Cruveilhier plexus: an anatomical study and a potential cause of failed treatments for occipital neuralgia and muscular and facet denervation procedures

Laboratory investigation

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Object. The nerves of the posterior neck are often encountered by the neurosurgeon and are sometimes the focus of denervation procedures for muscular, joint, or nervous pathologies. One collection of fibers in this region that has not been previously investigated is the Cruveilhier plexus, interneural connections between the dorsal rami of the upper cervical nerves.

Methods. Fifteen adult cadavers (30 sides) were subjected to dissection of the upper cervical and occipital regions with special attention given to identifying potential connections between adjacent extradural dorsal rami of the cervical nerves. When connections were identified, measurements were made and random samples were immunohistochemically stained.

Results. At least one communicating branch was identified on 86.7% of sides. Sampled nervous loops were composed primarily of sensory fibers, but occasional motor fibers were identified. For C-1, a communicating loop joined the medial branches of C-2 on 65.4% of sides. On 29.4% of sides, this loop pierced the obliquus capitis inferior muscle before joining C-2. On 54% of sides, a communicating loop joined the medial branches of the dorsal rami of C-2 and C-3; and on 15.4% of sides, a communicating loop joined the medial branches of the dorsal rami of C-3 and C-4. No specimen had communicating branches between the dorsal rami of cervical nerves C-5 to C-8. Articular branches arose from the deep surface of the interneural connections as they crossed the adjacent facet joint on 34.6% of sides. Loops giving rise to fibers that terminated into surrounding musculature were seen on 35% of sides.

Conclusions. Physical examinations that reveal unexpected results, such as altered sensory dermatome findings, may be attributed to the Cruveilhier plexus. Based on findings in the present study, surgical procedures, such as those aimed at completely denervating the upper posterior cervical musculature, facets, or nerves supplying the skin of the occiput, must also transect the Cruveilhier plexus. (DOI: 10.3171/2011.5.JNS102058)

Key Words • Cruveilhier plexus • neck • occiput • neuralgia • nerve connection • pain

Approaches to the posterior cranial fossa and posterior cervical spine often risk damaging regional sensory nerves. Such damage may result in unbearable pain and neuroma formation with severe dysesthesia. Moreover, pain from the occipital region and craniocervical junction is fairly common and often difficult to treat, and patients with severe recalcitrant symptoms can become disabled. Therefore, a thorough knowledge of the vicinal nerves and their variable connections between adjacent nerves may be important to the surgeon. One collection of dorsal rami in this area has been referred to as the “Cruveilhier plexus” (Jean Cruveilhier, French anatomist, 1791–1874) and is unusual in that these rami take part in the formation of a plexus, which is usually standard for their counterparts, the ventral rami (Fig. 1).

In 1844, Cruveilhier\textsuperscript{4} stated that “as the posterior branch of the third cervical nerve emerges from the posterior intervertebral foramen, it gives off an ascending branch, which forms an anastomotic arch with the descending branch of the second nerve: the succession of arches formed by the anastomoses of the first, second, and third nerves and the very numerous branches which arise
from their convexities constitute a plexus, which may be called the “posterior cervical plexus.” Today, Cruveilhier’s name lives on eponymously with this plexus of nerves.

As the Cruveilhier plexus might be associated with a variable clinical examination to assess dermatomal sensory distributions or failed denervation of the posterior cervical muscles or facets, or with occipital neuralgia procedures, the present study was focused on this anatomy in detail.14

Methods

Fifteen adult cadavers (30 sides) were subjected to dissection of the upper cervical and occipital regions. Eight specimens were embalmed and 7 were not. Eight specimens were female and 7 were male, with an age range at death of 53–101 years (mean 76 years). While each body was prone, the skin and superficial fasciae were removed, with special attention given to identifying the anatomy and relationships of the extradural dorsal rami of the upper cervical nerves. Once identified superficially, the dorsal rami were followed deeply through the nuchal musculature (for example, trapezius, splenius capitis and cervicis, and semispinalis capitis muscles) to their origin near the upper cervical intervertebral foramina with the aid of an operating microscope (Zeiss). We measured the length and diameter of the neural interconnections between adjacent upper cervical nerve dorsal rami. All measurements were made 3 times by the same observer (R.S.T.) using digital calipers (Mitutoyo), and the average was obtained. To verify neural content, random samples were taken and submitted for routine histological analysis (H & E staining) and immunohistochemical staining (cholinesterase staining for motor axons and carbonic anhydrase staining for sensory axons). Statistical analysis between sides and cadaver sex was performed using Statistica for Windows, with significance set at p < 0.05.

Results

Via histological analysis, all sampled interconnections were found to be neural. Immunohistochemistry revealed that these nervous loops were composed primarily of sensory fibers, although occasional motor fibers were identified. On all but 4 sides (1 left and 3 right sides, all from male cadavers; 86.7%), at least one communicating branch was identified between the upper cervical dorsal rami and specifically between their medial branches. This series of looping nerve communications always occurred deep to the semispinalis capitis muscle and near the posterior bony elements of the vertebrae and never spanned more than one segment (Fig. 2). The majority of loops had a curvilinear form with their convexities usually directed laterally. For the C-1 dorsal ramus (suboccipital nerve), a communicat-
ing loop joined the medial branch of the dorsal ramus of C-2 (greater occipital nerve) on 65.4% of sides. This branch joined the C-1 dorsal ramus at its emergence between the posterior arch of the atlas and the horizontal segment of the vertebral artery within the suboccipital triangle and descended to attach to the medial division of the C-2 dorsal ramus usually at its course below the obliquus capitis inferior muscle. On 29.4% of sides, however, this loop pierced the obliquus capitis inferior muscle before joining C-2. On 54% of sides, a communicating loop joined the medial branches of the dorsal rami of C-2 and C-3 (third occipital nerve); and on 15.4% of sides, a communicating loop joined the medial branches of the dorsal rami of C-3 and C-4. Connections between C-2, C-3, and C-4 occurred between the semispinalis capitis muscle posteriorly and the anteromedial semispinalis cervicis muscle (that is, inferior to the suboccipital triangle). Connecting branches between C-2 and C-4 occurred near the origin of the dorsal rami at these levels. No specimen had communicating branches between the dorsal rami of cervical nerves C-5 to C-8. Articular branches arose from the deep surface of these interneural connections as they crossed the adjacent facet joint on 34.6% of sides. These facet branches originated most commonly from the communicating loop connecting C-2 to C-3 (66.7%), less typically from the loop connecting C-1 and C-2 (33.3%), and never from loops connecting C-3 and C-4. Furthermore, 35% of the loops had fibers emanating from them that terminated in surrounding musculature (for example, semispinalis capitis muscle). Branches usually, but not always, arose from the convexity of the anastomosing loops. The mean diameter of these anastomosing loops was 1.1 mm (range 0.8–1.2 mm), with the connections between C-2 and C-3 typically being the larger of these. Of all the communicating loops, the ones joining C-1 to C-2 were the longest and were on average 21 mm in length (range 15–25 mm). No signs of past surgical procedures or gross pathology were noted in the areas dissected on any cadaver. No statistical significance was identified in comparing sides or sex. However, significance was found when analyzing for the absence of these connections, which was only noted in male cadavers.

Discussion

Regarding the Cruveilhier plexus, more recently, Hollinshead9 stated that “the upper parts of the back muscles in the cervical region are also supplied by direct twigs from the dorsal rami of the second and third cervical nerves, and by branches that arise from the so-called posterior cervical plexus, a very simple series of loops between the first and second and the second and third dorsal rami, sometimes also with a loop to the fourth.” This description is consistent with our findings, which also revealed articular branches arising from some loops. Furthermore, we found both sensory and motor fibers in sampled neural interconnections.

Neural interconnections are known to exist between many different parts of the nervous system. Normally, these are seen between various ventral rami whereplexuses are formed (for example, brachial plexus) and distally between certain peripheral nerves. One example of this latter connection is the Martin-Gruber anastomosis.
between the median and ulnar nerves in the forearm. Less common are neural interconnections between nerves that are not ventral rami. For example, Schwartz\textsuperscript{15} reported such connections between intradural dorsal cervical nerve roots, which he suggested as being one reason for variation in the “normal” dermatome distribution of the neck. This author\textsuperscript{15} also found that the most frequent intradural communications were between C-6 and C-7 and that none of the connections extended farther than one segment, a finding echoed by Marzo et al.\textsuperscript{12} Pallie\textsuperscript{13} found that these connections were best developed in the superior cervical region. We found dorsal extradural neural intercommunications most commonly between C-1 and C-2, and no connection spanned more than one segment. Moreover, no communications were found inferior to the C-4 dorsal ramus.

Embryologically, the presence of an unbroken ridge of neural crest tissue traveling the length of the spinal cord may provide the means for neighboring nerves such as described herein to intercommunicate during development.\textsuperscript{13} According to Pallie,\textsuperscript{13} communications between adjacent neural segments most likely occur between the 4- and 10-mm embryonic stages.

As neural interconnections, such as the Cruveilhier plexus, can affect outcomes following cervical muscular and facet denervation procedures, additional knowledge regarding their anatomy may minimize surgical complications such as inadvertent tension on adjacent nerves.\textsuperscript{5} Additionally, some have found articular branches to the C2–3 facet joint arising from communicating branches between the third occipital nerve and C-2 dorsal ramus (that is, from the Cruveilhier plexus).\textsuperscript{2} We found such articular branches on 36.4% of sides and most commonly to the C2–3 facet joint. Based on our histological findings, these neural loops would need to be sought and transected during denervation procedures (posterior ramiectomy) of facet joints or muscles, as sampled loops were composed of sensory and somatic motor fibers that, if not addressed, may lead to less effective postoperative results. Routine posterior cervical spine procedures may also reveal such neural connections, which should be avoided if possible because muscular denervation can occur. Surgical dissection deep to the semispinalis capitis muscle will most likely disrupt these fibers. Therefore, if denervation is not the goal of the approach, then these nerves should be avoided. The most common connections existed posterior to the posterior arch of C-1 and lamina of C-2. The latter connections were usually more medially placed. For both, midline dissection through the nuchal ligament would avoid most if not all of these neural interconnections.

Additionally, anatomical variations in the craniocervical region, such as the Cruveilhier plexus, may result in pain that is recalcitrant following invasive procedures such as partial upper dorsal rhizotomy or other treatments for occipital neuralgia.\textsuperscript{4,10,16} Moreover, occipital neuralgia is often cervicogenic.\textsuperscript{2,7,8,11,18,19} Given that occipital neuralgia can be a debilitating disease and can occur following operative procedures near the occiput and nuchal regions,\textsuperscript{2} a thorough understanding of the anatomy of the nerves supplying this region and their potential intercon-

nections is important during such neurosurgical procedures.

Conclusions

Physical examinations that reveal unexpected results, such as altered sensory dermatomes from expected segmental innervation patterns, may be the result of extradural communication between adjacent dorsal rami (for example, Cruveilhier plexus).\textsuperscript{20} Based on our cadaveric findings, surgeons who are performing procedures, such as those aimed at completely denervating the upper posterior cervical musculature,\textsuperscript{1} should also consider transecting branches of the Cruveilhier plexus when present.

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, D’Antoni, Shoja. Analysis and interpretation of data: all authors. Drafting the article: Tubbs, Mortazavi, Loukas, D’Antoni. Critically revising the article: all authors. Study supervision: Tubbs.

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