The Sagittal Angle of the Trigeminal Nerve at the Porus Trigeminus is a Radiologic Predictor of Surgical Outcome in Microvascular Decompression for Classical Trigeminal Neuralgia

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BACKGROUND AND OBJECTIVES: Classical trigeminal neuralgia (cTN) is a painful disease. Microvascular decompression (MVD) provides immediate and durable relief in many patients. A variety of positive and negative prognostic biomarkers for MVD have been identified. The sagittal angle of the trigeminal nerve at the porus trigeminus (SATNaPT) is an MRI biomarker that can identify a subset of patients with cTN whose trigeminal nerve anatomy is different from normal controls. The purpose of this case-control study was to determine whether an abnormally hyperacute SATNaPT is a negative prognostic biomarker in patients with cTN undergoing MVD.

METHODS: Preoperative MRIs from 300 patients with cTN who underwent MVD were analyzed to identify patients with a hyperacute SATNaPT (defined as less than 3 SDs below the mean). The rate of surgical success (pain-free after at least 12 months) was compared between patients with a hyperacute SATNaPT and all other patients.

RESULTS: Patients without a hyperacute SATNaPT had an 82% likelihood of surgical success, whereas patients with a hyperacute SATNaPT had a 58% likelihood of surgical success ($P < .05$). Patients with a hyperacute SATNaPT who also had no evidence of vascular compression on preoperative MRI had an even lower likelihood of success (29%, $P < .05$).

CONCLUSION: In patients with cTN being considered for MVD, a hyperacute SATNaPT is a negative prognostic biomarker that predicts a higher likelihood of surgical failure. Patients with a hyperacute SATNaPT, particularly those without MRI evidence of vascular compression, may benefit from other surgical treatments or a modification of MVD to adequately address the underlying cause of cTN.

KEY WORDS: Microvascular decompression, Porus, Sagittal angle, Trigeminal neuralgia, Trigeminal nerve

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Classical trigeminal neuralgia (cTN) is a facial pain syndrome with specific diagnostic criteria, including paroxysms that last 1–120 seconds, are sharp, stabbing, or electric in character and are induced by innocuous stimuli.[1] The most commonly accepted cause of cTN is neurovascular compression of the proximal cisternal segment of the trigeminal nerve by an adjacent artery, most commonly the superior cerebellar artery. The relationship between artery and nerve can be delineated on MRI by a variety of methods, including the use of high-resolution T2-weighted imaging.[2-5]

ABBREVIATIONS: cTN, classical trigeminal neuralgia; **MVD,** microvascular decompression; **SATNaP,** sagittal angle of the trigeminal nerve at the porus trigeminus; **SSFP,** steady-state free procession.

Classical trigeminal neuralgia is initially treated with derivatives of carbamazepine, but when medication therapy no longer controls the pain, microvascular decompression surgery (MVD) or an ablative procedure may be recommended. With MVD, neurovascular compression of the trigeminal nerve may be relieved by transposition of the artery or placement of an interpositional pledget. Although MVD provides durable relief of pain in most patients with cTN, some negative prognostic biomarkers have been identified.[6-10] Additional negative prognostic biomarkers, especially those that can

potentially be reversed intraoperatively, may permit surgeons to personalize care for patients with these markers.

The sagittal angle of the trigeminal nerve at the porus trigeminus (SATNaPT) is known to be hyperacute in a subset of patients with cTN.[11] The purpose of this study was to determine whether this subset of patients is more likely to have persistent pain after MVD and whether the SATNaPT can thus be used as a preoperative predictor of surgical success.

METHODS

The study population consisted of 300 patients diagnosed with cTN by criterion 13.1.1.1A of the International Headache Society's International Classification of Headache Disorders Version 3.[1] All 300 patients underwent preoperative MRI at a field strength of 1.5 or 3.0 T to delineate arterial anatomy and then underwent MVD. These were consecutive patients treated at 2 hospitals within a single, large medical center between 2013 and 2021. Only patients with unilateral cTN were included. Patients who had undergone previous surgery for MVD were excluded, as were patients who had nondiagnostic MRIs because of motion artifact. This patient population is the same as that used in a previous publication that established the range of normal for the SATNaPT.[4] Our Institutional Review Board approved this protocol as research on existing data without the need for explicit patient consent.

The MRI protocol included full brain imaging with sagittal T1, axial fluid-attenuated inversion recovery, and axial diffusion-weighted images. In addition, steady-state free procession (SSFP) images (brand names include CISS [constructive imaging in the steady state] and FIESTA [fast imaging employing steady-state acquisition]) were acquired in axial, coronal, and sagittal planes. We prefer 3-plane acquisition over reformatted images at our institution to ensure high image quality in each plane. The SSFP sequences use optimized repetition time and time to echo (usually about 5.5 and 2 msec), field-of-view of 18 cm, flip angle of 65°, matrix of 384 × 256, 1.0 mm slice thickness, 0.5 mm slice interval, and 2 number of excitations.

The images were analyzed by a single board-certified radiologist with a certificate of added qualification in Neuroradiology and 20 years of experience in head and neck imaging. Using the sagittal SSFP sequence, the SATNaPT was measured bilaterally as the angle between the trunk of the trigeminal nerve in the prepontine cistern and the most superior branch of the nerve within Meckel's cave (Figure 1). The radiologist was blinded to the patient's symptomatic side and to the surgical outcome.

After routine postoperative clinical assessment, all patients were contacted by the surgical team every 6 months (most commonly by telemedicine visit). A minimum follow-up of 12 months was required for inclusion in this study. Surgical success was defined as pain-free without medication.

The mean and SD of the SATNaPT in normal trigeminal nerves have been previously reported.[11] An SATNaPT more than 3 SDs smaller than the mean (135° or less) was classified as hyperacute. The surgical success rate for patients with hyperacute SATNaPT was compared with the success rate for all other patients by using χ^2 analysis. A *P*-value less than .05 was considered statistically significant.

Degree of vascular compression has been associated with likelihood of surgical success for MVD. To avoid this potential confounding variable, the degree of vascular compression on the nerves with hyperacute SATNaPT was evaluated in the manner previously described in the literature, dividing the nerves into those distorted in the susceptible segment by the superior cerebellar artery and those without arterial distortion.[12] The patients with hyperacute SATNaPT were subdivided into those with arterial distortion on preoperative MRI and those without; the rates of surgical success were compared between these 2 groups, again using χ^2 analysis with a *P*-value threshold of .05.

RESULTS

Of the 300 patients, 116 were men (39%) and 184 were women (61%). The average patient age was 63 years (range: 23-87). The average time of clinical follow-up was 55 months (range 13-107 months). The 2 groups of patients (with and

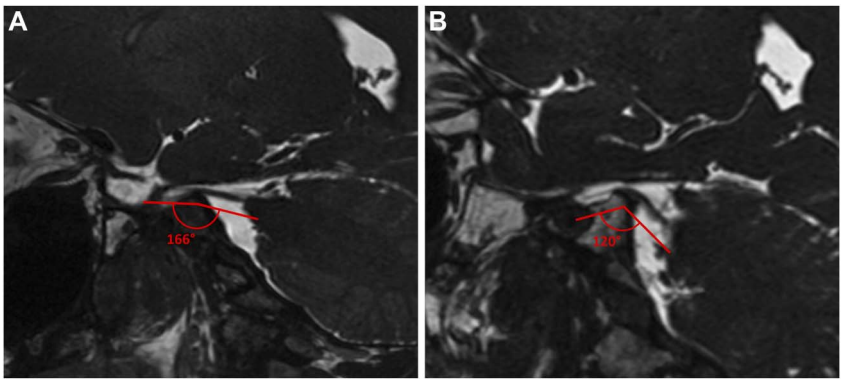

FIGURE 1. *Example measurements of the sagittal angle of the trigeminal nerve at the porus trigeminus. Sagittal steady-state free procession MR images show* **A**, *a normal angle of 166° and* **B**, *a decreased angle of 120°. The angle measurements are shown below the nerves to avoid obscuring the anatomy. [Reprinted with permission from Ref. 11].*

without hyperacute SATNaPT) did not differ significantly in age or sex (Table). Patients without a hyperacute SATNaPT had an 82% likelihood of surgical success (236/288). Patients with a hyperacute SATNaPT in their affected nerves had a 58% likelihood of surgical success (7/12). This difference was statistically significant (P = .041). Figure 2 shows the likelihood of surgical success as a function of the SATNaPT. Because there are too few patients to calculate proportions at each SATNaPT angle, the probabilities reflect the likelihood of success for all patients with a SATNaPT less than the value on the horizontal axis, this produces a smoother curve.

Of the 12 patients with a hyperacute SATNaPT, 5 (42%) showed the superior cerebellar artery distorting the nerve in its susceptible segment on the preoperative MRI. All 5 of those patients had surgical success. Of the other 7 patients, who did not have distortion of the trigeminal nerve on MRI, only 2 (29%) had surgical success. This difference was also statistically significant (P = .013) despite the small number of patients.

TABLE. Demographics of Patients With and Without Hyperacute SATNaPT

	Acuity of SATNaPT	
	Normal	Hyperacute
Average age	63	58
Age range	23–87	42–68
% female	61%	67%
Average follow-up (mo)	56	59
Range of follow-up (mo)	12–107	13–97

SATNaPT, sagittal angle of the trigeminal nerve at the porus trigeminus.

DISCUSSION

In a large group of patients who underwent MVD for cTN, the subset of patients with an abnormally hyperacute SATNaPT had a lower likelihood of surgical success. Patients with hyperacute SATNaPT can be identified on routine preoperative imaging if routine measurements of the angle are performed.

In a pilot study involving 42 patients with cTN, Brinzeu and Sindou did *not* note a statistically significant difference of the SATNaPT between the symptomatic and asymptomatic sides, respectively.[13] They did, however, note a statistically significant difference in the SATNaPT between the symptomatic side of patients with cTN and a small control group of patients with hemifacial spasm.

It is important to emphasize that more than half of the patients in our series with a hyperacute SATNaPT still achieved pain-free status after MVD, and the exact mechanism by which a hyperacute SATNaPT may predispose to surgical failure (eg, ischemia related to stretch of nerve over petrous ridge) is unclear. Thus, it may still be appropriate to offer MVD surgery to patients with cTN, even in the setting of an abnormal SATNaPT. However, in patients who are not pain-free after MVD, additional surgical techniques, such as widening of porus trigeminus or freeing of arachnoid,[14] to address the anatomic abnormality causing the

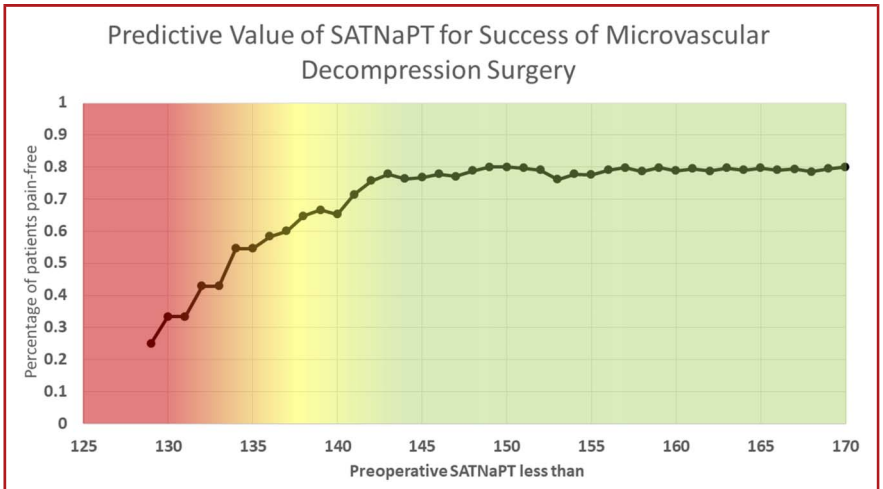

FIGURE 2. *Predictive value of SATNaPT for success of microvascular surgery. Fraction of patients who are pain-free at least 12 months after surgery, as a function of SATNaPT. The red portion of the graph represents patients with hyperacute SATNaPT (more than 3 SDs from the mean of normal individuals). The yellow portion of the graph represents patients more than 2 SDs from the mean. SATNaPT, sagittal angle of the trigeminal nerve at the porus trigeminus.*

hyperacute SATNaPT could be of benefit. Further research may also provide a clearer understanding of which patients with a hyperacute SATNaPT are at greatest risk of surgical failure, for example, those whose trigeminal nerves are not displaced by the offending artery.[12]

Limitations

This study is limited by the inclusion of patients from a single surgeon and measurements being made by a single radiologist. Some of the patients in this study underwent imaging on a 1.5 T MRI, but the differences in image quality between high-field strength magnets would not be expected to affect the measurement of SATNaPT. Another potential criticism is that the hyperacute SATNaPT is a result of severe displacement of the trigeminal nerve by a compressive artery, rather than an independent anatomic phenomenon. But in our study, the patients with hyperacute SATNaPT did not have a high likelihood of nerve displacement or distortion. In fact, patients with both a hyperacute SATNaPT and lack of vascular distortion to the trigeminal nerve had the lowest rates of surgical success. This combination of imaging biomarkers should be particularly concerning to surgeons when considering MVD.

CONCLUSION

In patients with cTN being considered for MVD, a hyperacute SATNaPT is a radiologic biomarker that predicts a higher likelihood of surgical failure, particularly in patients who do not have radiologic evidence of vascular compression. Neurosurgeons and radiologists who interpret preoperative imaging of patients with cTN should be familiar with the technique for measuring the SATNaPT.[11] In patients with a hyperacute SATNaPT and lacking arterial distortion of the trigeminal nerve, the increased risk of surgical failure should be included in informed consent and prognosis discussions. Patients with a hyperacute SATNaPT may require modified surgical techniques to adequately address the underlying cause and pain of cTN. Further research on new techniques to address patients with this anatomic anomaly should be pursued.

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COMMENTS

Not all of the patients with a primary trigeminal neuralgia (TN), even the classical one—which according the IHS definition is likely due to a neurovascular compression on preoperative imaging—are relieved after MVD. Therefore, searching for other or additional factor(s) is of practical importance. In that perspective, the authors' presented work should be commended.

In 2018, we paid attention on the possible role of an angulation, and subsequent stretching of the trigeminal nerve (TGN) at crossing over the petrous ridge, as a contributing factor to some of the neuralgias.[1a]

In our study, the averaged bony angle of the petrous ridge was found (slightly) more acute on the neuralgia (86°) than on the asymptomatic (90°) side (P = .06, ie, above significance) but significantly sharper (86°) than in a control group (98°) (P = .004). In the same study, in patients with grade II or III of compression by the conflicting artery, the angle of the nerve on crossing the petrous ridge was found at 140° on average on the neuralgia vs 149° on the asymptomatic side (P = .003).

Angulation with stretching of the root on crossing over the petrous ridge is frequently observed in elder patients with important global atrophy, corresponding to a so-called "sagging phenomenon" of brainstem and cerebellum in the posterior fossa. This anatomical/imaging phenomenon is so that those structures are submitted to ptosis with traction of the TGNs on the petrous ridge. At the point of the angulation, the root—most often atrophic—is ribbon-shaped, with a greyish aspect likely to correspond to local demyelination. Such mechanism can be evocated also to explain a number of so-called idiopathic TNs, especially in aged patients. Those patients should not undergo open MVD surgery.

We agree—as pointed out by the authors—that "Neurosurgeons and radiologists who interpret preoperative imaging of patients with cTN should be familiar with the technique for measuring the SATNaPT" due to its practical impact.

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The proposed novel biomarker is straightforward and easily assessed on routine preoperative imaging. As the authors acknowledge, multiple other imaging biomarkers have been proposed to correlate with outcome after MVD, and it is not clear how (or whether) SATNaPT might be related to other anatomic characteristics of the trigeminal nerve and cerebellopontine angle. It is notable that most patients improved regardless of their SATNaPT, and the small number of patients who had hyperacute measurements make definitive conclusions problematic. Nevertheless, the results of this study suggest that trigeminal nerve anatomy may be associated with a meaningful difference in surgical outcome.

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