The Anatomy of the Greater Occipital Nerve: Implications for the Etiology of Migraine Headaches

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An interest in pursuing new theories of the underlying etiology of migraine headaches has been sparked by previously published reports of an association between amelioration of migraine headache symptoms and corrugator resection during endoscopic brow lift. This theory has further been reinforced by recent publications documenting improvement in migraine headaches following injection of botulinum A toxin. There are thought to be four major "trigger points" along the course of several peripheral nerves that may cause migraine headaches. Among these peripheral nerves is the greater occipital nerve. For this reason, the authors have undertaken an anatomic study of this nerve to determine its usual course, potential anatomic variations, and possible points of potential entrapment or compression. The results of this anatomic study have enhanced further development of techniques designed to address these points of entrapment/compression and potentially lead to relief of migraine headaches caused by this mechanism. Twenty cadaver heads from patients with an unknown history of migraine headaches were dissected to trace the normal course of the greater occipital nerve from the semispinalis muscle penetration to the superior nuchal line. Standardized measurements were performed on 14 specimens to determine the location of the emergence of the nerve using the midline and occipital protuberance as landmarks. On the basis of this information, the location of emergence was determined to be at a point centered approximately 3 cm below the occipital protuberance and 1.5 cm lateral to the midline. This location can, in turn, be used to guide the practitioner performing chemodenervation of the semispinalis capitis muscle in an attempt to provide migraine symptom relief. (*Plast. Reconstr. Surg.* 113: 693, 2004.)

Traditionally, migraine headaches are thought to be related to an underlying centrally based neurovascular phenomenon. However, recent evidence suggests that a more peripheral mechanism may play a significant role. Four peripheral areas have been identified as trigger points for migraine headaches. Three are in the frontal, temporal, and occipital regions (relating to the supraorbital, zygomaticotemporal, and greater occipital sensory nerve regions, respectively), while the fourth is related to turbinate and septal pathology.

One of the senior authors (B.G.) recently described the unexpected amelioration or resolution of migraine headaches after endoscopic brow lift with corrugator supercilii resection.[1] In that retrospective study, approximately 39 percent of patients with a history of migraines reported complete resolution of their symptoms, while 41 percent observed significant improvement. A follow-up prospective study by the same author found that 55 percent of patients treated with botulinum toxin A (to their corrugators) demonstrated complete elimination of their headache symptoms, while almost 28 percent experienced significant improvement. Furthermore, in those patients who responded favorably to botulinum toxin injection, subsequent surgical resection of corrugator supercilii muscle (with or without release of the zygomaticotemporal branch of the trigeminal nerve) resulted in elimination or significant improvement in headaches in 96 percent of patients.[2]

These promising results have begged the question of whether this technique can be applied to other trigger points with the same

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outcome. The focus of this study was to identify the site of muscular investment of the greater occipital nerve and to determine external landmarks to aid in precise injection of botulinum toxin A and operative location of this region.

Background

Anatomy texts describe the course of the greater occipital nerve as curving medially *around* the semispinalis muscle and only piercing a fascial plane in the region of the superior nuchal line.[3,4] Other anatomy texts and further studies have shown, however, that in the vast majority of cases, the greater occipital nerve actually pierces the semispinalis muscle on its way to the subcutaneous layer.[5–8] This muscular investment of the greater occipital nerve may be a source of compression, entrapment, or irritation. Several elegant anatomic studies exist that describe the course of the nerve, yet the clinician cannot readily find the greater occipital nerve course through the semispinalis muscle on the basis of useful external landmarks. This study was designed to review the anatomy, corroborate the previous findings, and identify topographic landmarks for accurate injection of botulinum A toxin.

Materials and Methods

Twenty fresh human cadaver heads were obtained and shaved (40 greater occipital nerves total). The first six cadavers were used to study the course of the greater occipital nerve and its relationship to the semispinalis capitis only. In the remaining 14 specimens (28 greater occipital nerve specimens), a marking and measurement protocol was used. The skin was marked vertically in the midline using the spinous processes and the external occipital protuberance. A horizontal line was drawn extending between the external auditory canals and through the occipital protuberance (Fig. 1).

A 19-gauge needle was dipped in methylene blue and passed perpendicularly through the skin to mark the subcutaneous tissue along these lines and at the occipital protuberance. This allowed measurements in the deeper layers of dissection to accurately correlate with these external landmarks. Flaps of skin and subcutaneous tissue were elevated to expose the galea, superior nuchal line, and trapezius muscle bilaterally (Fig. 2, *above, left*).

The trapezius muscle with oblique fibers was elevated to reveal the splenius and semispinalis muscle layer, and the greater occipital nerve was found to be piercing the semispinalis muscle in this region (Fig. 2, *above, center*).

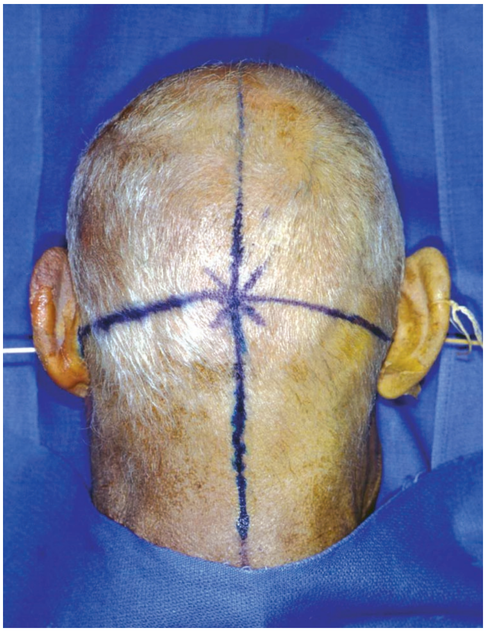

FIG. 1. Marking of cadaver head. Auditory canals and occipital protuberance were marked externally and then transcutaneously with methylene blue.

Using a 25-gauge needle, the nerve was marked with methylene blue at the site of its exit through the muscle, and this point was measured laterally from the midline and inferiorly from the occipital protuberance. Next, the semispinalis muscle with vertical fibers was elevated along its medial border and the deep penetration of the nerve was noted, which was also marked (Fig. 2, *above, right* and *below, left*).

After muscle division, the distance between the two markings on the nerve was measured, representing the intramuscular course (Fig. 2, *below, right*).

It was noted that in all specimens this represented the approximate thickness of the muscle, because the nerve did not run significantly cranially or caudally within the muscle; instead, it essentially pierced the structure, running directly from deep to superficial. The nerve width was also measured 5 mm proximal to the site of muscle penetration (point A), at the site of emergence (point B), and 5 mm distal to the site of emergence (point C).

Results

On both sides of all 20 cadavers (40 sites), the greater occipital nerve was found to pierce the semispinalis capitis. For the 14 heads in which measurements were taken, the mean dis-

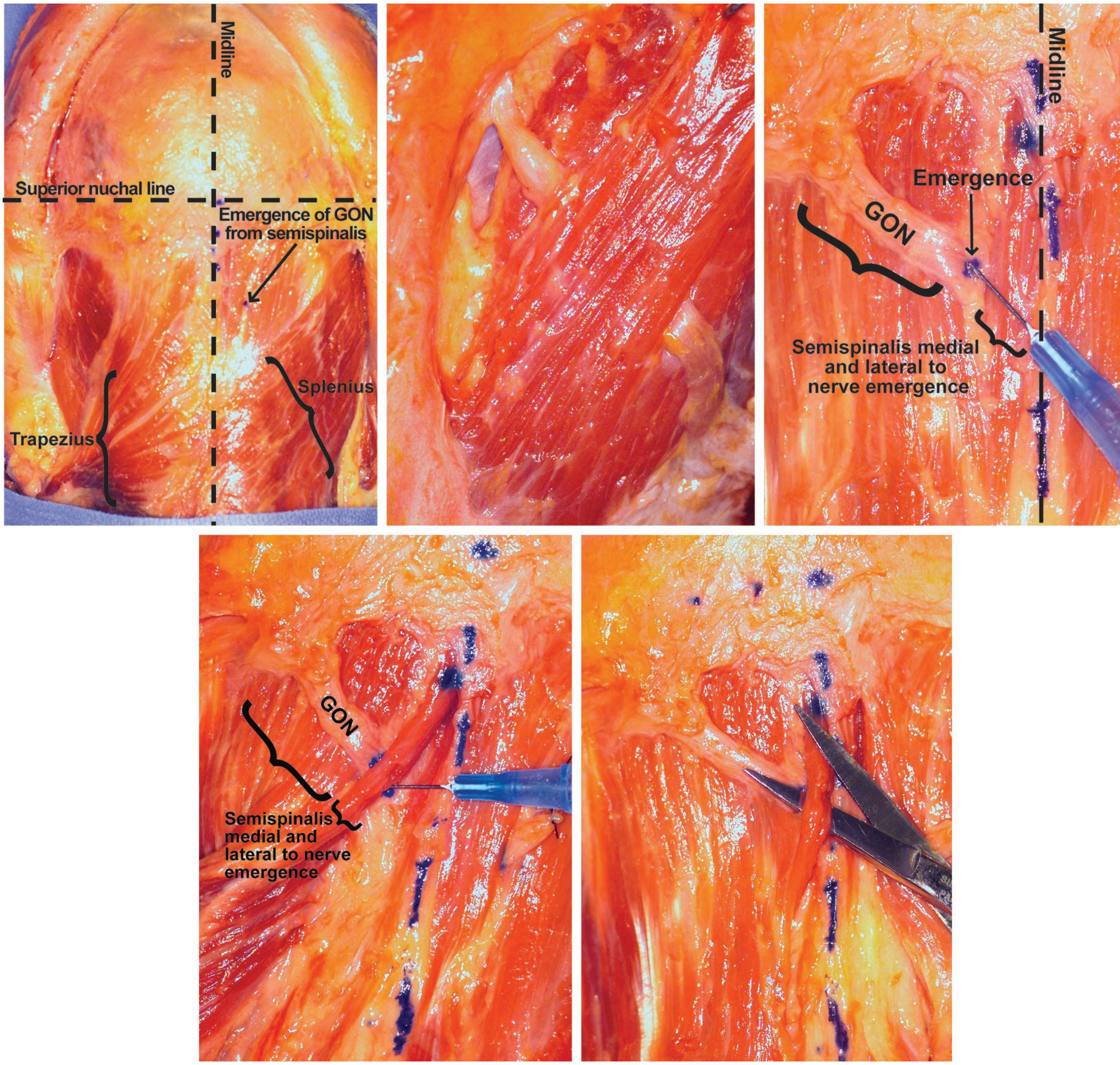

FIG. 2. (*Above, left*) Elevated scalp and subcutaneous tissue. The trapezius has been elevated on the specimen's right side to reveal the semispinalis and splenius muscles. (*Above, center*) Greater occipital nerve seen running through the semispinalis muscle. (*Above, right*) Superficial marking of the greater occipital nerve. (*Below, left*) Deep marking of the greater occipital nerve. *Dashed line* marks the midline. (*Below, right*) Division of overlying muscle to measure intramuscular distance. *GON*, greater occipital nerve.

tance of emergence of the greater occipital nerve from the midline was 14.1 mm on the right and 13.8 mm on the left (SD, 4.4 mm and 4.3 mm, respectively). The mean point of emergence inferior to the occipital protuberance was 29.1 mm on the right and 28.7 mm on the left (SD, 7.8 mm on the right and 6.6 mm on the left). The mean distance of intramuscular investment was 7.6 mm on the right and 8.9 mm on the left (SD, 2.9 mm and 3.2 mm, respectively) (Table I).

TABLE I
Results from Measurements of Site of Greater Occipital Nerve Emergence from Semispinalis

	Right (mm)	Left (mm)
Point of emergence from midline, mean ± SD	14.1 ± 4.4	13.8 ± 4.3
Point of emergence inferior to occipital protuberance, mean ± SD	29.1 ± 7.8	28.7 ± 6.6
Intramuscular investment, mean ± SD	7.6 ± 2.9	8.9 ± 3.2

On the basis of our measurements and mean distribution of the emergence of 28 greater occipital nerves, we have concluded that there is a region 1.5 cm in diameter that is centered approximately 3 cm below and 1.5 cm lateral to the occipital protuberance where the muscular investment of the greater occipital nerve can be reliably interrupted, either pharmacologically or surgically (Fig. 3).

Nerve width changed on average from 2.7 mm to 2.4 mm on the right and 3.0 mm to 2.9 mm on the left as it came through the muscle (Table II). Though the overall trend in nerve width was to become slightly smaller as it emerged through the semispinalis, paired *t* test analysis of nerve width did not demonstrate statistical significance with respect to a change in nerve diameter around the site of emergence in this study (Table III).

Discussion

In 1982, Bogduk[8] traced the routes of the sensory nerves from the cervical rami. The greater occipital nerve, which is the continuation of the medial branch of the C2 dorsal root, was traced from the dorsal root to its ultimate arborization in the subcutaneous tissue above the superior nuchal line. An important finding of this elegant study was that the semispinalis muscle was the only site of consistent muscular investment of the greater occipital nerve.

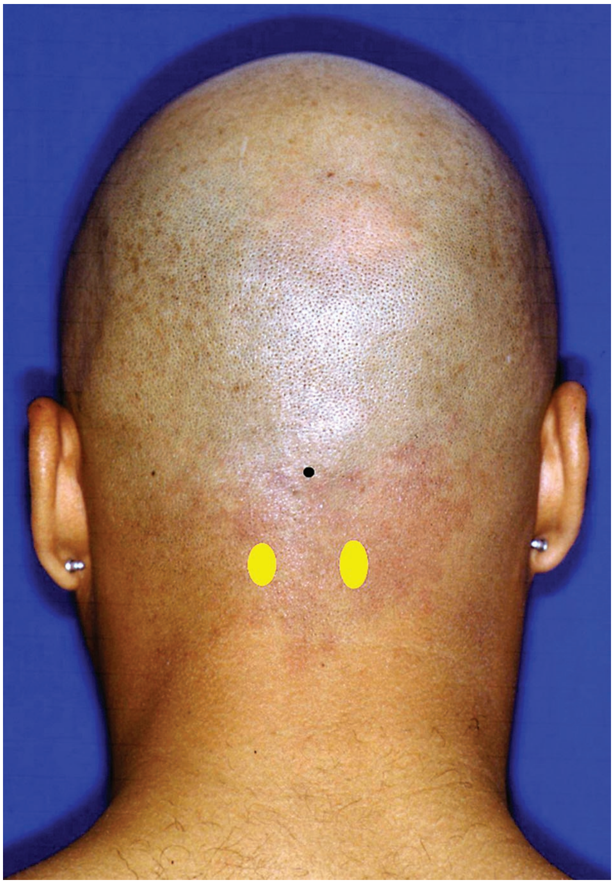

Fig. 3. Marking of area of nerve localization bilaterally. *Black dot* is the occipital protuberance and the *green ovals* mark the site of greater occipital nerve emergence bilaterally to 1 SD.

In 1991, Bovim et al.[7] revisited the anatomic course of the greater occipital nerve and, contrary to Bogduk's earlier work, found three potential sources of muscular investment. In their study, 40 greater occipital nerve specimens were dissected in 20 fresh cadaver heads. Their results demonstrated that the greater occipital nerve pierced the semispinalis most often (36 of 40, or 90 percent of the time), followed by the trapezius (18 of 40; 45 percent of the time), and only rarely did it pierce the inferior oblique (three of 40; 7.5 percent of the time). Though the authors described a distance from the occipital protuberance to the semispinalis penetration, which on average was located 1.6 cm laterally and 3.7 cm inferiorly, they did not report a standard deviation. Therefore, the distribution of their measurements around the mean is unknown, which detracts from the clinical applicability of their results.

Although previous authors have developed elaborate means of standardizing head position and internal reference lines for locating the greater occipital nerve, we were able to achieve a high degree of consistency in locating the emergence of the greater occipital nerve using external landmarks. As mentioned above, the greater occipital nerve has been described as piercing several muscles along its length, specifically the inferior oblique, the trapezius, and the semispinalis. Theoretically, any one (or combination) of these muscular investments could serve as a source of compression or irritation of the nerve. In contrast to others,[9] we have found in our study that there is little or no muscular investment of the greater occipital nerve through the trapezius and therefore it is not likely to be a probable site of compression. We did find, however, that the only consistent transmuscular course was in the region of the semispinalis, which is the most likely point of compression or irritation.

Based on early evidence suggesting a more peripheral mechanism for migraine headaches,[2] this study attempted to further eluci-

TABLE II
Width of Nerve around the Site of Emergence

	Average Width 5-mm Proximal	Average Width at Emergence	Average Width 5-mm Distal	Regression *p*
Right	2.7 mm	2.6 mm	2.4 mm	0.233
Left	3.0 mm	2.8 mm	2.9 mm	0.822

date the anatomic course of one particular nerve, the greater occipital nerve, and detect possible points of muscle or fascial entrapment, which may lead to compression or irritation. The clinical sequelae of muscular paralysis and surgical release of the greater occipital nerve using this data are now being studied. If outcomes correlate with results from our prior experience in the corrugator region, the case for a peripheral mechanism as the etiology of migraine headaches (and the existence of trigger points) is strengthened. To our knowledge, there has been no attempt to utilize botulinum toxin in the suboccipital region specifically to address migraine headaches. We are currently using this information to begin injections and have started performing surgical release of this nerve with institutional review board approval from two different centers.

Conclusions

There is evidence to suggest that the underlying etiology of migraine symptomatology may be peripherally rather than centrally mediated. Trigger points along peripheral nerves have been identified, and preliminary evidence suggests that interruption of these trigger points leads to improvement of the patient's symptoms. This study was designed to specifically address one trigger point, the greater occipital nerve, and to define its anatomic location so that points of chemodenervation using external landmarks can be used to relieve migraine symptoms. Our study has resulted in the identification of an area approximately 1.5 cm in diameter, 3 cm inferior to the occipital protuberance and 1.5 cm lateral to the midline, that corresponds to the location of the greater occipital nerve as it emerges from the underlying semispinalis. The utility of this information will be determined in further studies.

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TABLE III
Results of Comparison of Nerve Widths at Various Points*

Comparison of Nerve Width Measurement Groups	Paired *t* test *p*
Group A—group B	0.84
Group A—group C	0.77
Group B—group C	0.65

* Group A represents nerve widths at a point 5 mm proximal to superficial nerve emergence from the semispinalis muscle. Group B represents nerve widths at the location of superficial emergence. Group C represents nerve widths at a 5 mm distal to the point of superficial emergence. There was no statistically significant change in nerve width across these points.

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