Anatomical study of the third occipital nerve and its potential role in occipital headache/neck pain following midline dissections of the craniocervical junction

Laboratory investigation

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Object. Occipital neuralgia can be a debilitating disease and may occur following operative procedures near the occipital and nuchal regions. One nerve of this region, the third occipital nerve (TON), has received only scant attention, and its potential contribution to occipital neuralgia has not been appreciated. Therefore, in the present study the authors aimed to detail the anatomy of this nerve and its relationships to midline surgical approaches of the occiput and posterior neck.

Methods. Fifteen adult cadavers (30 sides) underwent dissection of the upper cervical and occipital regions. Special attention was given to identifying the course of the TON and its relationship to the soft tissues and other nerves of this region. Once identified superficially, the TON was followed deeply through the nuchal musculature to its origin in the dorsal ramus of C-3. Measurements were made of the length and diameter of the TON. Additionally, the distance from the external occipital protuberance was measured in each specimen. Following dissection of the TON, self-retaining retractors were placed in the midline and opened in standard fashion while observing for excess tension on the TON.

Results. Articular branches were noted arising from the deep surface of the nerve in 63.3% of sides. The authors found that the TON was, on average, 3 mm lateral to the external occipital protuberance, and small branches were found to cross the midline and communicate with the contralateral TON inferior to the external occipital protuberance in 66.7% of sides. The TON trunk became subcutaneous at a mean of 5 cm inferior to the external occipital protuberance. In all specimens, the cutaneous main trunk of the TON was intimately related to the nuchal ligament. Insertion of self-retaining retractors in the midline placed significant tension on the TON in all specimens, both superficially and more deeply at its adjacent facet joint.

Conclusions. Although damage to the TON may often be unavoidable in midline approaches to the craniocervical region, appreciation of its presence and knowledge of its position and relationships may be useful to the neurosurgeon who operates in this region and may assist in decreasing postoperative morbidity.

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Key Words • anatomy • craniocervical anatomy • pain syndromes

First described in 1821 by Beruto y Lentijo and Ramos, occipital neuralgia is a common and sometimes debilitating disorder characterized by recurrent occipital headaches.27 The symptoms of occipital neuralgia include paroxysmal burning pain in the occipital region that sometimes radiates to the forehead and may follow surgery of the occiput or nuchal regions.18,20,23 Hyperalgesia, dysesthesia, and paroxysmal vertigo have also been associated with this condition, a syndrome similar to migraine headaches.2,23 Occipital neuralgia has been referred to by many names, including Arnold neuralgia, syndrome sympathique, cervicale posterieur, migraine cervicale, occipital neuritis, cervicogenic headache, and spinally transformed migraine.3,7,13,19,30

Occipital neuralgia can be conservatively managed in several ways, including nonsteroidal analgesics, opioids, neuromodulators, transcutaneous electrical nerve stimulation, and external orthosis.1,25 While pharmacotherapy and

Abbreviation used in this paper: TON = third occipital nerve.
noninvasive procedures can help manage the symptoms of mild occipital neuralgia, refractory pain usually warrants surgery. The procedures used to treat occipital neuralgia include neurolysis and decompression, neurectomy, rhizotomy and ganglionotomy, C1–2 fusion, radiofrequency ablation, and peripheral nerve stimulation.2,4,12,20,24–26,33

Several causes of occipital neuralgia have been implicated, including trauma, fibrositis, myositis, fracture of the atlas, and compression of the C-2 nerve root, C1–2 arthrosis syndrome, atlantoaxial lateral mass osteoarthritis, cervical cord tumor, Chiari malformation, neurosyphilis, and surgery.1,7–9,28,29,32

Third Occipital Nerve
Of the nerves potentially contributing to occipital neuralgia, the TON is by far the least referenced, and the symptoms of TON neuralgia commonly mimic those of greater occipital nerve neuralgia (Fig. 1 left). Furthermore, many textbooks of anatomy fail to mention this structure, which is readily visible on sonography and MR imaging.16 The third cervical dorsal ramus has a complex branching pattern, which starts at the articular pillar of the C-3 vertebra.31 The nerve then divides into lateral and medial branches, the latter of which ramifies into deep and superficial divisions. The superficial medial branch, referred to as the third occipital nerve, travels around the dorsolateral surface of the C2–3 facet joint, which it innervates. Interestingly, at levels below C2–3, each joint is innervated by 2 branches of the dorsal rami, but the C2–3 joint is innervated solely by the TON.15 The TON then supplies the semispinalis capitis muscle and travels deeply along the muscle before sending a communicating branch to the greater occipital nerve. After exiting overlying muscles, the nerve becomes cutaneous and supplies a small area of skin just below the superior nuchal line.31,36

The C2–3 Facet Joint
Perhaps the most heavily implicated area in TON neuralgia results from the nerve’s innervation of the C2–3 facet joint, which is a less familiar potential source of headache.5 While the atlantooccipital and atlantoaxial joints lie ventral to the emerging spinal nerves, the C2–3 facet joints are positioned behind the intervertebral joints at the level of the intervertebral disc.6 This biomechanical vulnerability, compared with the other upper cervical synovial joints, has been documented in the literature concerning TON entrapment.5,14,35 For example, Trevor-Jones35 reported on 3 patients in whom the TON was entrapped by osteophytes, and, following decompression, all patients had resolution of their preoperative headaches. An epidemiological analysis by Lord et al.27 revealed that a combination of headache and tenderness over the C2–3 facet joint yields a positive likelihood ratio of 2:1 for TON neuralgia.

![Fig. 1. Schematic drawings. Left: The nerves of the posterior cranio cervical region. Note the deep and superficial course of the TON. Right: Note the tension observed on the TON following the use of a self-retaining retractor. Also note that the superficial fascia that is pierced by the TON acts as a pulley, thus placing additional tension on the deeper components of the TON, including its facet branches.](Image)
As occipital neuralgia can be a debilitating disease and result from operative procedures near the occiput and nuchal regions, a thorough understanding of the anatomy of the nerves supplying this region is important. Moreover, of craniotomies, subtemporal and suboccipital approaches are associated with the most postoperative pain.11 Some authors have posited that such chronic pain may be due to scar tissue enveloping the occipital nerves and that, with movement, these nerves no longer have the capacity to move tension free.11 Therefore, the aim of the present study was to further elucidate the anatomy, course, and relationships of the TON to better understand its relationship to midline approaches to the posterior cranio cervical region.

Methods

Fifteen adult cadavers (30 sides) underwent dissection of the upper cervical and occipital regions. In the cadavers in the prone position, we removed the skin and superficial fasciae with special attention to identifying the course of the TON and its relationship to the soft tissues and other nerves of this region. Once identified superficially, the TON was followed deeply through the nuchal musculature (for example, the splenius and semispinalis capitis muscles) and to its origin from the dorsal ramus of C-3. Its relationships to these deeper muscles and the adjacent facet joint were documented. Nine specimens were female and 6 were male with an age range at death of 42–85 years (mean 71 years). Ten specimens were formalin fixed and 5 specimens were not embalmed. Measurements were made of the length and diameter of the TON. Additionally, the distance from the external occipital protuberance was measured in each specimen. All measurements were made twice and the average taken. Following dissection of the TON, self-retaining retractors were placed in the midline and opened in standard fashion while observing for excess tension on the TON. Statistical analysis comparing sides and sexes was performed using Statistica for Windows. The significance level was set at p < 0.05.

Results

In all specimens, the TON arose from the dorsal ramus of the third spinal nerve and traveled posteriorly, where it divided into a medial and a lateral branch (Fig. 2). Articular branches were noted arising from the deep surface of the nerve as it crossed the facet joint in 63.3% of sides. At the level of the C-2 spinous process, the TON turned dorsally and pierced the semispinalis capitis, splenius capitis, and trapezius muscles. We found that the TON was, on average, 3 mm (range 1.8–12 mm) lateral to the external occipital protuberance, and small branches were found to cross the midline and communicate with the contralateral TON inferior to the external occipital protuberance in the majority (66.7%) of sides. The mean diameter of the main TON trunk was 1.5 mm (range 1–2.2 mm). This trunk became subcutaneous at a mean of 5 cm (range 3.4–8 cm) inferior to the external occipital protuberance. The TON was found to often send fine communicating branches (range 0–5, mean 2.5) to the terminal branches of the greater occipital nerve. In all specimens, the cutaneous main trunk of the TON was intimately related to the nuchal ligament. Placement of self-retaining retractors in the midline created significant tension on the soft tissues surrounding the TON in all specimens, both superficially and more deeply at the adjacent facet joint with the turn of the nerve through the superficial fascia acting as a pulley (Fig. 1 right). No statistical difference was noted for measurements of the TON between sides or sexes.

Discussion

Anatomical Findings

Based on our cadaveric findings, in a midline dissection through the nuchal ligament one will encounter
and potentially injure the TON in the majority of patients. Additionally, placement of self-retaining retractors in the midline may place significant tension on the TON. The small branches found to cross the midline and communicate with the contralateral TON inferior to the external occipital protuberance would be difficult to avoid in midline surgical procedures. However, based on our findings, knowledge that the main TON trunk becomes subcutaneous at a mean of 5 cm inferior to the external occipital protuberance may allow early identification and minimize its damage. Finally, for potential surgical decompression of the TON, the surgeon should consider our observation of the nerve’s upward turn at the C-2 spinous process, the muscle layers that it traverses, and its relation to its adjacent facet joint. Other theories have been suggested that account for the pain distribution of TON headaches. Dash and colleagues have also suggested that the TON could be constricted peripherally by its musculotendinous investment.

Clinical Features of TON Compression

Although restricted neck movements and facet tenderness are cited as putative diagnostic signs of TON neuralgia, the only true diagnostic feature of TON headache is a positive response to TON blocks. Lord et al. stated that the prevalence of TON-related headaches among patients in whom headache is the predominant complaint after whiplash was as high as 53%. This suggests that TON neuralgia is the most common cause of headache in patients who experienced whiplash. Although there exists no standard treatment for TON neuralgia, Lord et al., Govind et al., and Bogduk and Marsland listed several therapies including intraarticular injections of steroids, percutaneous radiofrequency neurotomy, and cryocoagulation. However, Bogduk and Marsland found that open neurlectomy achieved the most enduring responses.

Conclusions

Although damage to the TON may often be unavoidable in midline approaches to the craniocervical region, appreciation of its presence and knowledge of the TON’s position and its relationships may be useful to the neurosurgeon who operates in this region and may assist in decreasing postoperative morbidity. Based on our anatomical study, we found that midline retraction in this region will place tension on the TON both superficially at its cutaneous branches and deeper near its facet branches. This tension, with subsequent injury to the TON, could be one reason for postcraniotomy headaches—either from local cutaneous nerve irritation/compression or cervicogenic from traction on the deeper facet branches of this nerve. Maneuvers such as intermittently releasing the retractors may minimize long periods of tension on the TON.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Tubbs. Acquisition of data: Tubbs, Mortazavi, Chern. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: all authors. Approved the final version of the paper on behalf of all authors: Cohen-Gadol. Study supervision: Tubbs.

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