Assessment of pain control, quality of life, and predictors of success after gamma knife surgery for the treatment of trigeminal neuralgia

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Object. There are various surgical treatment alternatives for trigeminal neuralgia (TN), but there is no single scale that can be used uniformly to assess and compare one type of intervention with the others. In this study the objectives were to determine factors associated with pain control, pain-free survival, residual pain, and recurrence after gamma knife surgery (GKS) treatment for TN, and to correlate the patients' self-reported quality of life (QOL) and satisfaction with the aforementioned factors.

Methods. Between the years 2000 and 2004, the authors treated 81 patients with medically refractory TN by using GKS. Fifty-two patients responded to a questionnaire regarding pain control, activities of daily living, QOL, and patient satisfaction.

The median follow-up duration was 16.5 months. Twenty-two patients (42.3%) had complete pain relief, 14 (26.9%) had partial but satisfactory pain relief, and in 16 patients (30.8%) the treatment failed. Seven patients (13.5%) reported a recurrence during the follow-up period, and 25 (48.1%) reported a significant ($> 50\%$) decrease in their pain within the 1st month posttreatment. The mean decrease in the total dose of pain medication was 75%. Patients' self-reported QOL scores improved 90% and the overall patient satisfaction score was 80%.

Conclusions. The authors found that GKS is a minimally invasive and effective procedure that yields a favorable outcome for patients with recurrent or refractory TN. It may also be offered as a first-line surgical modality for any patients with TN who are unsuited or unwilling to undergo microvascular decompression.

KEY WORDS • gamma knife surgery • trigeminal neuralgia • quality of life • neurosurgical outcome

Trigeminal neuralgia is the most common cranial neuropathy, with a mean incidence of four per 100,000 in the healthy population.¹² Most patients are treated initially with a variety of medications (for example carbamazepine, phenytoin, gabapentin, and baclofen) up to the maximal dose that they can tolerate. For those who do not receive adequate pain relief from medications or who cannot tolerate the side effects, surgical intervention is a feasible option, although the designation of the best surgical treatment for TN in the general population remains controversial.^{7,30,33}

The description of the first documented case of TN is found in the book *Diseases of the Head*, written by Dr. Johann Wepfer in 1727; subsequently, Nicholas André de-

scribed two cases of true TN in 1732.⁴ Since then, a variety of treatments have been advocated and practiced by surgeons throughout the world. Various safe and effective surgical treatment alternatives for TN now exist, such as MVD,⁴⁶ percutaneous radiofrequency rhizotomy,³ glycerol rhizolysis,¹⁴ percutaneous balloon microcompression,²³ and GKS.³⁵ All of these surgical procedures have been proposed as treatments of choice for TN in various studies published at different times.^{24,49}

None of these studies, however, used uniform outcome measures for success or failure, thus making it difficult for clinicians and patients to determine what treatment may be most efficacious for individual situations. Because pain is both the presenting and the hallmark symptom in TN, the status and severity of the disease at presentation as well as after any procedure largely depend on patients' subjective experience, self-reported QOL, and impairment of ADL due to pain. A variety of factors like age, sex, duration of disease, pain threshold, and, possibly, the emotional makeup of the patient can influence these criteria. Therefore, no single, reliable scale exists in the literature that has gained con-

Abbreviations used in this paper: ADL = activities of daily living; EOITP = evaluative overall intensity of total pain experience; GKS = gamma knife surgery; MR = magnetic resonance; MVD = microvascular decompression; PPI-VAS = present pain intensity-visual analog scale; PRI = pain rating index; QOL = quality of life; TN = trigeminal neuralgia; V₁ = first division of the trigeminal nerve; V₂ = second division of the trigeminal nerve; V₃ = third division of the trigeminal nerve.

sensus as a uniform method that can be used to assess and compare one form of intervention for pain control with another in patients suffering from TN.

It is extremely important that long-term follow-up evaluation should be diligently pursued because TN, a subjective disorder, can often be difficult to assess. The patients may have no pain, slight pain, or moderate pain from one day to the next, and their degree of pain may vary during the course of days, weeks, or years. Most physicians, however, agree that any reliable report should include details about the study design, patient selection criteria, follow-up duration, definitions of the outcome measures, recurrences, successes and failures, details of any complications, and, of course, descriptions of surgical techniques.²⁹ We reviewed and stratified our data on the results of GKS treatment for TN based on these recommended criteria. Our study objectives were to determine factors associated with pain control, pain-free survival, residual pain, and recurrence after GKS treatment for TN and to correlate patients' self-reported QOL and satisfaction with these aforementioned factors.

CLINICAL MATERIAL AND METHODS

Patient Population

Between 2000 and 2004, 81 patients with medically refractory TN were treated with GKS by using the Leksell Gamma Knife Model B (Elekta Instruments, Atlanta, GA) at the Gamma Knife Radiosurgery Center of Louisiana State University Health Sciences Center in Shreveport. The follow-up duration was at least 6 months in 68 patients, and these were the ones who were contacted to participate in the study. A questionnaire was mailed to all of them, and subsequent telephone calls were made to solicit their response. Fifty-two patients (76.5%) responded to the follow-up questionnaire, two patients had died (one at 6 and one at 7 months after radiosurgery) due to cardiac disease, two did not respond to the questionnaire, and the other 12 could not be contacted.

The study cohort consisted of the 52 patients (18 men [34.6%] and 34 women [65.4%]) who responded to a survey regarding the outcome of their GKS treatment. Patients ranged in age from 37 to 88 years, with a median age of 66.5 years. Twenty-seven patients (51.9%) had left-sided pain and 25 (48.1%) had pain on the right side. Only one patient (1.9%) presented with bilateral pain and underwent bilateral GKS. The distribution of pain among the branches of the trigeminal nerve was as follows: four in V_1 , 16 in V_2 , 14 in V_3 (including one patient with bilateral V_3 pain), six in V_1 and V_2 , and nine in V_2 and V_3 . Two patients presented with pain involving all divisions of the trigeminal nerve on the affected side (Table 1).

The pain was clinically characterized as "typical" in 47 patients (90.4%); atypical features were present in five (9.6%). The median pain duration was 70 months (range 5–282 months), whereas the median time between establishing the diagnosis of TN and GKS treatment was 60 months (range 4–240 months).

Patient Selection and Pain Management Criteria

Patients with electrical shock–like paroxysmal facial pain involving one or more divisions of the trigeminal nerve and

TABLE 1

Side and branches of the trigeminal nerve involved in pain in 52 patients with refractory TN who underwent GKS

Side	Branch							Total
	V_1	V_2	V_3	$V_1 + V_2$	$V_2 + V_3$	$V_1 + V_3$	$V_1 + V_2 + V_3$	
rt	1	9	5	4	3	1	1	24
lt	3	7	8	2	6	0	1	27
bilat	0	0	1	0	0	0	0	1
total	4	16	14	6	9	1	2	52

with no findings of pathological entities on cranial MR imaging or computerized tomography scans were considered to have idiopathic TN. All of our patients had been evaluated using cranial MR imaging prior to referral for GKS to exclude any lesion in the cerebellopontine angle, petrous apex, cavernous sinus, or cranial base, and none had abnormal neurological findings related to the trigeminal nerve at the time of diagnosis.

Because medical treatment is always the first step for the management of TN, all patients in this study had undergone a trial of medications that failed to provide adequate pain control, although they had a good response at earlier stages of their disease. Carbamazepine was the principal medication used before GKS. Twenty-three patients (44.2%) taking this agent and 12 patients (23.1%) taking narcotic drugs reported serious side effects like dizziness, difficulty concentrating, drowsiness, nausea, vomiting, and blurred vision, and were unable to increase their medication dose up to a level that might be sufficient for pain relief.

Twenty-six patients (50%) in this cohort had previously undergone various surgical interventions and failed to get either adequate or permanent pain relief from those procedures. Our institutional policy is to offer GKS for TN to patients who are older than 65 years (although we do not enforce a strict age limit for MVD), those who do not want MVD, and to those with poor medical status.

Surgical Procedure

A Leksell model G stereotactic head frame was affixed to the patient's head after induction of conscious sedation and local anesthesia. One-millimeter-thick, Gd-enhanced axial MR imaging slices of the brain were obtained with the spoiled gradient-recalled acquisition in steady state sequence. It has been reported that in patients who have not undergone previous surgery for TN, blood vessel–fifth cranial nerve contact revealed with high-resolution MR imaging might indicate a particularly favorable response to GKS.¹⁸ Nevertheless, in a previous study performed at our center¹⁷ it was concluded that the presence or absence of vascular compression at the trigeminal nerve root entry zone was not a predictor of favorable outcome after GKS, so this factor was not taken into consideration for the current study.

The imaging data were transferred to the Gamma Knife computer workstation via the Ethernet. Leksell Gamma Plan software was used to localize the radiosurgical target. A team composed of a neurosurgeon, a radiation oncologist, and a medical physicist performed dose planning. A

50% isodose line enclosed the target margin receiving the prescribed dose in all patients. A single 4-mm collimator was used to target the trigeminal nerve root entry zone approximately 2 to 4 mm distal to the nerve's exit from the pons before it enters the Meckel cave. The irradiated tissue volume was 88 mm³ for all patients. The mean maximum prescribed dose was 80 Gy (range 70–90 Gy) and the mean marginal dose was 40 Gy (range 35–45 Gy). During targeting, precautions were taken to prevent the pons and brainstem from receiving more than 15 Gy at the maximal exposure point. Radiosurgery treatment was administered using the Leksell Gamma Knife model B-2 (Elekta Instruments) before July 2003 and we have used model C since then. At our institution, we follow the policy of administering a single intravenous dose of 40 mg methylprednisolone at the conclusion of the radiosurgery procedure in all the cases to prevent the occurrence of immediate postradiosurgery edema in the normal brain tissue surrounding the target volume, which is unavoidably exposed to fall-off radiation isodoses. Patients were observed overnight at the hospital and discharged home the following day.

Follow-Up Protocol

Regular follow-up evaluations consisted of clinic visits at 6-month intervals post-GKS. Success of the procedure was assessed subjectively (degree of pain relief) with patient interviews and objectively with a focused neurological examination, looking for any possible complications related to GKS. It has been reported in a previous study that results of enhanced MR imaging at 3 to 6 months after GKS at a maximal dose of 70 to 90 Gy do not correlate with the clinical response, and therefore routine posttreatment MR imaging is not warranted.²⁶ We therefore did not include any imaging studies as a part of our routine follow-up protocol.

Data Acquisition and Outcome Parameters

All data available from previous surgical and clinical follow-up records were reviewed and stored in a computer database. This data set was matched and updated using the information acquired from a detailed questionnaire that included the short-form McGill pain questionnaire, a PPI-VAS, select items from the Short Form-36 related to ADL, QOL, impairment due to TN, and a patient satisfaction scale. Together these instruments provided information about the degree and duration of pain relief, the need for further therapy, the presence of any surgical sequelae, and a subjective assessment of the patients' overall degree of improvement regarding ADL and QOL, as well as satisfaction with the outcome. All instruments have already been validated in previous studies.^{9,28,37,41}

Parameters to determine pain control were derived from the short-form McGill pain questionnaire. The sensory PRI, affective PRI, total PRI, PPI-VAS, and EOITP were assessed in the patients before and after GKS treatment to determine the amount of pain control. Pain control due to GKS was calculated as either the difference in PPI-VAS or EOITP (sensory PRI + affective PRI), before and after GKS. Data on other patient characteristics were obtained to determine factors associated with pain control and TN recurrence.

Statistical Analysis

Except for age, the quantitative variables measured in the patients such as pain control measures, QOL and satisfaction scores, pain duration, and radiosurgery prescription dose were distributed nonnormally. Hence, nonparametric methods such as the Spearman rank correlation and Wilcoxon rank-sum tests were used to determine factors significantly correlated with recurrence and pain control. A general linear model was used to determine independent significant factors for pain control. To account for possible correlations among multiple pain-producing branches within patients, the proportion of patients with residual pain in a branch that was a source of the initial pain were compared among the three possible branches for pain by using a general estimating equation method.

The latency period after which they became free of pain for the first time after GKS was determined for all patients. The Kaplan–Meier method was used to estimate the pain-free survival rate and the latency period to being free of pain. The Cox proportional hazards model was used to determine significant factors for pain-free survival or period to being pain-free. The same survival analyses were performed to determine significant factors for disease-free interval or time to recurrence. A 5% level of significance was used for all statistical tests, and SAS Version 8.2 software (SAS Institute Inc., Cary, NC) was used for statistical computing.

Because most of the previously published studies regarding outcome of surgical treatment for TN used more global measures to stratify their results, for ease of comparison we also included a similar stratification: complete pain relief (free of pain with no medications); partial, satisfactory pain relief (recurrent or residual pain was less severe than that occurring preoperatively and that pain could be controlled with medication); or treatment failure (had no relief and/or worsening of symptoms or needed a subsequent procedure).

RESULTS

The patients were followed for a mean period of 16.5 months (range 6–45 months). Thirty-six patients (69.2%) in the current study experienced complete or satisfactory pain relief at least once after GKS; however, seven of these patients (19.4%) had recurrence of pain at various intervals. Overall, 22 patients (42.3%) had complete pain relief, 14 (26.9%) had partial but satisfactory pain relief, and in 16 (30.8%) the treatment failed. Twenty-five patients (48.1%) reported a significant (> 50%) decrease in their pain within the 1st month following GKS.

The mean decrease in the total dose of pain medication was 75%. The mean improvement on PPI-VAS was 49.5%, the patients' self-reported QOL scores improved 90%, and the overall patient satisfaction was 80%. Table 2 displays in greater detail all the parameters that were used to analyze the outcome for the current study. During the follow-up period, the proportions of residual pain were six (46.2%) of 13, 15 (45.4%) of 33, and 15 (57.7%) of 26 for the sixth, seventh, and eighth cranial nerve branches, respectively. Also, a general estimating equation model showed that the chance of having residual pain after GKS did not depend on the branch of the trigeminal nerve that was initially involved with pain ($p = 0.93$).

TABLE 2

*Quantitative variables in 52 patients
with medically refractory TN who underwent GKS**

Variable	Median (range)
age (yrs)	66.5 (37–88)
pain duration (mos)	70.0 (5–282)
pain duration from diagnosis (mos)	60.0 (4–240)
FU duration (mos)	16.5 (6–45)
% decrease in meds	75.0 (0–100)
QOL score (scale 1–5)	4.5 (1–5)
satisfaction score	4.0 (1–5)
Δ PPI-VAS (scale 0–100)	49.5 (–6–100)
Δ EOITP (scale 0–5)	3.0 (–1–5)
Δ S-PRI (scale 0–27)	9.0 (–6–28)
Δ A-PRI (scale 0–12)	2.0 (–3–12)
Δ T-PRI (scale 0–39)	10.0 (–6–39)
max radiation dose (Gy)	80.0 (70–90)

* A-PRI = affective PRI; meds = medications; S-PRI = sensory PRI; T-PRI = total PRI.

Correlations among quantitative factors were analyzed using the Spearman rank correlation coefficient. Significant correlations among the different pain control measures proved that the different indices were consistent in measuring pain (Table 3). The pain control measures were significantly correlated with QOL and the patients' self-reported satisfaction scores, and these in turn were highly correlated with each other. Age and pain duration had no significant correlations with pain control, QOL, or patients' self-reported satisfaction scores.

Table 4 shows significant group comparisons for pain control between those with and without residual pain as well as between those with and without a decrease in pain within 1 month after GKS. It also shows significant comparisons in pain duration between those with and without previous procedures. Those without residual pain and with a significant decrease in pain after less than 1 month had significantly better pain control, and those without a previous procedure had a significantly shorter duration of pain. There were no observed significant differences in pain control or duration for the categories of sex, side of pain, number of branches involved, recurrence, and branch. Hence, these were not significantly associated with pain control or duration.

TABLE 3

Significant correlations among quantitative variables

Variable Correlated	w/ Variable	Correlation Coefficient	p Value
Δ VAS	Δ EOITP	0.891	<0.01
	Δ T-PRI	0.766	<0.01
	Δ S-PRI	0.747	<0.01
	Δ A-PRI	0.665	<0.01
	QOL	0.649	<0.01
Δ EOITP	satisfaction score	0.628	<0.01
	Δ S-PRI	0.757	<0.01
	Δ A-PRI	0.636	<0.01
	QOL	0.668	<0.01
Δ S-PRI	satisfaction score	0.636	<0.01
	Δ A-PRI	0.743	<0.01
	QOL	0.613	<0.01
QOL	satisfaction score	0.586	<0.01
	satisfaction score	0.781	<0.01

To determine independent, significant factors for pain control, defined as either the change in PPI-VAS or EOITP, a multivariate model using the change in these parameters as the dependent variable and the factors observed to be significantly associated with pain control from individual univariate analyses (QOL, overall patient satisfaction score, presence of residual pain, and pain decrease within 1 month after GKS) was constructed from the data. Given the high correlation between QOL and overall patient satisfaction scores and between the presence of residual pain and a decrease in pain within 1 month after GKS, the only independent, significant predictors for pain control were the QOL score and the presence of residual pain. The results of the multivariate analysis are shown in Table 5.

Figure 1A shows the proportion of patients who were not yet free of pain at different times after GKS treatment, and Fig. 1B shows the proportion of patients without recurrence at different follow-up times after GKS. The median time to pain control after GKS was 9 months and the median interval at which patients remained pain-free was 17 months (95% confidence interval 10–23 months) after GKS. The recurrence rate was estimated to be 23.1% and the median time to recurrence was 17.5 months after GKS treatment.

Using separate univariate analyses, the factors significantly associated with first time to reaching pain-free status

TABLE 4

Significant group comparisons on pain control measures

Pain Control/Duration	Group	No. of Patients	Median (range)	p Value
Δ PPI-VAS	w/o residual pain	22	92.5 (–3–100)	<0.01
	w/ residual pain	30	24 (–6–82)	
Δ EOITP	w/o residual pain	22	5 (1–5)	<0.01
	w/ residual pain	30	1.5 (–1–5)	
Δ PPI-VAS	w/o pain decrease in <1 mo	27	31 (–6–96)	0.016
	w/ pain decrease in <1 mo	25	59 (–3–100)	
Δ EOITP	w/o pain decrease in <1 mo	27	2 (–1–5)	0.024
	w/ pain decrease in <1 mo	25	3 (0–5)	
duration of pain from diagnosis	w/ previous procedure	26	62 (4–240)	<0.01
	w/ no previous procedure	26	39.5 (4–160)	
duration of pain	w/ previous procedure	26	96 (9–282)	<0.01
	w/ no previous procedure	26	51 (5–167)

Fig. 1. A: Graph showing pain-free survival curve. Abbreviation: Fr = fraction. B: Graph showing recurrence-free survival curve.

are listed in Table 6. Using a Cox proportional hazards model for first time to pain-free status and a stepwise selection of variables among those listed in Table 6, the only independent, significant predictors of the first time pain-free status would be reached were the QOL score of a patient ($p = 0.025$) and change in PPI-VAS ($p < 0.01$), which are shown in Table 7. There were no significant predictors for recurrence.

DISCUSSION

Trigeminal neuralgia is the most frequently encountered type of craniofacial neuralgia. It is usually the foremost consideration in the differential diagnosis when a patient reports intermittent, paroxysmal pain confined to the distribution of the trigeminal nerve. Pain may be confined to a small area or spread throughout the distribution of one or more divisions of the trigeminal nerve.^{2,12} The features of the pain that characterize TN, other than its location, are its severity and its lancinating or electrical shock-like quality. The pain can be spontaneous or triggered by almost any stimulus.^{6,47} Many procedures have been devised in an attempt to alleviate TN in patients in whom medical treatment failed to control pain.

As can be expected, most authors have advocated the superiority of the procedure that they use; hence, large series documenting a considerable number of patients have been published during the last 30 years.²⁶ The cause of idiopathic TN has not been fully explained, although compression

of the trigeminal nerve by a vascular structure (as first observed by Dandy) is the most common finding during surgical exploration of the cerebellopontine angle, and pain is usually relieved after the patient undergoes MVD.^{36,38,44,50} Therefore, MVD has been considered the most appropriate surgical intervention for pain control in TN.^{10,11} The initial success rate has been reported as 92.7%, with mortality rates as low as 0.7% in larger published series.¹ In some series, the mean time to recurrence was reported as 1.9 years, with 47 to 75% of recurrences occurring in the 1st year, and the likelihood of recurrence thereafter was 2% per year.^{1,21,31,49} In another series, major recurrences averaged 3.5% and minor recurrences averaged 1.5% annually.¹⁹

Even with high success rates, surgical complications such as cerebellar infarction, cerebrospinal fluid leakage, and pulmonary complications have been observed at a rate of less than 1%, whereas palsies of the seventh and eighth cranial nerves were also noted as unique complications after MVD, occurring in approximately 4% of patients.⁵² Prevention of complications is extremely important because although TN itself is eminently treatable, deafferentation pain (as a complication of destruction of the trigeminal system) is virtually untreatable. The absence of vascular compression during exploration of the cerebellopontine angle is another critical issue because approxi-

TABLE 5
Independent, significant predictors of pain control measures in patients with refractory TN

Pain Control Measure	Predictor	p Value
ΔPPI-VAS	residual pain	<0.01
	QOL score	<0.01
ΔEOITP	residual pain	<0.01
	QOL score	<0.01

TABLE 6
Significant predictors of first time reaching pain-free status (univariate analyses)

Factor	p Value
ΔS-PRI	0.011
ΔA-PRI	<0.01
ΔT-PRI	<0.01
ΔPPI-VAS	<0.01
ΔEOITP	<0.01
QOL score	<0.01
satisfaction score	0.013
% decrease in meds	<0.01

TABLE 7
Independent, significant predictors of first
time reaching pain-free status (multivariate analysis)

Factor	p Value
ΔPPI-VAS	<0.01
QOL	0.025

mately 15% of patients may not have a detectable vascular compression.⁴⁹ Patients with anomalies of the posterior fossa and bone structure variations present another serious challenge during exploration.³⁷ Therefore MVD, although it continues to be accepted as the intervention of choice for medically refractory TN by a vast majority of neurosurgeons, has also been subjected to a lot of skepticism, thus mandating the search for other less invasive procedures.

Within the past decade, stereotactic radiosurgery has been proposed as a therapeutic modality for patients with TN,^{8,43,48,52} although its exact mechanism of action is still unclear.^{22,45} Most reports in which the outcomes of radiosurgery for TN are assessed have inadequately addressed the issue of patients' QOL after treatment.⁴² Some authors have reported an overall response with GKS that is similar to that obtained with other surgical therapies performed as the first procedure for the treatment of TN.¹⁶ Nevertheless, there is no consensus regarding the factors that may influence the favorable outcome. Some say that GKS is among appropriate options for TN for patients in whom optimal medical management, with or without prior invasive treatment, has failed.²⁰ Others have proposed that patients with no previous surgical interventions have a better chance of complete pain relief after GKS.^{13,25,34,42,48} Some authors have also reported that patients with an atypical pain component had a lower rate of pain control after GKS.^{20,35} In our study we did not identify a significant difference in pain relief for patients who had undergone previous interventions compared with those receiving radiosurgery as the primary intervention.

It has been asserted that the long-term outcome for secondary TN after GKS is very similar to the outcome for cases of idiopathic TN treated with the same modality and that GKS is safe and effective in both idiopathic and secondary TN, particularly in patients with inoperable lesions.^{32,51} The results of GKS treatment for patients with postherpetic neuralgia are also reported to be satisfactory, and this was corroborated in our study.³⁹

A strong correlation between the development of new facial sensory loss and achievement and maintenance of pain relief after GKS has been reported,³⁴ although contradicting reports also exist.⁵² We did not find a significant association between pain relief and the development of a new sensory deficit after GKS.

The duration of pain preceding the treatment (< 50 months) has also been proposed to have an influence on favorable outcome after GKS;⁴³ thus, early GKS (once the diagnosis is established) is recommended for patients with TN.⁴⁸ In our cohort, we found no significant association between pain duration and favorable outcome.

We used a mean maximal radiosurgery prescription dose of 80 Gy (70–90 Gy). It has been reported that a maximal dose of more than 70 Gy is associated with a significantly

greater chance of pain relief,⁴⁰ and radiosurgery prescription doses up to 90 Gy have been shown to be safe.¹⁴ Within the given dose limits, our statistical analysis did not show a correlation between the maximal radiosurgery prescription dose and good pain control.

In a previous study, patients with sustained pain relief reported a mean 100% improvement in their QOL as a direct result of pain relief after GKS, and 100% believed that the procedure was successful, whereas 65% thought their treatment was a success after a mean 80% improvement in QOL.⁴² We found similar results; the improvement in QOL and patient satisfaction correlated well with pain control measures. Several measures used to quantify the pain also correlated well with each other, which further supports the reliability of our findings. We were not able to demonstrate any significant association between pain control or recurrence and patients' age, sex, the side and branch of the trigeminal nerve involved in pain, and the radiosurgery prescription dose.

To summarize, there is no single, standardized protocol for treating medically refractory TN. The most important aspects in selecting the procedure are the suitability to the patients' individual condition, their expectations and willingness to take any risks associated with each particular treatment, and the surgeon's comfort level and experience with a particular procedure.

CONCLUSIONS

Gamma knife surgery is a minimally invasive and effective procedure that may be indicated for TN of both primary and secondary origin, with a favorable outcome that is comparable to the results obtained with MVD. There are still not enough long-term follow-up data available from large series. Considering the satisfactory results in our own experience, GKS may be offered as a feasible modality for patients with refractory TN, provided that the patient clearly understands the advantages and disadvantages of each and every treatment option available.

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