The Lesser and Third Occipital Nerves and Migraine Headaches

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Background: Reports of a correlation between relief of migraine headaches and resection of corrugator muscles or injection of botulinum A toxin have renewed interest in finding the cause of migraine headaches and identifying the trigger sites. Four trigger sites have been described. One of these is along the course of the greater occipital nerve. Recent anatomical studies of this nerve have defined its location with respect to external landmarks, leading to new studies with gratifying results. There is a subset of patients who undergo chemodenervation or surgical release of the greater occipital nerve and note improvement or elimination of the symptoms along the greater occipital nerve course but who experience an emergence of migraine headache symptoms laterally. The authors propose the lesser occipital nerve as the source of pain in those who experience headaches laterally and involvement of the third occipital nerve in those who notice residual symptoms in the midportion of the occipital region.

Methods: To test this hypothesis anatomically, 20 cadaver heads were dissected to trace the course of the lesser occipital nerve and third occipital nerve and define the location of these nerves with respect to external landmarks. The midline and a line drawn between the inferiormost points of the external auditory canals were used to obtain standardized measurements of these nerves.

Results: The location of emergence of the lesser occipital nerve was determined to be an area centered 65.4 ± 11.6 mm from midline and 53.3 ± 15.6 mm below the line between the external auditory canals. The third occipital nerve was found 13.2 ± 5.3 mm from midline and 62.0 ± 20.0 mm down from the line between the two external auditory canals.

Conclusions: This information can be used to conduct clinical trials of chemodenervation of these nerves in an attempt to eliminate migraine symptoms in the subset of patients who continue to experience residual symptoms after surgical release of the greater occipital nerve. (*Plast. Reconstr. Surg.* 115: 1752, 2005.)

Recent studies have challenged the traditional teaching of exclusive centrally mediated activation of migraine headaches, suggesting instead a major contribution from the peripheral trigger sites.[1] Four such peripheral trigger sites have been described.[4] Three of these areas (frontal, temporal, and occipital) correspond to a particular sensory nerve (supraorbital/supratrochlear, zygomaticotemporal, and greater occipital, respectively) that is thought to be the cause of migraine symptoms originating from that location. The fourth trigger point corresponds to the nasal septum and turbinates.

The senior author of this article (Guyuron) has studied the first two trigger points (supraorbital and zygomaticotemporal nerves)

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and described the improvement or elimination of migraine headaches in patients who were treated with injections of botulinum A toxin to the corrugator supercilii muscle, underwent surgical resection of the corrugator supercilii muscle, or underwent transection of the zygomaticotemporal nerve.[1,2] A more recent study guided by the senior author has examined the third trigger point, or occipital area, specifically identifying sites of muscular penetration of the greater occipital nerve and external landmarks important in locating these sites.[3] Results from this study revealed a consistent location of muscular investment of the greater occipital nerve.[3] As a result of this study, the senior author has injected botulinum toxin A into this area on patients who described migraine symptoms originating from the occipital location. In patients who had a positive response to these injections, a partial resection of the semispinalis muscle was performed. In his most recent study, the senior author has described 34 such patients, 21 of whom experienced complete relief of migraine symptoms after partial resection of the semispinalis muscle and 13 of whom experienced a decrease of at least 50 percent in either the severity or frequency of their migraines.[4]

The symptoms of this latter group of 13 patients are the focus of the current study. It is our belief that the persistence of symptoms in the occipital area despite adequate release of the greater occipital nerve is secondary to entrapment of other nerves in this area. Specifically, the third occipital nerve, because of its proximity to the greater occipital nerve, is a logical choice. Furthermore, in the 13 patients with persistent symptoms, some described a shifting of their symptoms laterally.[4] This information prompted an investigation of the lesser occipital nerve as well, because it is located lateral to the greater occipital nerve. Thus, the purpose of the present study was to examine the anatomy of the third occipital nerve and lesser occipital nerve and to identify external landmarks and the muscles that they pierce to reach the subcutaneous plane, to aid in the treatment of these areas through either chemodenervation or surgical release. In addition, the anatomy of the greater occipital nerve was reexamined to confirm the previous findings.

Pertinent Anatomy

The lesser occipital nerve is the ventral ramus of C2 and sometimes C3. It is responsible for providing sensory innervation to the superior ear, postauricular skin, and skin of the lateral neck.[5–8] The third occipital nerve is the dorsal ramus of C3. The third occipital nerve provides sensory innervation to the medial posterior scalp and neck.[5–7] Most anatomy textbooks do not provide detailed descriptions of either the lesser occipital nerve or the third occipital nerve. However, there have been several sophisticated studies that have examined the course of these nerves through dissections from the root to the periphery. Most of these studies did not examine the nerves in relation to external landmarks. Becser et al. conducted one such anatomical study of the lesser occipital nerve in which they concluded that there was wide variability in the location of this nerve and, therefore, no single correct location at which to block it.[9] The current study intends to reexamine the anatomy of the lesser occipital nerve and the third occipital nerve, specifically with respect to muscle penetration and external landmarks, and determine the consistency of this localization.

Materials and Methods

Twenty fresh human cadaver heads were used for this study. Each cadaver head was marked in the following way: A fine hemostat was placed in each external auditory meatus at the inferiormost portion of the canal. A silk suture was used to connect these two points, creating a transverse line across the occiput that was illustrated with a marking pen. The spinous processes were used to identify the midline, and a vertical line was drawn connecting these processes. A 19-gauge needle dipped in methylene blue was then inserted into the skin to mark the skin and subcutaneous tissues along the course of both the transverse and vertical lines (Fig. 1).

Both the vertical and horizontal lines were incised and the skin flaps were raised (Fig. 2). Next, the trapezius muscle was elevated in a medial to lateral direction. Similarly, the splenius muscle and semispinalis muscle were raised as separate muscle flaps (Fig. 3). On each side, the distance from the greater occipital nerve to the vertical and horizontal lines was calculated. Also determined was whether the nerve pierced the trapezius muscle or the semispinalis muscle and, if so, the location of this muscular investment. During this part of the dissection, the third occipital nerve was

FIG. 1. Marking of a cadaver head. Inferiormost position of each external auditory canal was used to draw the transverse line, whereas the spinous processes were used to draw the vertical line. These lines were marked transcutaneously with a 19-gauge needle.

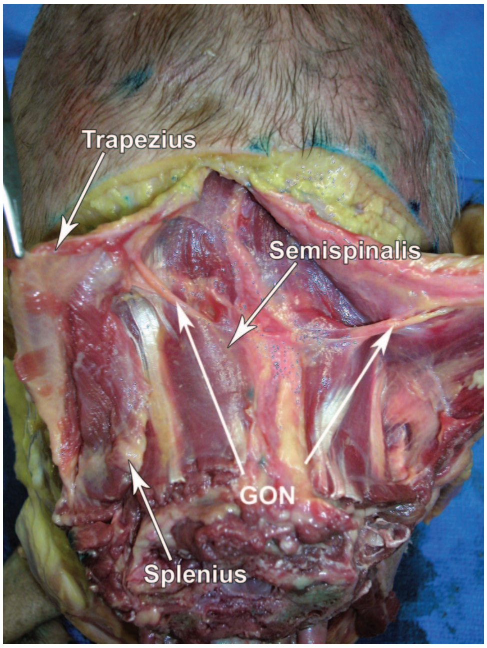

FIG. 3. Trapezius and splenius muscle flaps raised to reveal the semispinalis muscle. Note the greater occipital nerve (*GON*) penetrating the semispinalis muscle.

FIG. 2. Elevated skin and subcutaneous tissue.

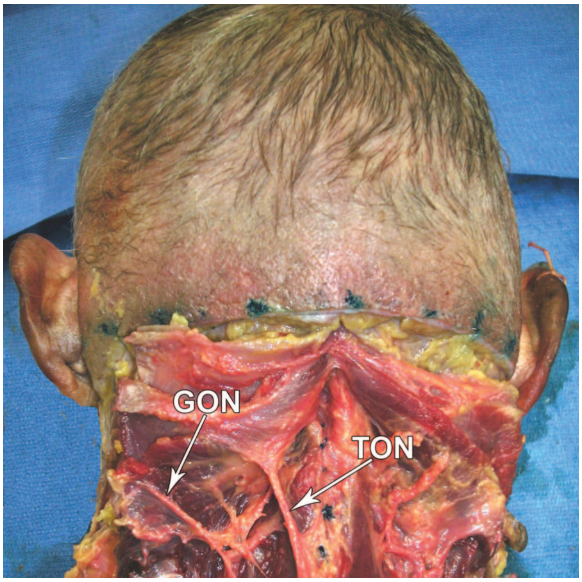

FIG. 4. Dissection of the greater occipital nerve (*GON*) and the third occipital nerve (*TON*).

found and its location as it pierced the semispinalis muscle was recorded (Fig. 4). Attention was then turned laterally. The lesser occipital nerve was located as it emerged from the posterior border of the sternocleidomastoid muscle (Fig. 5). The precise location of its emergence was then determined by calculating the distance from the lesser occipital nerve to the vertical and horizontal lines.

RESULTS

Greater Occipital Nerve

The greater occipital nerve was found on both sides of 19 cadavers. In the remaining cadaver, the muscles had been damaged centrally. In all cases in which the nerve was found, the greater occipital nerve was found to pierce the semispinalis capitis muscle. In one cadaver,

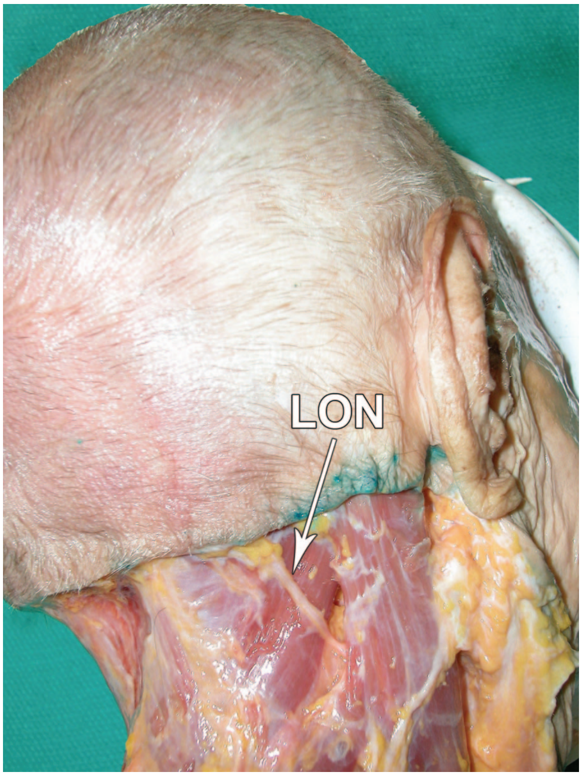

FIG. 5. Lesser occipital nerve (*LON*) as it emerges from behind the posterior border of the sternocleidomastoid muscle.

the left greater occipital nerve had two branches before penetration of the semispinalis capitis muscle. In another cadaver, the right greater occipital nerve had two branches before entering the muscle. The mean horizontal distance of the greater occipital nerve from the midline to its point of muscle penetration was 11.0 ± 4.8 mm on the left and 11.8 ± 4.6 mm on the right. The mean vertical distance from the line drawn between the lowest portion of the external auditory canals was 26 ± 9.6 mm on the left and 27 ± 11.7 mm on the right (Table I).

Lesser Occipital Nerve

Thirty lesser occipital nerves were found in 16 cadavers. In four cadavers (seven nerves), the neck was cut too high to find the lesser occipital nerve. Three other lesser occipital nerves could not be found on our dissection. Of the 30 nerves found, the mean horizontal distance from their point of emergence from beneath the sternocleidomastoid muscle to the midline was 68.9 ± 10.1 mm on the left and 61.3 ± 12.3 mm on the right. The mean vertical distance from the line drawn between the lowest points of the external auditory canals

TABLE I
Greater Occipital Nerve*

	Left	Right
Mean horizontal distance to midline, mm	11.0	11.8
Median horizontal distance, mm	11.5	11
Range, mm	0–17	8–28
SD, mm	4.8	4.6
Mean vertical distance from line between the external auditory canals, mm	26	27
Median vertical distance, mm	28.5	30
Range, mm	7–37	9–43
SD, mm	9.6	11.7
Percentage piercing the semispinalis muscle	100	100

* Data are from 19 cadavers.

was 53.2 ± 16.1 mm on the left and 53.5 ± 15.7 mm on the right. In one cadaver, the nerve ascended beneath the muscle. In this case, the point of ascension was just anterior to the posterior muscle border, and this point was recorded. Four of the lesser occipital nerves (13.3 percent) pierced the sternocleidomastoid muscle. None penetrated the trapezius muscle (Table II).

Third Occipital Nerve

Twenty-two third occipital nerves were found in 13 cadavers. In one cadaver, the muscles were damaged centrally so that neither third occipital nerve could be found. In three cadavers (six third occipital nerves), the neck was cut too high to locate the third occipital nerve. Ten other third occipital nerves could not be found on dissection. Of the 22 nerves that were found, all pierced the semispinalis muscle. The mean horizontal distance from the midline was 13.0 ± 5.0 mm on the left and 13.3 ± 5.8 mm on the right. The mean vertical distance from the line between the external auditory canals was 60.7 ± 20.2 mm on the left and 63.4 ± 20.8 mm on the right (Table III). In one cadaver, two branches of the third occipital nerve were noted on the left side piercing the muscle adjacent to each other.

DISCUSSION

The location of the greater occipital nerve has been studied by the senior author (Guyuron) in a recent article.[3] In that study, 28 greater occipital nerves were located in a manner similar to the one described here, and the authors concluded that the greater occipital nerve could be reliably found approximately 3 cm below the occipital protuberance and 1.5 cm lateral to the midline. The current study

TABLE II
Lesser Occipital Nerve*

	Left	Right	Overall
Mean horizontal distance to midline, mm	68.9	61.3	65.4
Median horizontal distance, mm	70	61	69
Range, mm	50–85	42–80	42–85
SD, mm	10.1	12.3	11.6
Mean vertical distance from line between external auditory canals, mm	53.2	53.5	53.3
Median vertical distance, mm	56.5	55	55
Range, mm	28–82	30–78	28–82
SD, mm	16.1	15.7	15.6
Percentage piercing the sternocleidomastoid	12.5	14.3	13.3

* Data are from 16 cadavers.

corroborates this information with distances that are very similar. Specifically, the distances to midline in the previous study were 14.1 mm on the right and 13.8 mm on the left, compared with 11.8 mm on the right and 11.0 mm on the left in the current study. Vertical distances in the previous study were 29.1 mm on the right and 28.7 mm on the left, whereas the current study found vertical distances of 27 mm on the right and 26 mm on the left. Thus, the consistency in the anatomical location of the greater occipital nerve observed in the previous study was repeated in this study.

Much less has been written about the anatomy of either the lesser occipital nerve or the third occipital nerve. In 2000, Pantaloni and Sullivan investigated the anatomy of the lesser occipital nerve in 19 hemifaces to determine its contribution to the sensory innervation of the ear and to assess how best to avoid injury to this nerve during a face-lift procedure.[8] They found that, although in the majority of cases the great auricular nerve was the dominant nerve supplying sensory innervation to the ear, in five of 19 cases the lesser occipital nerve supplied two-thirds or more of this sensory innervation. They also found that the lesser occipital nerve reliably emerged from the posterior border of the sternocleidomastoid muscle superior to the point of emergence of the great auricular nerve. Furthermore, the authors noted that the lesser occipital nerve penetrated the subcutaneous plane at a variable location. They did not, however, measure the point of emergence of the lesser occipital nerve in relation to external landmarks, nor did the authors measure any distances between the lesser occipital nerve and great auricular nerve.

In 1994, Lucas et al. also studied the anatomy of the lesser occipital nerve with respect to cervicogenic headache.[10] This study involved dissecting eight cadaver heads starting peripherally, finding the nerve beneath the skin, and then tracing the nerve proximally to the root of C2. This study provided a very detailed description of the course of the lesser occipital nerve from the extradural segment of C2 to its terminal branches in the skin. Furthermore, the relationship of the lesser occipital nerve to surrounding nerves and vascular structures was described in an effort to explain involvement of the lesser occipital nerve in cervicogenic headaches. The authors concluded that pain in the face or the head can be caused by either compression or stretching in various areas along the course of the lesser occipital nerve, or from the relationship of the lesser occipital nerve to the superior cervical ganglion or the

TABLE III
Third Occipital Nerve*

	Left	Right	Overall
Mean horizontal distance to midline, mm	13.0	13.3	13.2
Median horizontal distance, mm	12.5	11.5	12
Range, mm	5–23	5–22	5–23
SD, mm	5.0	5.8	5.3
Mean vertical distance from line between external auditory canals, mm	60.7	63.4	62.0
Median vertical distance, mm	56	56	56
Range, mm	35–106	34–95	34–106
SD, mm	20.2	20.8	20.0
Percentage piercing semispinalis muscle	100	100	100

* Data are from 13 cadavers.

ophthalmic branch of the trigeminal nerve. However, although the authors described the course of this nerve in detail, they did not obtain any measurements of the distances between the lesser occipital nerve and surrounding structures, nor did they comment on the consistency of this anatomy.

In 1998, Becser et al. conducted an anatomical study of the occipital nerves with the purpose of finding suitable locations for nerve blockade.[9] In this study, the median distance from the lesser occipital nerve to the midline at the intermastoid line was 53 mm. However, the authors concluded from this study that there is no single, correct location for blocking the occipital nerves because not only was there considerable variation in the distances between the lesser occipital nerve and the midline (32 to 90 mm), but almost half of the lesser occipital nerves dissected had branches at or above the intermastoid line. Instead, the authors advocated blocking this nerve in more than one location. The current study measured the lesser occipital nerve at the point of emergence from the posterior border of the sternocleidomastoid muscle. This location is more proximal than where Becser et al. noted the lesser occipital nerve branches in their study. Therefore, this more proximal location would be a better site at which to block the nerve. Becser et al.'s measurements consisted of horizontal distances to the midline with an SD of 16.1 mm, compared with an SD of 11.6 mm in our study. Furthermore, the scope of our study is broader, as we examined 30 lesser occipital nerves, compared with the 19 nerves examined by Becser et al. Therefore, given the proximal location, less variability in the data, and broader scope of the current study, it is our opinion that the lesser occipital nerve can be reliably blocked. The point for blockage of the lesser occipital nerve, according to our findings, is an area approximately 3 cm in diameter centered at a point 6.5 cm from midline and 5.3 cm below the line between the external auditory canals. Recent studies indicate that botulinum toxin A can diffuse a distance of 3 cm or more from the injection site.[11] Given this information, our data would advocate blocking the lesser occipital nerve in only one location.

The third occipital nerve is the least well studied of the three nerves discussed in this article. In 1986, Bogduk and Marsland studied the third occipital nerve with respect to headaches caused by osteoarthritis of the C2–3 zygapophyseal joint.[12] They described a technique for blocking the third occipital nerve that involved injection of local anesthetic under fluoroscopic guidance at the C2–3 joint. Their aim was to confirm the hypothesis that osteoarthritis at this joint and its subsequent irritation of the third occipital nerve was the cause of headaches. Seven of 10 patients experienced relief of symptoms after this type of nerve block.

Our hypothesis is very different in that we believe the third occipital nerve may be constricted peripherally by its muscular investment. Our objective was to define the location of the third occipital nerve with respect to external landmarks so that this nerve could be either chemically or surgically denervated to allow relief of symptoms. The data from the present study demonstrate that the third occipital nerve can be found in an area located 1.3 cm from midline and 6.2 cm down from the line between the two external auditory canals. The SD for the vertical distance is 20 mm, which suggests greater variability in the vertical emergence of this nerve. To reliably locate this nerve, one would need an area approximately 4 cm in length. For this reason, chemical denervation would be more reliably achieved with two injections along a 4-cm vertical line located 1.3 cm from midline. We suggest administration of one injection at 1 cm above the horizontal line and the other injection at 1 cm below the horizontal line. In this way, taking into account the diffusion distance of botulinum toxin A, the third occipital nerve can be reliably blocked.

Conclusions

A peripheral cause has been suggested for migraine headaches. Interruption of any of the four defined trigger points has been shown to relieve migraine symptoms in patients. The greater occipital nerve has been defined as one of these trigger points. This study aimed to investigate the location of two adjacent nerves, the lesser occipital nerve and the third occipital nerve, to provide landmarks for either chemodenervation or surgical release. The lesser occipital nerve was found to emerge from the posterior border of the sternocleidomastoid muscle in a region 3 cm in diameter centered 6.5 cm from midline and 5.3 cm below the line drawn between the two external auditory canals. The third occipital nerve was found to emerge in a region 4 cm in diameter centered 1.3 cm from midline and 6.2 cm below the line between the two external auditory canals. We hope this information will prove useful in clinical applications for relief of migraine headaches.

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