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Predictability of vascular conflict by MRI in trigeminal neuralgia

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ABSTRACT

Objective: Magnetic resonance imaging (MRI) has been investigated extensively in its success or failure to identify preoperative vascular compression in patients with trigeminal neuralgia (TN). To this end, we reviewed our case load to evaluate the concordance or discordance between preoperative MRI and intraoperative findings.

Patients and Methods: Sixty-nine patients with Type 1 TN and retrievable MRI images, operative reports, and intraoperative photographs were retrospectively reviewed.

Results: Our review shows that MRI predicted conflict (arterial or venous) in 58 cases that was confirmed at surgery in 55 cases. MRI predicted no conflict in 11 cases, whereas surgery revealed no conflict in a total of 6 cases. Thus, in predicting conflict at surgery, MRI had a sensitivity of 87%, and specificity of 50%, respectively. Conversely, MRI accurately predicted intraoperative conflict (positive predictive value) in 95% of cases, and the absence of conflict (negative predictive value) in 27%. These results reveal that MRI is more accurate in predicting conflict than the absence of conflict at surgery.

Conclusion: Our results support the reliance on the clinical diagnosis of Type 1 TN to recommend microvascular decompression (MVD). The presence of vascular compression by MRI should encourage the surgeon to persevere in search of the offending vessel when it proves elusive. MRI positive and negative predictive values for conflict are expected to increase with better resolution imaging. The absence of neurovascular conflict on high-resolution MRI should not negate MVD in the treatment of a patient with classic TN.

1. Introduction

Trigeminal neuralgia is a complex disease with multiple contributing etiologies. Classic trigeminal neuralgia (TN) is attributed to vascular compression upon the root entry zone of the trigeminal nerve. [1–5] Secondary TN includes demyelinating disease, neoplastic processes, and traumatic events, to mention but a few. In some cases of TN, no cause is identifiable, necessitating the classification of idiopathic TN. [2] On clinical grounds, TN can further be divided into Type 1 with episodic, lancinating pain separated by pain-free intervals, and Type 2, or atypical that is chronic and persistent. [4] Several modalities of treatment of classic TN have developed over the years. These include microvascular decompression (MVD), stereotactic radiosurgery, radiofrequency rhizotomy, glycerol injections, and balloon compression. [3,6–13] These span the gamut from non-destructive to destructive treatments. The literature supports the use of MVD as the treatment of choice in classic TN for relief of pain without associated numbness. In addition, compared to other modalities of treatment, MVD is the one least likely to fail and least likely to require additional interventions.

As the success of MVD is associated with the presence of vascular conflict, preoperative suspicion or confirmation of vascular conflict implies a higher degree of success with MVD. Magnetic resonance imaging (MRI) has been investigated extensively in its success or failure to identify preoperative vascular compression. [1,14] To this end, we elected to pursue a review of our case load to examine the cases of Type 1 TN to examine the concordance or discordance between preoperative MRI and intraoperative findings.

2. Patients and methods

We retrospectively reviewed our patients with classic TN in whom intraoperative photographs and MRI studies were available. Over the past 10 years, we have treated 104 patients with MVD, 100 with stereotactic radiosurgery, and 39 with radiofrequency rhizotomy. The choice of treatment was at the patients' discretion. The risks and benefits of each of the three procedures were presented verbally as well as

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in a handout. Those patients who favored long-term relief without numbness and did not particularly mind an overnight stay in hospital often chose MVD. Prior to scheduling MVD, patients with co-morbidities, including cardiac, renal, or uncontrolled diabetes or hypertension, were evaluated and cleared for surgery by our Surgical Co-management team, consisting of internists and anesthesiologists. Patients who desired a simple outpatient procedure, not requiring craniotomy, and were willing to wait several weeks for results, chose stereotactic radiosurgery. Patients who were suffering severe pain desiring an outpatient procedure with immediate relief, and were ambivalent about numbness, often chose radiofrequency rhizotomy.

Intraoperative photographs, reports, and MRI studies were available in 69 of the 104 patients. Patients whose MRI studies were unavailable for review owing to the passage of time or performance elsewhere (35) were to be excluded from analyses. The period of treatment for this cohort extended from April of 2008 until December of 2018. All candidates for MVD underwent preoperative MRI study. CISS sequences were available for 62 patients and were primarily utilized to evaluate for the conflict. In the remaining 7 patients, this determination was made based either on the volumetric contrast-enhanced T1W imaging (typically with a slice thickness of 1 mm) or time of flight MR angiogram studies. In total, 11 scans were performed on a 3 T magnet, while 58 studies were performed on a 1.5 T magnet. Given the tertiary nature of the clinical setting, a number of patients (24) had imaging performed elsewhere and were subsequently referred. The imaging parameters for the CISS sequence that was used for patients scanned at our institute were as follows: For 1.5 T magnet, the scanning parameters were 1200 ms repetition time, 259 ms echo time, 256 × 256 matrix, 0.8 mm slice thickness, 20 cm field of view, 70° flip angle. For 3 T magnet, the parameters were 1000 ms repetition time, 125 ms echo time, 320 × 320 matrix, 0.5 mm slice thickness, 16 cm field of view, 100° flip angle.

MRI images were reviewed for the presence or absence of vascular conflict blinded to the operative report. The relationship of the trigeminal nerve and adjacent blood vessels (artery, vein, or none) was evaluated based on the morphologic contact between the outer walls of the offending vessel and the trigeminal nerve. Arterial branches adjacent to the trigeminal nerve were identified by following the superior cerebellar or anterior/posterior inferior cerebellar arteries on MRI. Other vascular structures were identified as venous. Images were reviewed by our neuroradiologists with greater than 15 years of experience in neuroimaging. Our neuroradiologists were blinded to the operative findings. All image analysis was performed on a standard PACS workstation with multiplanar reconstruction capabilities. The surgical procedure was accomplished utilizing techniques documented in the literature. [1,4,15,16]

Descriptive statistics were reported as across-patient medians and ranges. Concordance of MRI and intraoperative findings was evaluated in terms of sensitivity and specificity, positive and negative predictive values. Clinical outcomes following MVD were scored using the Barrow Neurological Institute Pain Intensity Scoring System. [17] Difference in outcomes between patients who had arterial conflict, venous conflict, or no conflict, was assessed using the Freeman-Halton extension of the Fisher exact test. [18]

3. Results

3.1. MRI/Surgery concordance

There were 69 patients with retrievable MRI images, intraoperative photographs, and operative records. In this cohort, there were 42 females and 27 males (median age 60 years old, range 26–83 years old). The side of affliction was 29 cases on the left and 40 on the right. The length of hospitalization subsequent to surgery was 1 day in 31 cases, 2 days in 23 cases, 3 days in 9 cases, 4 days in 3 cases, and 9 days in 1 case (median 2 days). The 9-day hospitalization was in a patient who developed atrial fibrillation postoperatively and required uneventful cardioversion. Median follow-up was at 6.3 months (range 0.2–108.73 months.

Table 1
Predictability of conflict by MRI.

Conflict by MRI		Conflict at surgery		
		Artery	**Vein**	**None**
Artery	50	43	5	2
Vein	8	2	5	1
None	11	6	2	3
Total	69	51	12	6

MRI predicted arterial or venous conflicts in 58 patients, which were confirmed at surgery in 55 (Table 1, Fig. 1), with 2 turning out to be arterial conflicts (Fig. 2) and a venous conflict in the remaining 1. MRI predicted a venous conflict in 8, which at surgery was confirmed in 5, but revealed an arterial conflict in 2 and no conflict in 1. MRI showed no conflict in 11 patients, which was confirmed at surgery in only 3 (Fig. 3). The remaining 8 revealed arterial conflicts in 6 (Fig. 4) and venous in 2.

The above data shows that MRI predicted conflict (arterial or venous) in 58 cases, that was confirmed at surgery in 55 cases. MRI predicted no conflict in 11 cases, whereas surgery revealed no conflict in a total of 6 cases (Table 2). Thus, our review shows an MRI sensitivity of 87% [55/(55 + 8)] and specificity of 50% [3/(3 + 3)], respectively. MRI accurately predicted intraoperative conflict (positive predictive value) in 95% of cases [55/(55 + 3] and the absence of conflict (negative predictive value) in 27% [3/(3 + 8)].

3.2. Clinical outcomes

Forty-four of the 51 patients with arterial conflict are pain-free off medication (Barrow Grade I, Table 2). Three patients are adequately controlled with medication (Barrow Grade III). Two patients are inadequately controlled with medication (Barrow Grade IV) and have persistent pain. Two patients continued to experience severe pain (Barrow Grade V), achieving relief in one after stereotactic radiosurgery. Of 12 patients with venous conflict, 8 are pain-free subsequent to surgery (Barrow Grade I), whereas 3 are controlled with medication (Barrow Grade III). One continued to have pain (Barrow Grade V), achieving some relief after stereotactic radiosurgery. There were 6 patients without conflict at the time of surgery, all of whom were rendered pain-free subsequent to their operation and are off medication. A Freeman-Halton extension of the Fisher exact test failed to reveal a difference in outcomes between the three groups (arterial conflict, venous conflict, no conflict) ($p = 0.578$). [18]

3.3. Complications

There was one case of postoperative cerebrospinal fluid (CSF) leakage from the incision necessitating treatment with a spinal drain. This patient had a venous conflict and was postoperatively pain-free. One case of CSF rhinorrhea with arterial conflict was successfully treated with spinal drainage and was postoperatively pain-free. One patient developed a pulmonary embolus postoperatively. Following discharge, she became symptomatic and was treated locally with anticoagulants without sequelae. Two other patients developed deep vein thrombosis and were treated with anticoagulants, also without sequelae. All three cases with vascular events had arterial conflicts and were pain-free following the surgery. Two patients suffered an operative site wound infection necessitating debridement and antibiotics, for *Pseudomonas aeruginosa* infection in one case and methicillin-sensitive *Staphylococcus aureus* in the second. Both cases had arterial conflicts and were pain-free following the surgery.

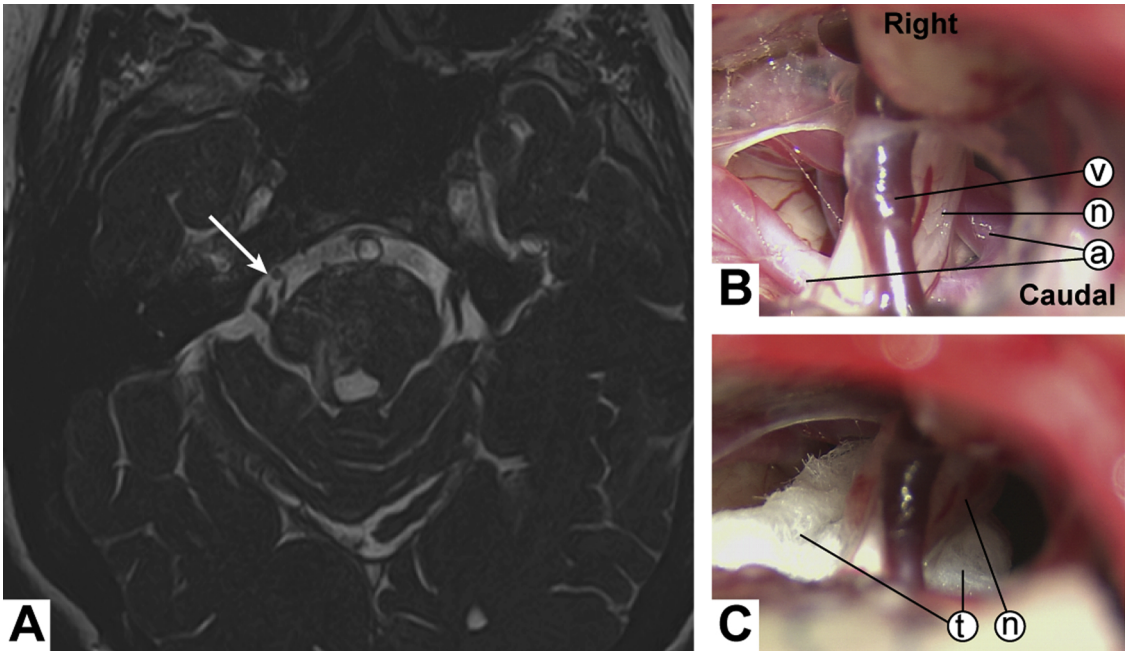

Fig. 1. Example of concordant (true positive) MRI and intraoperative findings. The patient is an elderly woman with right TN for the past 2 years unresponsive to medication. **A:** MRI reveals a neurovascular conflict on the right side (arrow). **B:** Intraoperative photograph of the supracerebellar artery (a) ventral to the trigeminal nerve (n), with the petrosal vein (v) lying posterior to the nerve. **C:** Teflon sponge barrier (polytetrafluoroethene) (t) is inserted ventral to the nerve (n) from medial to lateral. The patient is relieved of TN.

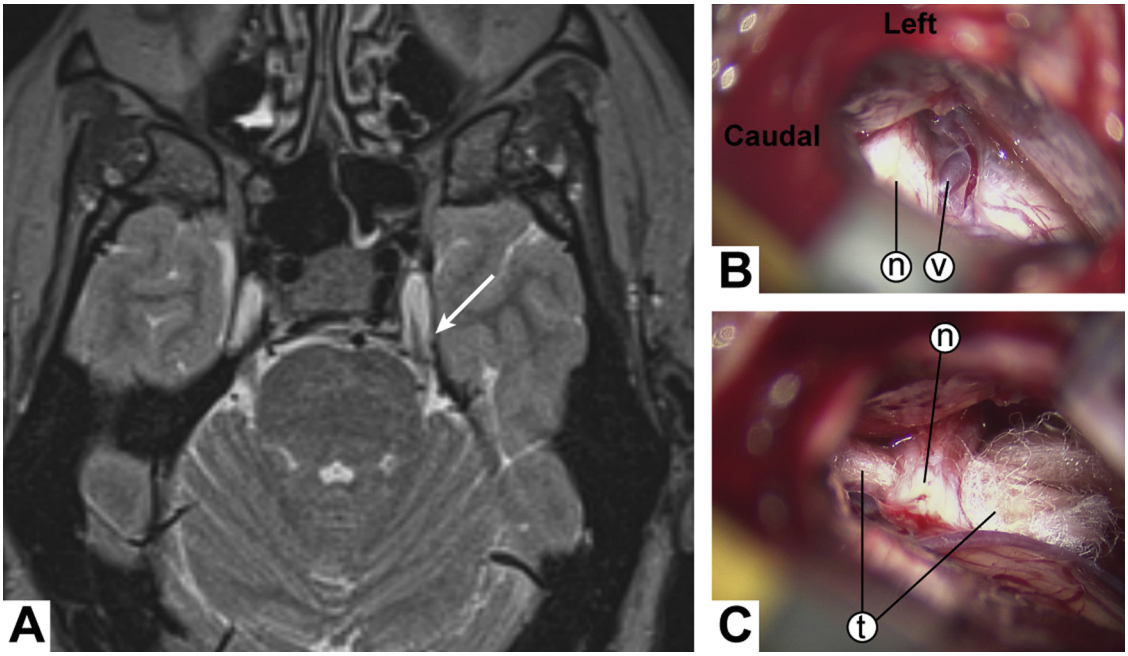

Fig. 2. Example of an MRI-predicted arterial conflict that is confirmed at surgery to be venous. A middle-aged male with left TN for the past 10 years unresponsive to carbamazepine and phenytoin. **A:** MRI is interpreted as showing vascular compression on the left trigeminal nerve by the superior cerebellar artery (arrow). **B:** Intraoperative photograph demonstrating compression of the trigeminal nerve (n) by a vein (v). **C:** Teflon sponge (t) surrounding the trigeminal nerve (n). The patient is pain-free on Neurontin.

4. Discussion

The role of MRI in establishing the diagnosis of TN and assisting in selection of treatment has evolved over the recent past. The American Academy of Neurology (AAN) and the European Federation of Neurological Societies (EFNS) assembled a panel of experts to review publications on TN in MEDLINE, EMBASE, and the Cochrane Library from the time of inception of these databases until December 2007. [3] In their review, there were 16 papers addressing high-resolution MRI in TN. There were 9 studies graded Class IV, 1 study considered Class III, and 5 prospective studies considered Class I. Sensitivities and specificities of high-resolution MRI studies in the Class I through III studies varied widely (sensitivity 52–100%; specificity 29–93%). The heterogeneity in results was attributed to the inconsistent MRI techniques adopted by the various centers. As a result of their analysis, the panelists concluded that at that time there was insufficient evidence to

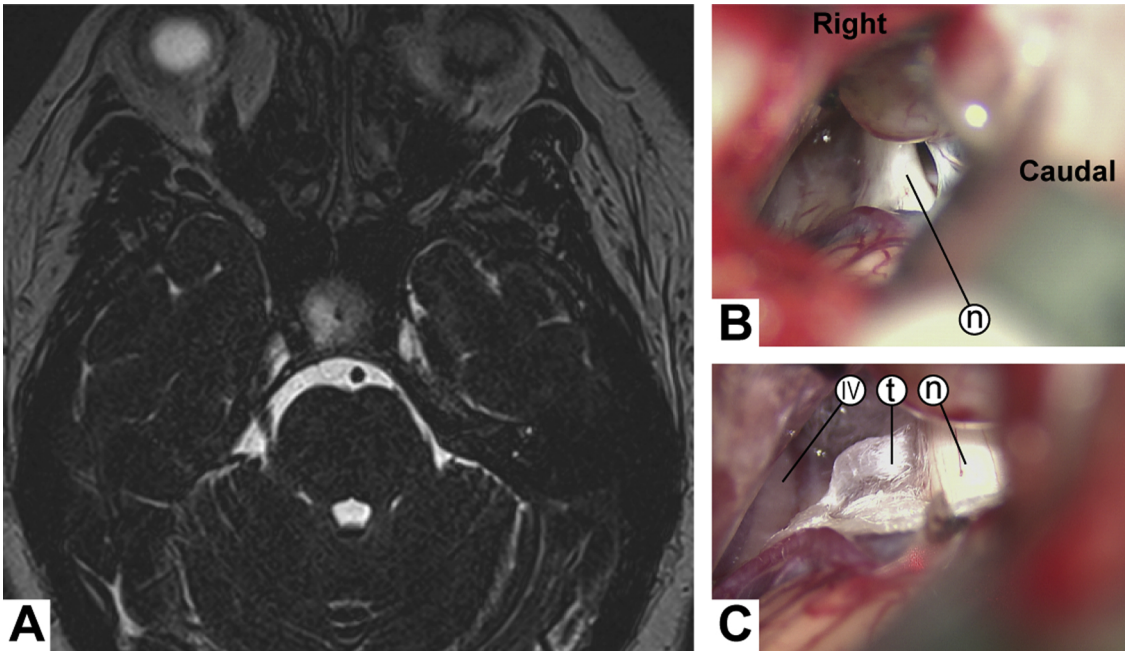

Fig. 3. Example of concordant (true negative) MRI and intraoperative findings. The patient is a young female with right TN for approximately 4 years. **A:** MRI is interpreted as showing no evidence of vascular compression. **B:** Intraoperative photograph showing no evidence of conflict. **C**: The trigeminal nerve (n) has been enveloped in Teflon (t), and the trochlear nerve (IV) is seen rostral. The patient is pain-free off medication.

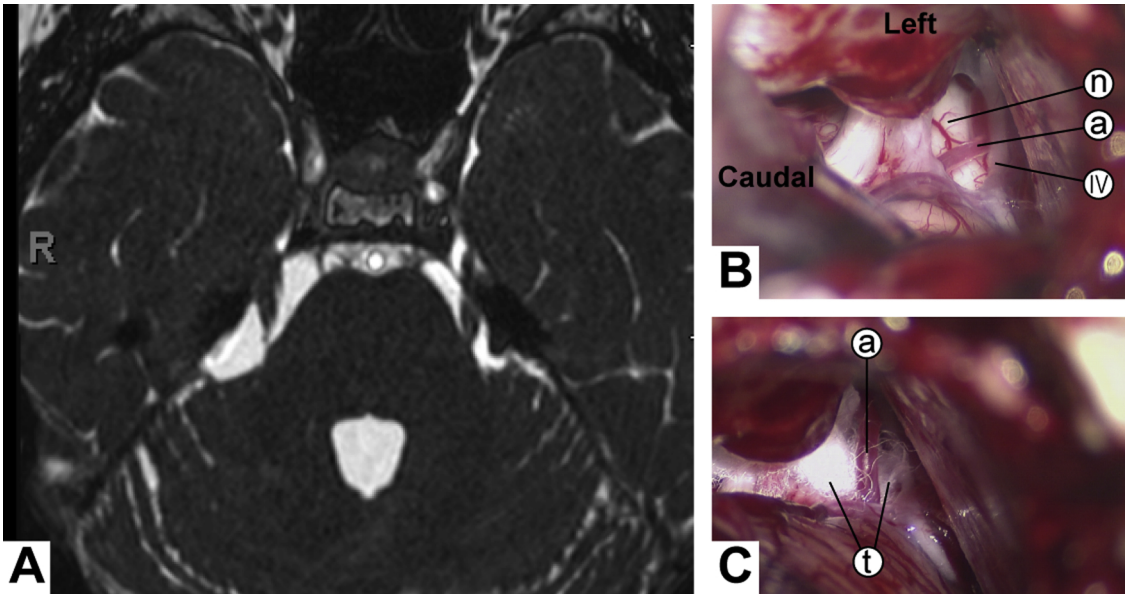

Fig. 4. Example of discordant (false negative) MRI and intraoperative findings. The patient is a middle-aged woman with left TN for the past 6 months unresponsive to medication. **A:** MRI is interpreted as showing no vascular conflict on either side. **B:** Intraoperative photograph showing the trigeminal nerve (n) bisected by branch of the superior cerebellar artery (a) in close proximity to the trochlear nerve (IV). **C:** Teflon sponge (t) separating the trigeminal nerve from the artery (a). The patient is relieved of TN.

Table 2
Clinical outcomes following MVD based on the Barrow Neurological Institute (BNI) pain intensity score.

Conflict at surgery		BNI pain intensity score				
		I	II	III	IV	V
Artery	51	44	–	3	2	2
Vein	12	8	–	3	–	1
None	6	6	–	–	–	–
Total	69	58	–	6	2	3

support or refute the usefulness of MRI in identifying vascular conflict. Our review demonstrated comparable findings. In our review of 69 cases, MRI accurately predicted conflict and absence of conflict (true positive and negative) in 55 and 3 cases, respectively (Table 1). On the other hand, MRI falsely predicted conflict and absence of conflict (false positive and false negative) in 3 and 8 cases, respectively; thus, MRI sensitivity and specificity rates of 87% and 50%, respectively. It is important to note that, even in the 6 patients without conflict at surgery, patients were rendered pain-free (Table 2).

Maarbjerg et al. examined 3869 patients at the Danish Headache Center with strict criteria of TN consisting of “paroxysmal attacks of

pain lasting from a split second up to 2 min in the distribution of the trigeminal nerve". [14] After excluding patients with missing data and atypical or bilateral TN, the investigators ended up with 135 patients. The latter all underwent an MRI scan within 2 months after their diagnosis. The imager was a 3 T unit equipped with a 32-channel head coil with multi-transmit parallel RF transmission. They classified their vascular conflict into three categories of A, B, and C, from displacement at the site of contact, atrophy, and reduced volume of the trigeminal nerve, and finally severe contact with displacement and atrophy, respectively. The conclusion from this prospective review was that vascular contact was prevalent on both symptomatic as well as asymptomatic sides (89% vs. 78%, $p = 0.014$). Arterial conflict was more prevalent on the symptomatic than the asymptomatic side (74% vs. 56%, $p = 0.001$). Moreover, the presence of neurovascular contact was significantly associated with the pain side. The data suggested that the degree of vascular compression could be a significant criterion when selecting patients for surgery. Considering the existence of neurovascular contact on both sides, sensitivity was 89% while specificity was 22%. Our MRI sensitivity and specificity were comparable at 87% and 50%, respectively.

A recent study by Brinzeu et al. investigated the reliability of MRI in predicting intraoperative vascular conflict. [1] To this end, 100 consecutive patients with classical TN who had benefited from MVD that was undertaken based on an MRI deemed positive for neurovascular compression were retrospectively reviewed. The reviewer was blinded to the clinical and surgical findings, including the side of the neuralgia. The routine preoperative MRI protocol at the Pierre Wertheimer Hospital in Lyon, France, included three high-resolution sequences centered on the trigeminal root: 3D T2-weighted driven equilibrium, 3D time-of-flight angiography, and 3D T1-weighted sequences with gadolinium. This review showed a neurovascular relationship on MRI in 94 patients, and none in 6 on the side of the neuralgia. Of these 6 patients, 3 had no conflict at surgery (false positive), whereas the other 3 did have a small-grade conflict (i.e., false negative). Based on these data, the overall sensitivity, specificity, and positive predictive value were 97%, 50%, and 97% respectively. Our sensitivity, specificity, and positive predictive value of MRI over a 10-year period were 87%, 50%, and 95% respectively. The disparity in sensitivity between our results and those of Brinzeu et al. [1] is likely due to a combination of higher resolution and combined assessment from three high-resolution sequences, which were not always available in our series.

In our review, 6 of 69 patients were without conflict at the time of surgery, 3 of whom were accurately predicted by MRI (Table 1). As noted above, the absence of conflict at surgery in patients with classic TN and Type 1 TN is by no means rare and has been described in multiple other reports. [1,4,14,19–23] In the report by Maarbjerg et al, there was no vascular conflict identified in 15 patients (11%). [14] In the report of 100 cases by Brinzeu et al, 6 patients had no conflict at surgery (6%). [1] The absence of neurovascular conflict at surgery leads to the conclusion that, in patients with classic TN, a vascular conflict is not consistently encountered. Good outcomes in such patients is attributed to nerve manipulation [4] or decompression of a vessel that was not visualized intraoperatively. Thus, in view of the false positive and false negative interpretation of MRI, the treatment of TN with MVD should be heavily based on clinical diagnosis of Type 1 TN rather than on preoperative MRI findings alone.

We had a venous conflict at surgery in 12 patients (17%). In the review by Maarbjerg et al, 20 of their 135 patients (15%) had a venous conflict, compared to 11 of 100 cases in the report by Brinzeu et al. [1,14] Pain relief in cases of venous compression has been shown to be comparable to that with arterial conflicts both in our series as well as that of others. [4] Thus, distinguishing venous from arterial conflict on the preoperative MRI, irrespective of resolution, is not always possible. Excellent outcomes with venous conflict should not dissuade the surgeon from offering MVD, even if suspected on preoperative MRI.

As noted in our results above, our complication rate was 7 of 69, or 10.1%. These rates are comparable to those described by Gronseth et al in their meta-analysis. [3] In their review, they encountered a mortality rate of 0.2 − 0.5%, with up to 4% of patients incurring CSF leaks, infarcts, or hematomas. Other complications included aseptic meningitis in 11% and hearing loss in 10% of patients.

A limitation of our review is that it is retrospective regarding the predictive role of MRI in identifying vascular conflict during MVD. It is based on a cohort of 69 patients derived from a population of 104 cases treated with MVD. Oftentimes, diagnostic MRI images were from the referral centers and were not all obtained at our university hospital. Thus, the MRI technique was not always consistent or ideal, resulting in some heterogeneity. Interpretation of the MRI scans was performed by seasoned neuroradiologists who were not privy to operative findings. Our series is by no means the largest; however, it is a single center experience in which the diagnosis and treatment was provided by a single surgeon. The absence of multiple providers supports consistency and minimizes heterogeneity in indications and technique.

In summary, in view of the false positive and false negative results in MRI interpretation, with a sensitivity of 87% and a specificity of 50%, our results support the reliance on the clinical diagnosis of Type 1 TN to recommend MVD for treatment. Whenever possible, thin-slice, 3-dimensional, constructive interference in steady state (CISS) or equivalent is the preferred MRI imaging technique. [24] High-resolution scans can improve MRI predictive values. The presence of vascular compression by MRI should demand perseverance in the search of vascular conflict when it proves elusive. [25] Conversely, the absence of neurovascular conflict on high-resolution MRI should not negate MVD in the treatment of a patient with classic TN.

Disclosures

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