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Long-term outcomes of microvascular decompression in trigeminal neuralgia: a systematic review

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Abstract

Objective: To assess the long-term results of microvascular decompression (MVD) using autologous muscle for trigeminal neuralgia (TGN).

Methods: We retrospectively reviewed all primary MVD patients for typical classic TGN without previous surgery between 2000 and 2019 at a tertiary supraregional neurosurgery centre. Age, sex, surgical findings, surgical outcomes, complications, and recurrence at 1 year, 5 years, and final follow-up were recorded. Pain relief was measured with the Barrow Neurological Institute (BNI) score. Categorical variables were compared using the Chi-squared test with continuity correction, and Kaplan-Meier curves and Cox regression were used to determine recurrence risk factors.

Results: We analyzed 1035 patients with a median follow-up of 8 years (IQR 5-13 years; range 3-20 years). Immediately after surgery, 893 patients (86.7%) had complete pain relief, 110 (10.3%) had partial pain relief (both groups did not need medication), and 32 (2.9%) had no relief. There were 141 recurrences (13.8%) at a median of 3 years (IQR 2-6 years) after surgery. The proportion of patients without recurrence at 1 year was 97%, 90% at 5 years, 85% at 10 years, 83% at 15 years, and 81% at 20 years. There was no difference in the likelihood of recurrence between patients with complete (114/907 12.6% recurrences) or partial (19/110 17.9% recurrences) pain relief (log-rank p=0.124). The rate of MVD failure was significantly higher in patients with venous compression (N=322, N=16, 5%) than arterial compression (N=14/703, 2%) (chi-squared p=0.015). In a Cox Proportional Hazards model, the hazards of recurrence for venous compression and no immediate postoperative pain relief were 1.62 (95% confidence interval (CI) 1.16-2.27) and 2.65 (95% CI 1.45-4.82), respectively. 124 (12.1%) complications were documented: 44 facial numbness (35.9%), facial nerve palsy (N=37, 29.8%), CSF leak (N=13, 10.5%), and diplopia (N=5, 4%) which resolved in all patients.

Conclusions: MVD with autologous muscle provides long-lasting pain relief in TGN with vascular compression with minimum morbidity and is a viable alternative to synthetic materials.

Keywords: Trigeminal Neuralgia (TGN);neurovascular compression (NVC) ; Computed Tomography (CT); microvascular decompression (MVD); Magnetic Resonance Imaging (MRI) and anterior inferior cerebellar artery (AICA).

1. Introduction

Trigeminal Neuralgia (TGN) is defined as paroxysms of severe ("lightning-bolt") facial pain in the somatosensory distribution of the trigeminal nerve [1]. The most widely accepted cause of classic primary TGN is neurovascular compression (NVC) of the trigeminal nerve at the root entry zone by a blood vessel. Primary TGN is considered classic,

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where the pain attacks are purely paroxysms, often with triggers, lasting from a fraction of a second to two minutes, and are of a severe, shooting/stabbing quality with no background pain [1]. A typical feature of TGN include a background of persistent or prolonged pain of a boring, aching or constantly nagging nature [1]. Treatment of classic TGN initially involves the use of anticonvulsants, but 44% of patients suffer from side effects and most patients require surgical treatment [2]. These are destructive procedures including radiofrequency thermal-rhizotomy, percutaneous glycerol rhizotomy, balloon micro-compression and stereotactic radiosurgery [3]. The only non-destructive procedure is microvascular decompression (MVD) [3]. The benefits and drawbacks, recurrence rates and complications of these procedures have been reported in several previous review articles, which have reviewed many series and non-randomized comparative studies [3-6]. The literature suggests MVD is the most effective procedure, with the lowest recurrence of pain and least complications [3-6]. But there is a wide range of literature on MVD for TGN, with recurrence rates between 6% and 40% [3,4,7-24]. The point estimates of many outcome measures, including recurrence, immediate and long-term pain relief, in systematic reviews are broad, the scales used to assess outcomes are not always objective, and the duration of follow-up is variable [3,4]. Previous series also demonstrate the need for patient selection as patients with an atypical range of symptoms have a poorer outcome [7,8,16,25-27]. Likewise, patients with prior destructive or concomitant procedures with MVD may have less pain relief and a higher failure rate after MVD [3,14,15,22-24,28-32]. So, while there are many series, there are only a few studies of a "pure MVD" (no prior or concomitant procedures) cohort with a large sample (typically greater than 200-300 patients) and a mean/median follow-up of greater than 5 years and with follow-up data for >10 or >15 years [3-5]. Finally, there will always be differences in individual surgeon techniques, practice and experience. Almost all published MVD studies have used synthetic materials for decompression (Teflon, Gore Tex) [3,4,33]. There is very little literature on the use of autologous muscle for decompression and no large series with long-term follow-up [34,35]. This paper reports our results of MVD for typical TGN with NVC in 1035 patients without prior procedures, using autologous muscle for decompression, and with long-term follow-up.

2. Materials and methods

2.1. Patient Population & Outcome Assessment

Patient Population & Outcome Assessment We retrospectively reviewed MVD cases for typical classic TGN operated mainly by the senior author in the neurosurgery departments of Lahore General Hospital/Punjab Institute of Neurosciences and Jinnah Hospital, Lahore, between 2000 and 2019. Secondary TGN cases were excluded. Atypical cases are not offered MVD in our practice. All patients were medically refractory/intolerant and were examined by a neurologist and neurosurgeon. Secondary TGN was ruled out by CT/MRI preoperatively. Information was obtained from patient admission notes, operative notes, discharge letters and follow-up reports. Data collected included patient demographics, pain property/distribution, surgical findings, operative outcomes, complications and recurrence. Pain outcome was measured using the Barrow Neurological Institute (BNI).36 This was initially done with two 6-monthly follow-up clinic visits and yearly visits up to five years. Subsequently, pain outcome was assessed by annual telephone surveys by people not involved with the operating neurosurgeon. If patients did not answer their phone calls or were deceased, their referring doctors/next-of-kin were contacted to get their last known status for follow-up. Patients who were not contactable for two or more years/or their whereabouts were unknown were censored as lost to follow-up. Their last follow-up data was used. The last date of follow-up was 2022 to ensure a minimum of 3 years of follow-up. We defined typical TGN as paroxysmal, shooting, stabbing/electrical lancinating pain and no continuous background facial pain. Pain recurrence was defined as progression from a BNI pain score of I and II to III, IV, and V. For patients with a BNI postoperative pain score of III, recurrence was defined as progression to BNI IV or V. Failed MVD was defined as no pain relief in the immediate postoperative period (BNI V).

2.2. Surgical Procedure

All patients were operated on in a park-bench position with the affected side up using a retro mastoid suboccipital approach. The head was turned to the opposite side and the neck flexed 30 degrees to the opposite shoulder, with a 2-3 finger gap between the chin and sternum. The vertex was dropped and the malar eminence was the highest point of the head, and a 6-7-cm linear incision was used. The head end was raised 10-15 degrees above the floor. The contralateral axilla was supported by a roll and the ipsilateral shoulder was drawn down with shoulder straps. A 3cm circular craniectomy was made adjacent to the transverse and sigmoid sinus to expose the transverse-sigmoid sinus junction laterally. This is essential to expose the neurovascular structures in the CP angle after durotomy. The dura was incised in an inverted L-shaped fashion, with the durotomy leaves hinged on the transverse and sigmoid sinuses. The lateral cerebellar hemisphere was retracted medially to open the corridor between the petrous pyramid and the lateral surface of the cerebellum. CSF was drained after opening the CP angle cistern and allowed to drain freely to achieve a floppy and pulsating cerebellum. The superior petrosal vein was preserved or sacrificed depending on its encroachment

into the surgical field. The fifth nerve from the cavum to the pons was completely exposed by a wide arachnoid dissection and cutting of trabeculae. The arachnoid over the 7th-8th complex was preserved to prevent damage. In cases where the superior cerebellar artery (SCA) was involved, the vessel was moved medially and a piece of muscle from the suboccipital muscles was interposed between the nerve and the vessel to prevent re-contact (Figure 1). The graft was typically large to prevent re-contact and could be crushed/flattened, which occasionally improved the mobility in complex conflict areas. The anterior inferior cerebellar artery (AICA) would elevate the nerve super medially and thus require inferolateral dissection to achieve a relaxed nerve, after which the graft was interposed. Tributaries of the superior petrosal vein and prepontine veins, as offending agents, were dissected carefully as the thin veins are fragile and prone to rupture as they are adherent to the nerve (Figure 2). The trigeminal nerve was dissected from the root entry zone to Meckel's cave to rule out an offending agent. Rarely, the nerve was caught between an artery and a vein, making the dissection complex. The rare vertebral/basilar encountered were difficult to deal with as they would return to the site of conflict from the new position. The muscle grafts used were larger and were lifted with the offending vessel using an instrument pushed against the tentorium and secured with fibrin glue.

2.3. Statistical analysis

STATISTICAL ANALYSIS The data were entered into and analysed by SPSS Version 26 (IBM) and Stata 17.0 (StataCorp LLC, Texas, USA). Descriptive statistics were used to describe the characteristics of the overall and the failed MVD cohort. Categorical variables were compared using the Chi-square test with continuity correction. We also used the Kaplan-Meier method to present the recurrence-free probability. The differences among groups were tested with the log-rank test. We performed a multivariable Cox regression analysis using a forward selection with the Likelihood Ratio test to determine the factors associated with TGN recurrence. All tests were two-tailed, and a P-value RESULTS Overall Cohort Characteristics A total of 1035 patients underwent MVD for TGN (table 1). None of the patients had undergone any previous MVDs or ablative surgeries. The median age at surgery was 47 years (IQR 41-53) (range 24-66 years). Most of the patients were female (N=601, 58.1%). The most common side affected was the right (N=584, 56.5%) and the most common pain distribution was in the region of V2+V3 branches of the trigeminal nerve (N=348, 33.7%). The SCA was the most frequent cause of trigeminal nerve root compression in 667 (66%) patients. The majority of patients (N=884, 85.8%) had a BNI pain score of V before surgery and the remainder had a score of IV. Following MVD, 893 patients (86.7%) had complete pain relief (postoperative BNI pain score of I) and 110 patients (10.3%) had partial pain relief without requiring any medication (postoperative BNI pain score of II). 32 patients (2.9%) had a failed MVD, i.e., no pain relief in the immediate postoperative period. These patients were given a 3–5-day trial of anticonvulsant medication, the response to which determined the further management (table 2). The median follow up of the whole cohort was 8 years (IQR 5-13 years) (range 3-20 years). A total of 985 (95.2%) patients had a follow-up of 3 or more years and 861 patients (83.2%) had a follow-up of 5 or more years. A total of 419 patients had a follow-up of 10 or more years and 193 patients had 15 or more years of follow-up. A total of 141 patients had a recurrence of TGN over a median follow-up of 3 years (IQR 2-6 years) with an incidence rate of 15 recurrences per 1000 person-years of follow-up.

Table 1 Characteristics of patients included in this study

Characteristic		**Count**	**% of Total (N=1,035)**
Age at operation (years), median (IQR)		1,035	47 (41 to 53)
Age Range	24 to 29 years	23	2%
	30 to 39 years	176	17%
	40 to 49 years	442	43%
	50 to 59 years	304	29.4%
	60 years or older	90	8.6%
Sex	Male	434	41.9%
	Female	601	58.1%
Side of Face Involved	Left	451	43.5%
	Right	584	56.5%
Pain Distribution	V1 Only	42	4.1%
	V2 Only	98	9.4%

	V3 Only	234	22.6%
	V1+V2	36	3.4%
	V2+V3	348	33.6%
	V1+V2+V3	277	26.7%
Operative Culprit	Superior Cerebellar Artery	679	65.6%
	Mixed Venous & Arterial Compression	229	22.1%
	Venous Compression	97	9.3%
	Anterior Inferior Cerebellar Artery	23	2.0%
	Basilar Artery	7	0.6%
Preoperative BNI Pain Score	IV	151	14.5%
	V	884	84.5%
Immediate Postoperative BNI Pain Score	I	893	86.2%
	II	110	10.6%
	V*	32*	2.9%
Recurrence		141	-

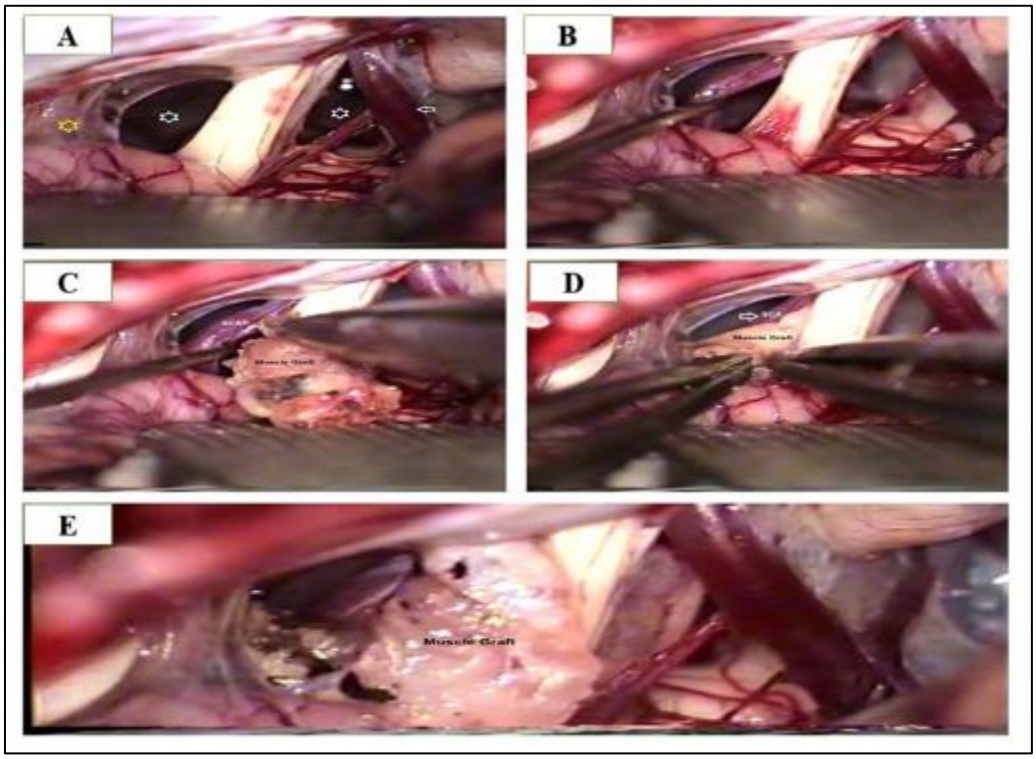

Figure 1 Left MVD with SCA as culprit vessel; (A) the corridor to the fifth nerve thoroughly dissected free of arachnoid (white star), whereas the 7th-8th complex should have an arachnoid shall preserved (yellow star), and the superior petrosal vein is visible (white arrow); (B) SCA causing the neurovascular conflict has been dissected off the conflict zone; (C) muscle graft being interposed between SCA and root entry zone; (D) the graft covers the entire length of the root entry zone and the inferior border of the nerve; (E) final position of the interposed graft

2.4. Operative Complications

In this study, there were 124 complications (12.1%) of the operation. The most frequent of these was facial numbness (N=44, 4.3%) and facial nerve palsy (N=37, 3.6%). There were 29 House-Brackmann grade II and eight grade III facial nerve palsies. All grade II palsies recovered with steroids and physiotherapy over time. Five of the grade III palsies recovered, and three improved to grade II. We reported a gross loss of hearing (clinically assessed) in seven of these cases, but it was not severe. These patients recovered on follow-up. There were 32 cases of facial numbness, which were grade II on the Barrow Neurological Institute facial hypesthesia scale,37 and 12 cases, which were grade III. Seven of the 12 cases improved to grade II, and the rest resolved. Since 2002, there has been no facial nerve palsy or numbness. Other complications include vertigo (N=25, 2.4%), CSF leak (N=13, 1.3%) and diplopia (N=5, 0.5%) which all resolved conservatively.

Table 2 Characteristics of patients who had a failed first MVD

Characteristic		**Count**	**% of Total (N=30)**
Failed MVD (Lack of Immediate Postoperative Pain Relief)		30	100.0%
Age of This Subgroup (years), median (IQR)		30	41 (33 to 47)
Sex	Male	16	53.3%
	Female	14	46.7%
Side of Face Involved	Left	17	56.7%
	Right	13	43.3%
Pain Distribution	V1 Only	1	3.3%
	V2 Only	3	10.0%
	V3 Only	11	36.7%
	V1+V2	2	6.7%
	V2+V3	6	20.0%
	V1+V2+V3	7	23.3%
Operative Culprit	Superior Cerebellar Artery	14	46.7%
	Mixed Venous & Arterial Compression	11	16.7%
	Venous Compression	5	36.7%
Preoperative BNI Pain Score	IV	7	23.3%
	V	23	76.7%
Management of Immediate Postoperative Failure*	Carbamazepine*	12	40.0%
	Re-exploration- Missed Loop	10	33.3%
	Re-exploration- Further Arachnoid Dissection	8	26.7%
BNI Pain Score after management of failure	I	18	60.0%
	III*	12	40.0%
Recurrence	Yes	12	-
	No	18	-

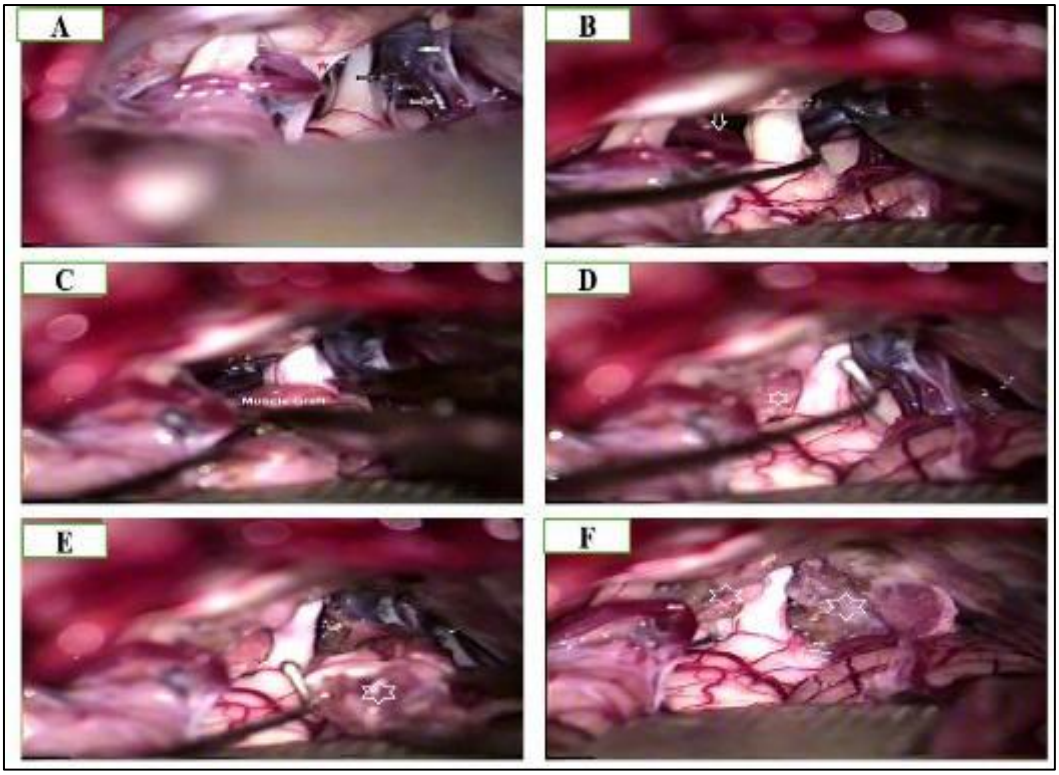

Figure 2 Pure venous compression (superior petrosal) in left sided MVD; (A) compression of the root entry zone being caused by the horizontal limb (black arrow) of the superior petrosal vein (white arrow solid), the opposite horizontal limb of the superior petrosal vein (white arrow hallow) and the caudal part of the vein is obscured by an arachnoid shawl (red star); (B) arachnoid dissection exposed the corridor and the underlying offending horizontal venous tributary (white arrow); (C) muscle graft being interposed between the vein and the root entry zone; (D) Caudal portion of the two-step graft interposition successfully completed (white star); (E) a second muscle graft being advanced for interposition of the rostral aspect of the offending vein (white star); (F) successful completion of a two-step interposition

2.5. Characteristics of Failed MVD Cohort

The details of the subset of patients who had a failed first MVD (N=30) are given in Table 2. Patients with venous compression of the trigeminal root entry zone (n=322) had a significantly higher rate of MVD failure (n=16, 5.0%) as compared to arterial compression (n=14/703, 2.0%) (Chi-square p = 0.015). While they were in hospital, they were started on a course of anti-convulsants and then, if they did not have pain relief (N=18, 60%) they were re-explored. In 10 patients, a missed loop was identified and in 8 patients, additional arachnoid dissection was performed along the entire course of the nerve. Two of these had grade III facial numbness, which decreased to grade II. The median follow-up period in this group was 12.5 years (IQR 3-16 years) and there were 18 recurrences during a median follow-up of 3 years (IQR 2.5-5 years).

2.6. Postoperative Outcomes

There were 141 recurrences in this study (13.75%). The success rate (i.e., no recurrence) was 97% at 1 year, 90% at 5 years (91% for patients with complete pain relief, 87% for those with partial pain relief, and 70% for those with a failed MVD), 85% at 10 years (86% for complete pain relief, 82% for partial pain relief, 59% for failed MVD), 82% at 15 years (83% for complete pain relief, 77% for partial pain relief, 59% for failed MVD) and 81% at the end of the follow-up period at 20 years (82% for complete pain relief, 77% for partial pain relief, 59% for failed MVD) (Figure 3a). The prognosis of cases of TGN where the offending vessel was a vein was worse compared to cases where only the artery was compressed (long-rank p-value = 0.001; Figure 3b). There was no difference in the chance of failure in patients who had complete (BNI I) or partial pain relief (BNI II) (log-rank p-value = 0.124; Figure 3c). The outcome was significantly worse in the patients who had a failed MVD with a greater probability of recurrence (long-rank p-value = 0.001; Figure 3c). In the patients who failed their first MVD, the worst outcome was in patients who were stabilized on anticonvulsant medication alone and were not reoperated, followed by those who had a missed loop, while the patients who had only further dissection of the arachnoid had no recurrence at all over the follow up period (long rank p-value = 0.014; Figure

3d). There were 51 (5%) patients aged more than 60 years in this study. Their median follow up was 6 years (IQR 4-8). The recurrence of TGN in this group of patients was not different from the other patients (long-rank p-value = 0.944). The annual recurrence rate was 3% in the first postoperative year, 2% in the following 3 postoperative years (life-table analysis, figure 4 and table 3). From the fifth postoperative year, the annual percentage of recurrence of patients was mainly less than 2%, and after the 16th year, 0%. The risk of recurrence in the first 5 years after the first MVD was high in patients who failed the first MVD (average annual recurrence 6%) and reduced by half in the following 5 years. All the recurrences in this group occurred in the first 10 years.

Table 3 Life table for annual recurrence of trigeminal neuralgia

Interval Start Time (Postoperative Year)	Number Entering Interval	Number Withdrawing during Interval	Number Exposed to Risk	Number of Recurrences	Proportion of Recurrences	Proportion Remaining	Cumulative Proportion Remaining at End of Interval	Std. Error of Cumulative Proportion Remaining at End of Interval
0	1035	0	1035.0	0	0.00	1.00	1.00	0.00
1	1035	2	1034.0	27	0.03	.97	0.97	0.01
2	996	0	996.0	20	0.02	0.98	0.95	0.01
3	976	25	963.5	24	0.02	0.98	0.93	0.01
4	927	54	900.0	20	0.02	0.98	0.91	0.01
5	853	92	807.0	7	0.01	0.99	0.90	0.01
6	754	97	705.5	8	0.01	0.99	0.89	0.01
7	649	98	600.0	10	0.02	0.98	0.88	0.01
8	541	44	519.0	5	0.01	0.99	0.87	0.01
9	492	67	458.5	7	0.02	0.98	0.85	0.01
10	418	44	396.0	2	0.01	0.99	0.85	0.01
11	372	63	340.5	0	0.00	1.00	0.85	0.01
12	309	20	299.0	4	0.01	0.99	0.84	0.01
13	285	46	262.0	2	0.01	0.99	0.83	0.02
14	237	41	216.5	4	0.02	0.98	0.82	0.02
15	192	42	171.0	0	0.00	1.00	0.82	0.02
16	150	43	128.5	1	0.01	0.99	0.81	0.02
17	106	40	86.0	0	0.00	1.00	0.81	0.02
18	66	32	50.0	0	0.00	1.00	0.81	0.02
19	34	2	33.0	0	0.00	1.00	0.81	0.02
20	32	32	16.0	0	0.00	1.00	0.81	0.02

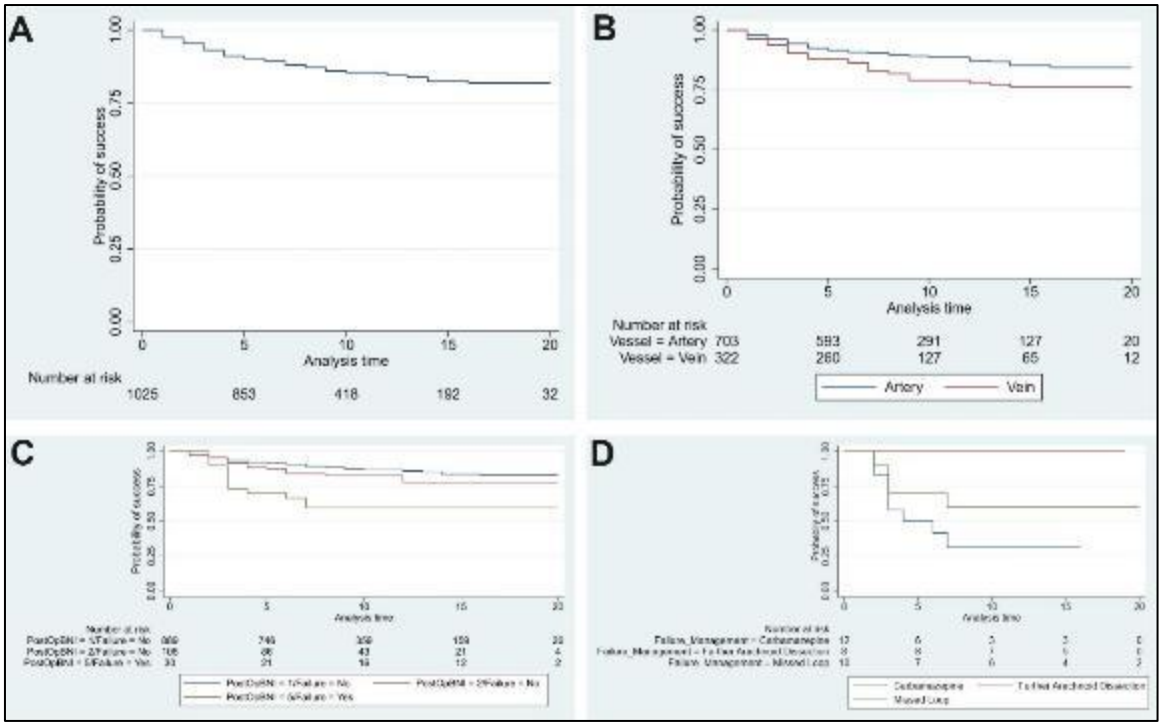

Figure 3 (A) Kaplan-Meier analysis for the recurrence of trigeminal neuralgia after MVD; (B) Kaplan-Meier analysis for the recurrence of trigeminal neuralgia after MVD by postoperative BNI pain score; (C) Kaplan-Meier analysis for the recurrence of trigeminal neuralgia after MVD by culprit vessel; (D) Kaplan-Meier analysis for the recurrence of trigeminal neuralgia after a failed first MVD by failure management

2.7. Prognostic Factors for Recurrence

A failed first MVD (compared to those who had complete or partial pain relief) and venous compression (compared to arterial compression) of the trigeminal root entry zone were the only prognostic factors found to be associated with an increased risk of recurrence for TGN in a multivariable Cox regression (Hazard Ratio (HR) 2.65, 95% Confidence Interval (CI): 1.45-4.82 and HR 1.62, 95% CI: 1.16-2.27, respectively).

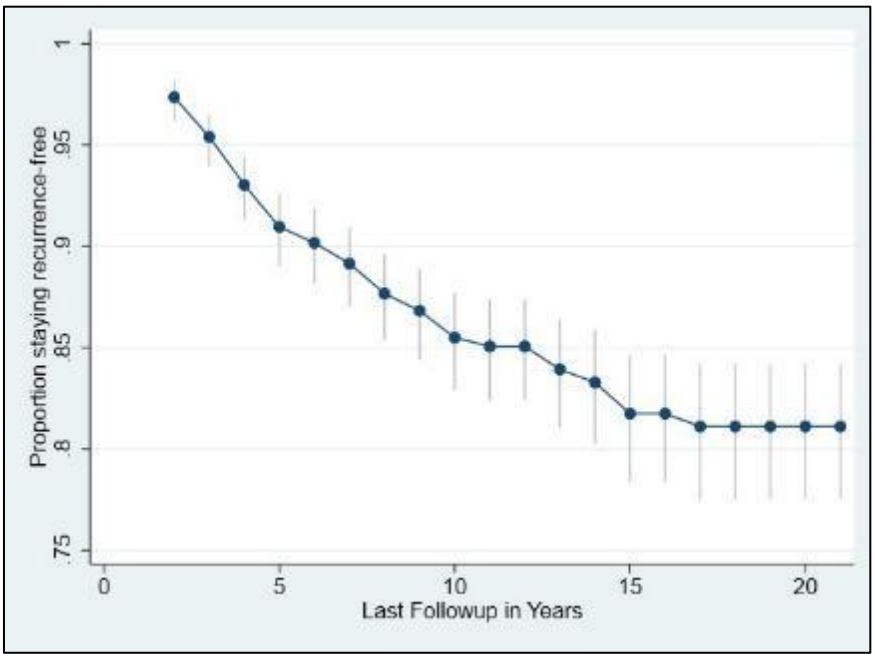

Figure 4 Life table analysis for annual risk of recurrence

3. Result and Discussion

In 1996, Barker et al. [15], published their landmark series of 1185 TGN patients who had MVD.15 The immediate postoperative MVD failure rate was 2%, 16% had partial pain relief (no medication required), and 82% had complete pain relief, with 70% still having complete pain relief after 10 years [15]. This is consistent with our findings, where 87% of patients achieved complete pain relief, and 10% achieved partial pain relief without medication. Moreover, these findings are consistent with several large series of MVDs where the pain-free rate is 60-84%, with an average follow-up of 5-12 years [7 14,16,17]. In a meta-analysis of 4884 MVDs, the average acute pain-free rate was 91%, and the average follow-up pain-free and recurrence rates were 76.6% and 18.3%, respectively [3]. But the ranges in this meta-analysis are broad; only a few series have a survival analysis, and follow-ups are variable [3]. The 95% confidence intervals for the above point estimates are broad, reflecting the uncertainty. There is little literature where an autologous muscle piece is comprehensively analyzed. One study reported a 5-year series of 137 patients, with 108 (78%) reporting complete pain relief and 21.2% (N=29) with good pain relief.35 But the selection of patients is not mentioned, and there is no survival analysis of the 14% recurrence rate [35]. We have used autologous muscle since 1992 in our department because synthetic materials were not affordable/available. We had treated TGN with Frazier's technique or glycerol rhizolysis since 1964. Theoretically, an autologous material was safe and affordable, but there is little literature as muscle resorption has been a concern [35]. The use of a large piece as an interposition material has several benefits. It overcomes the issue of resorption, and muscle is easily accessible. It can be tailored to any size and, if needed, can be re-harvested. We found muscle to be smooth and only minimal manipulation is needed to transpose the vessel. The graft slips between the smallest of spaces created by the transposition of the vessel and conforms to the shape of the space, thus having a low risk of displacement. Jagannath et al [36]. found that the perineural adhesions in recurrence cases where a muscle was used were less than synthetic interposition materials [35]. We have also observed this in cases which have required a second MVD; the graft was contracted but not calcified, and there were no perineural adhesions. A small series found a higher recurrence rate in cases where synthetic interposition materials were used compared to muscle [38]. After MVD, Teflon grafts have been reported to be the cause of recurrence in 18-50% of recurrent TGNs [39]. Subgroup analysis of a large series found 13% of recurrences were due to Teflon adhesion/compression [40]. Other, less common complications of synthetic materials include granuloma formation (estimated incidence of up to 7.3%) and chemical meningitis [35,39]. Microvascular decompression (MVD) outcomes depend on patient selection. In 2021, Chen et al. [5], performed a meta-analysis of 8,172 MVDs and found that the factors significantly associated with recurrence were atypical TGN symptoms, non-arterial compression, and longer duration of symptoms [5,7-9]. Atypical TGN is associated with less pain relief and increased recurrence following MVD, as reported in several retrospective studies [5,7-9]. A recent large study found a 40% recurrence rate with a median time to recurrence of 10.6 months, which may be explained by their patient population [16]. Wu et al. [27] even showed a high long-term recurrence rate (60%) for typical TGN patients that develop mixed/atypical symptoms. The exact relationship between disease duration, development of atypical symptoms and when the effectiveness of MVD here is lost remains unclear. Barker et al [15]. reported a disease duration of more than 8 years to have a higher recurrence (HR 1.3), which has also been the experience of many authors [4,12,13,15,41]. But it is not mentioned if these patients had atypical symptoms. Increased recurrence here is likely due to irreversible nerve root damage from prolonged compression [5]. On the other hand, a recent study of 425 patients did not report any correlation between disease duration and recurrence. But this study excluded TGN patients without NVC, who the authors claimed were more likely to have atypical symptoms [8]. The natural history of TGN, the evolution of atypical symptoms and their association with an absence of neurovascular compression remain to be determined. It is noteworthy that none of our patients had an absence of NVC at operation. Although there are large series of TGN patients who report this [12,15], there are also series of typical TGN patients who report an absence of NVC in a minority of patients [8,9,16]. We believe this is due to patient selection as only MVD was not offered in our series to patients who may have typical TGN but, by the Burchiel Classification (type 1), also have an accompanying degree of persistent background pain, which can be prominent or severe for up to 49% of the day.42 Thus, clinically, we operated on purely ‘classic’ TGN, which is in line with the diagnostic criteria of the International Headache Society ICHD-III, which differentiates classic TGN that is purely paroxysmal (13.1.1.1) and not classic TGN with concomitant persistent facial pain (13.1.1.2) [43]. Although the degree of NVC differed between patients, its effect on outcome cannot be determined as it was not adequately and objectively recorded. However, in all cases, even those with contact but without morphological changes, the cause was some form of compression (at the very least pulsatile compression) as MVD resulted in pain relief. This is consistent with the European Academy of Neurology guidelines (2019) which state classic TGN is strongly associated with NVC and ‘idiopathic’ TGN includes patients with neurovascular contact without morphological changes to the REZ, which can still be the etiological factor.1 And that in both cases, MVD can be successful.1 Neither sex nor location were significant for recurrence and long-term outcome, which is consistent with Chen et al.'s meta-analysis [5]. However, the absence of immediate pain relief is a risk factor for recurrence, which is supported by our study where 40% of patients without immediate pain relief had recurrence [15]. Recurrence was statistically more likely to be venous or mixed compressions. This is noted in the literature due to intricate anatomy and dissection required to relocate culprit vessels [5]. Most of the recurrence after MVD happened

beyond 2 years. In our series, the recurrence rate remained less than 2% per year after the fourth year and almost nil thereafter. We speculate that the relocation of the involved vessel in MVD may initially work as the muscle interposition may dampen the pulsation from the offending vessel. This may then be followed by a degree of gliosis and fibrosis of the graft so that the vessel relocates. It is possible that in the immediate post-operative period the vessel is not yet completely adherent to its new position and may be more likely to recede. But more research is needed to confirm our hypothesis. Our complications are in line with the MVD literature [3,4,7-17]. Our preference was to leave the arachnoid over the 7th-8th complex intact. Facial numbness is the most common complication reported in the literature, with one large study (N=401) reporting 5.5% [17] The incidence of more serious complications (cranial nerve palsy, hearing loss, CSF leak and infection) is generally less than 3% in most series [17,18,44]. But hearing loss may be underestimated as a review article shows the incidence of hearing loss to be 5.6% after MVD but as high as 13.47% in studies that used pre- and post-operative audiograms and intraoperative brainstem auditory evoked potential monitoring [45]. MVD is also extremely safe with respect to mortality, with most large series (including ours) reporting no mortality (overall mortality 0.3% (17/4906 patients) [3,4,7-20] Indeed, the complication rate from MVD has improved in recent years due to the improvement in technique, instruments, and the microscope [5,8,28]. The complication rate for MVD is lower than that reported for radiosurgery, destructive and percutaneous procedures, which generally report much higher rates of complications.3 Chen et al [15], meta-analyses have also shown that more recent papers have lower recurrence rates.5 Our findings are in line with this. Our results for acute pain relief, long-term pain-free, recurrence and complication rates are towards the better end of the spectrum [3,7-14]. While this may be due in part to the surgeon's expertise and technique, as recurrence and complication rates have been shown to be better in a higher volume MVD practice, meticulous patient selection and more widespread factors such as refinement of the surgical technique and instruments, improvements to the operative microscope and overall quality of neurosurgical care have all contributed to the trend towards better outcomes. This is a retrospective single surgical team study and is therefore not without bias and may not be generalizable. Only 5% of patients were aged over 60 and the median follow-up time was 6 years. We were unable to adequately record the length of the disease in our study and therefore unable to assess its association with recurrence and consider this a limitation of this study. And finally, we cannot answer whether muscle is better than synthetic materials as there is no control group and the decision for the interposition material will be dependent on the environment and practitioner. But there are advantages to using autologous muscle and the issue of size regression is overcome by taking a larger piece of muscle.

4. Conclusion

This article offers the largest collective experience of using autologous muscle for MVD, which offers long-term relief with minimal complications. Through judicious patient selection and meticulous technique, this operation has proven to be the most effective with many TGN patients being cured.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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