 71%, 47%, and 27%, respectively (Fig. 2).

Characteristics and Outcomes for the MVD Group

Compression characteristics for all patients who underwent MVD are depicted in Table 3. In 26% of the MVD cases, at the discretion of the attending surgeon, a partial sensory rhizotomy was performed in addition to the vascular decompression. Those who received MVD with partial sensory rhizotomy (MVD+Rhiz) had lower pain-free rates compared with those who received MVD alone. The cumulative 1-, 5-, and 10-year BNI-I rates for MVD alone were 84%, 64%, and 53%, respectively, and those for MVD+Rhiz were 80%, 50%, and 20%, respectively. Survival analysis confirmed this trend and showed a median pain-free interval of 45 months for the MVD+Rhiz group (IQR 14–113 months) compared with the MVD group, in which no median pain-free time was reached ($p = 0.022$, log-rank test; Fig. 3).

The presence of vascular compression of the trigeminal nerve on MRI and the presence of vascular compression confirmed intraoperatively were not associated with favorable outcome in patients who received MVD (Table 3). In addition, even when a compressing vessel was found intraoperatively, the specific blood vessel involved was not associated with the primary outcome. The culprit vessel involved in trigeminal nerve compression was found to be the superior cerebellar artery in 82 (50.0%) patients, the anterior cerebellar artery in 6 (3.6%) patients,

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multiple arteries in 17 (10.4%) patients, a single vein in 23 (14%) patients, and an artery in combination with a vein in 26 (15.9%) patients.

Post-MVD sensory changes were not associated with outcome. Multivariate analysis using Cox regression showed that longer preoperative symptom duration (HR 1.005, 95% CI 1.001–1.008; p = 0.006) and MVD with **[AQ: MVD with Rhiz, according to Table 4. Please clarify.]** Rhiz (HR 1.954, 95% CI 1.154–3.308; p = 0.013) were associated with unfavorable outcome (BNI Pain Intensity score of III-V) (Table 4).

Adverse events were more likely to occur in the MVD group than in the SRS cohort (11% for MVD vs 0% for SRS; p < 0.001, Table 2). There were 6 cases of CSF leaks, 5 pseudomeningoceles, 6 wound infections (including 1 case with concurrent CSF leak), 1 postoperative hematoma requiring evacuation, and 1 patient with facial nerve palsy that gradually improved (Table 5). Nine patients required reoperation for wound revision or washout. No patients had long-term hearing loss or neuropathic facial pain. Thus, the overall complication rate for MVD was approximately 11% in this series.

Characteristics and Outcomes for the SRS Group

For 168 patients who received SRS, the median time to freedom from pain was 27 weeks (Table 6). Sex, preoperative symptom duration, treatment side, and pain distribution were not predictors of favorable outcome (BNI score of I or II). Treatment dose seemed to have an effect on outcome (p = 0.041), but this difference was not significant on multivariate analysis. However, a posttreatment sensory deficit was significantly associated with achieving favorable outcome on multivariate analyses (HR 0.392, 95% CI 0.213–0.723; p = 0.003; Table 7).

Discussion

The reported efficacy of ablative and nonablative procedures for surgical treatment of medically refractory TN is highly variable due to differences in technique, study methods, and patient selection across different institutions. Here, we present the long-term experience of a single institution’s surgical outcomes following treatment of TN with MVD and SRS and we compare their relative efficacies. We found higher long-term pain-free rates in MVD-treated patients.

Pain-Free Rates Among Patients Who Underwent MVD or SRS

The pain control outcome for MVD in this study is similar to those of other studies reported in the literature.[2,17,30,31,37,40,41,43] We achieved a pain-free (BNI score of I) rate of 96% postoperatively, with a median estimated time to pain recurrence of 94 months. For SRS, up to 75% of our patients were free of pain postoperatively and the median estimated time to pain recurrence was 53 months, which is within the range reported in other large SRS series.[17,25,30,31,33] Importantly, the long length of time to pain recurrence for MVD and SRS demonstrates the need for long-term follow-up when comparing treatment efficacies. With the relatively recent advent of SRS technology as a standard of treatment for TN, to our knowledge our series represents one of the largest cohorts wherein a substantial number of patients (38%) had > 5 years of follow-up. Our results are consistent with other reports and support the conclusion that MVD has the most durable success in pain control.[41]

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Predictors of Freedom From Pain

Previous reports on outcome following MVD indicate that prognostic factors for success include immediate postoperative relief, male sex, arterial compression, shorter duration of symptoms, and typical trigeminal pain.[2,27,28,37,43] As for SRS, most studies show that postoperative facial numbness is a positive predictor of pain control,[14,17,34] which was confirmed by our results. The presence of postoperative facial sensory disturbance in our MVD cohort did not seem to be associated with outcome, which is in agreement with 2 previous studies.[1,4] In our MVD cohort, shorter symptom duration was a prognosticator for favorable outcome. For patients who received MVD, we found that neither the presence of vascular compression on MRI nor finding vascular compression during the operation was prognostic of outcome. This could be due to the fact that the reporting period began before the availability of high-resolution, fine-cut MRI with gradient echo sequences, which would be more likely to demonstrate neurovascular contact within the CSF space.

In addition, vascular compression may not be the only cause of trigeminal pain.[16,19] A recent study using blinded evaluation of 3.0-T MR sequences of patients with unilateral classical TN found that neurovascular contact was prevalent on both the symptomatic and asymptomatic sides, and only displacement or atrophy of the trigeminal nerve was highly associated with the symptomatic side.[24] TN involves numerous pathways from peripheral receptor activation; transmission and projection of nociceptive information; and convergence of afferents into the thalamus, limbic system, and somatosensory cortex.[29]

Besides physical compression, inflammation and demyelination have been implicated in the pathophysiology of TN.[22,23] Based on newer time-of-flight and diffusion-tensor imaging techniques, microstructural abnormalities in the trigeminal nerve in the form of demyelination without significant axonal injury is an essential pathological basis for the disease.[21] Therefore, it is not surprising that in some cases, decompressing or transposing the offending vessel alone is not sufficient to alleviate trigeminal pain.

In cases where there is no obvious vascular compression, a rhizotomy is performed in addition to MVD. Surprisingly, patients who received MVD+Rhiz had significantly higher rates of pain recurrence. One study compared pain-free rates in 142 cases of MVD with 68 cases of MVD+Rhiz and found significantly higher pain control rates in the group that received additional rhizotomy during a follow-up of 2 years.[45] Our response rates were similar between MVD and MVD+Rhiz initially, but after 6 months, the groups became divergent and the MVD+Rhiz group had higher pain-recurrence rates. This may suggest that patients without obvious vascular compression have a different pathophysiology than those with compression. Rhizotomy may work by temporarily interrupting the pathological pain pathway, but the underlying pathophysiology is still present.

Benefits of Ablative Versus Nonablative Procedures

Both ablative and nonablative treatment modalities have merits and limitations. Ablative procedures work by injuring the sensory fibers, whereas nonablative procedures work by physically decompressing the nerve, presumably without causing damage. Besides the relative efficacies of treatment, additional considerations must be made in patient selection. Although MVD has the best overall long-term efficacy, it is also the most invasive procedure and requires

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a longer hospital stay. Complications include CSF leak, chemical meningitis, wound infections, facial paresis, hearing loss, hematoma, and rarely, death.[2]

SRS is the least invasive procedure and does not require general anesthesia. It is well tolerated with low risk of complications. However, maximum efficacy takes months to achieve, and it is associated with a higher rate of trigeminal nerve dysfunction. RFA is generally safe and straightforward to perform, but requires patient cooperation with dermatome mapping. It has the benefit of providing immediate pain relief, but it also has higher rates of facial dysesthesia and pain recurrence.[6,9,15] Studies show that the risk of complications from MVD increases with patient age (primarily from cardiopulmonary and not neurological risks)[35] and is higher compared with RFA and SRS.[18,20] Although some studies have reported no difference in the rate of complications for MVD in the elderly,[38,39] MVD is generally recommended for younger and healthier patients.

This analysis does not take into account recurrent pain following failure of 1 procedure to control pain. No single procedure works 100% of the time, and it is necessary to have alternative treatment options when pain recurs. One prior study from our institution found that within a 7-year period, a small subgroup of patients (32 of 209 patients) required retreatment for recurrent TN; following any 2 procedures for recurrent TN, 94% had pain control.[36]

Limitations of the Study

Patients in our study were not randomly assigned to treatment; therefore, treatment selection was subject to bias. Because of differences in baseline characteristics between the MVD and SRS cohorts (age, symptom duration, and incidence of preoperative sensory disturbance), we cannot exclude the possibility that these differences may have contributed to the observed differences in outcome. Because medical management postprocedure is sometimes done by outside neurologists or primary care physicians, postprocedure management was not standardized in our study. We only reported results for surgically naïve patients with idiopathic TN. Therefore, our results are not applicable for patients with recurrent trigeminal pain,[36] atypical trigeminal pain,[27] or TN secondary to multiple sclerosis.[10]

Conclusions

Surgical decision making for treatment of TN depends on several factors. Several surgical options are quite effective. Our institutional experience shows that MVD is more effective than SRS in providing long-term pain-free benefits in patients with idiopathic TN. Limitations of MVD include the need for a hospital stay and an increased incidence of complications, although overall quite low. Ablative procedures such as SRS can still provide benefit to patients who are not good surgical candidates or who simply prefer not to undergo open surgery. Our data hopefully provide valuable information for counseling patients on treatment selection.

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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: Chang, Wang. Acquisition of data: Wang, Raygor, Cage, Ward, Westcott, Barbaro. Analysis and interpretation of data: Wang, Raygor, Barbaro. Drafting the article: Wang, Raygor. Critically revising the article: Chang, Wang, Cage, Ward. Reviewed submitted version of manuscript: Chang, Wang, Raygor, Cage, Ward, Barbaro. Statistical analysis: Wang, Raygor. Administrative/technical/material support: Chang. Study supervision: Chang, Barbaro.

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FIG. 1. Flow chart showing number of patients included in the study.

FIG. 2. Pain recurrence by procedure type: MVD versus SRS. Kaplan-Meier survival curves for the MVD and SRS cohorts are shown, with *tick marks* representing censored events. Values within the graph represent number of patients from each group reaching time points indicated by the *dashed line*.

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FIG. 3. Pain recurrence comparing MVD and MVD+Rhiz. Kaplan-Meier survival curves for the MVD and MVD+Rhiz cohorts are shown, with *tick marks* representing censored events. Values within the graph represent number of patients from each group reaching time points indicated by the *dashed line*.

TABLE 1. Demographic data and clinical characteristics of patients in the MVD and SRS cohorts

Variable	MVD	SRS	p Value
No. of patients	164	168	—
Median age in yrs (range)	63 (18–87)	72 (35–99)	<0.001
Sex, M	66 (40)	65 (39)	0.823
Median preop symptom duration in mos (IQR)	48 (24–84)	84 (44–168)	<0.001
TN laterality			0.823
Rt	96 (59)	101 (60)	
Lt	68 (41)	67 (40)	
TN distribution			0.234
V_1	12 (7)	15 (9)	
V_2	38 (23)	27 (16)	
V_3	39 (24)	35 (21)	
$V_1 + V_2$	25 (15)	20 (12)	
$V_2 + V_3$	36 (22)	48 (28)	
V_1–V_3	14 (9)	23 (14)	
Positive family history	3 (2)	9 (5)	0.139
Preop sensory disturbance	4 (2)	18 (11)	0.003
Follow-up in mos, mean ± SD	58.8 ± 34.7	58.7 ± 45.4	0.989

Values are expressed as number (%) unless otherwise indicated.

TABLE 2. Pain-free outcomes among patients in the MVD and SRS cohorts

Variable	MVD, n = 164	SRS, n = 168	p Value
Ever pain free, BNI I	157 (96)	126 (75)	<0.001
BNI Pain Intensity score, outcome			0.1167
I	93 (57)	74 (44)	
II	2 (1)	4 (2)	
IIIa	4 (2)	1 (1)	
IIIb	10 (6)	11 (7)	

IV	7 (4)	9 (5)	
V	48 (29)	69 (41)	
Favorable outcome (BNI score of I or II)	95 (58)	78 (46)	0.038
Median pain-free duration in mos (IQR)	94 (57–131)	53 (37–69)	0.006
Complications	18 (11)	0 (0)	<0.001

Values are expressed as number (%) of patients unless otherwise indicated.

TABLE 3. Univariate analysis of MVD outcomes

Variable	Total	Favorable, BNI Score of I or II	Unfavorable, BNI Score of III–V	p Value
No. of patients	164	95 (58)	69 (42)	—
Sex				>0.99
M	66 (40)	38 (58)	28 (42)	
F	98 (60)	57 (58)	41 (42)	
TN laterality				0.748
Rt	96 (59)	57 (59)	39 (41)	
Lt	68 (41)	38 (56)	30 (44)	
TN location				0.087
V_1	12 (7)	6 (50)	6 (50)	
V_2	38 (23)	18 (47)	20 (53)	
V_3	39 (24)	21 (54)	18 (46)	
$V_1 + V_2$	25 (15)	21 (84)	4 (16)	
$V_2 + V_3$	36 (22)	20 (56)	16 (44)	
V_1–V_3	14 (9)	9 (64)	5 (36)	
Median preop symptom duration in mos (IQR)	48 (24–84)	48 (24–72)	60 (23–99)	0.085
Median time until pain free, wks (IQR)	0 (0–0)	0 (0–0)	0 (0–0)	0.965
Median age in yrs (range)	63 (18–87)	63 (26–87)	63 (18–84)	0.502
Rhizotomy performed				0.047
Yes	43 (26)	19 (44)	24 (56)	
No	121 (74)	76 (63)	45 (37)	
MRI compression				0.389
Yes	74 (53)	46 (62)	28 (38)	
No	65 (47)	35 (54)	30 (46)	
Intraop compression				0.324
Yes	154 (94)	91 (59)	63 (41)	
No	10 (6)	4 (40)	6 (60)	
Compressing vessel				0.562
Artery only	105 (64)	62 (59)	43 (41)	
Vein only	23 (14)	15 (65)	8 (35)	
Artery + vein	26 (16)	14 (54)	12 (46)	
None	10 (6)	4 (40)	6 (60)	
Sensory changes post-MVD				0.577
Yes	37 (23)	23 (62)	14 (38)	
No	127 (77)	72 (57)	55 (43)	

Values are expressed as number (%) unless otherwise specified.

* Percentage reflects the number of patients for whom data were collected regarding vascular compression of the trigeminal nerve observed on MRI.

TABLE 4. Multivariate analysis of MVD outcomes

Predictor Variable	HR (95% CI)*	p Value
TN location	—	0.263
V_1 vs V_1–V_3	0.539 (0.162–1.791)	0.313
V_2 vs V_1–V_3	1.029 (0.405–2.612)	0.952
V_3 vs V_1–V_3	0.814 (0.313–2.113)	0.672
V_1–V_2 vs V_1–V_3	0.326 (0.091–1.167)	0.085
V_2–V_3 vs V_1–V_3	1.109 (0.43–2.861)	0.831
Preop symptom duration	1.005 (1.001–1.008)	0.006
Presence of rhizotomy	1.954 (1.154–3.308)	0.013

Multivariate Cox regression analysis using only variables with $p < 0.2$ from univariate analysis (Table 3).

* HRs < 1 suggest a higher likelihood of having a favorable outcome (BNI score of I or II).

TABLE 5. Complications among patients who underwent MVD

Complication	No. of Events (%)
CSF leak	6 (3.9)
Pseudomeningocele	5 (3.3)
Wound infection	6 (3.9)
Subdural hematoma	1 (0.7)
Facial nerve palsy	1 (0.7)

[AQ: Please explain how percentages were derived. They seem to be calculated on the basis of 153 patients, but my understanding is that there were 19 total complications among 18 patients.]

TABLE 6. Univariate analysis of SRS outcomes

Variable	Total	Favorable, BNI Score of I or II	Unfavorable, BNI Score of III–V	p Value
No. of patients	168	78 (46)	90 (54)	—
Sex				0.634
M	65 (39)	32 (49)	33 (51)	
F	103 (61)	46 (45)	57 (55)	
TN laterality				0.636
Rt	101 (60)	45 (45)	56 (55)	
Lt	67 (40)	33 (49)	34 (51)	
TN distribution				0.724
V_1	15 (9)	5 (33)	10 (67)	
V_2	27 (16)	11 (41)	16 (59)	
V_3	35 (21)	15 (43)	20 (57)	
$V_1 + V_2$	20 (12)	10 (50)	10 (50)	
$V_2 + V_3$	48 (28)	26 (54)	22 (46)	
V_1–V_3	23 (14)	11 (48)	12 (52)	
Median preop symptom duration in mos (IQR)	84 (44–168)	84 (45–180)	72 (36–165)	0.64
Median time until pain free in wks (IQR)	27 (7–53)	28 (8–52)	25 (6–50)	0.11
Median age in yrs (IQR)	72 (35–99)	78 (45–92)	70 (38–95)	0.059
Dose, Gy				0.041
70	11 (6)	1 (9)	10 (91)	
75	24 (14)	10 (42)	14 (58)	
80	132 (79)	67 (51)	65 (49)	
85	1 (1)	0 (0)	1 (100)	
Sensory changes post-SRS				0.005
Yes	83 (49)	48 (58)	35 (42)	
No	85 (51)	30 (35)	55 (65)	

Values are expressed as number (%) unless otherwise specified.

TABLE 7. Multivariate analysis of SRS outcomes

Predictor Variable	HR (95% CI)*	p Value
Age	0.972 (0.948–0.997)	0.027
Time until pain free	0.992 (0.983–1.002)	0.107
Dose, Gy	—	0.085
75 vs 70	0.146 (0.019–1.115)	0.064
80 vs 70	0.474 (0.086–2.632)	0.394
85 vs 70	2.333 (0.178–30.629)	0.519
Presence of post-SRS sensory changes	0.392 (0.213–0.723)	0.003

Multivariate Cox regression analysis using only variables with $p < 0.2$ from univariate analysis (Table 6).

* HRs < 1 suggest a higher likelihood of having a favorable (BNI I or II) outcome.