Sonography of the Normal Greater Occipital Nerve and Obliquus Capitis Inferior Muscle

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ABSTRACT: *Background.* To use sonography to measure the cross-sectional area (CSA) of the greater occipital nerve (GON) and the adjacent obliquus capitis inferior muscle (OCI) in normal subjects.

Methods. Data from 30 asymptomatic subjects between the ages of 22 and 35 were collected. CSA and circumference of the GON and CSA of OCI were measured using sonography. Interexaminer reliability analysis was performed using the intraclass correlation coefficient.

Results. The CSA of the GON and OCI were 2 mm^2 ± 1 mm^2 and 1.86 cm^2 ± 0.51 cm^2, respectively. The average circumference of the GON was 4.8 mm ± 1.3 mm. The interexaminer reliability of the measurements was excellent with intraclass correlation coefficient coefficients of 0.91, 0.84, and 0.73 for the GON CSA, GON circumference, and OCI CSA, respectively.

Conclusion. We report the normal values of the CSA of the GON and OCI. Knowledge of these normal values may facilitate the diagnosis of GON entrapment and provide outcome measures in therapeutic interventions. © 2010 Wiley Periodicals, Inc. *J Clin Ultrasound* **00**:000–000, 2010; Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/jcu.20693

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Occipital neuralgia is a type of headache characterized by severe paroxysmal lightening-like sharp pain and dysesthesia within the distribution of the occipital nerve (ie, greater, lesser, and/or third occipital nerves).[1,2] Occipital neuralgia is a common cause of protracted or severe intractable headache, which occurs more frequently in women.[3] The diagnosis is verified on clinical examination. Pain is typically found in the distribution of the greater occipital nerve (GON) and is usually localized to one side,[2] where “trigger point” sites have been described along the course of the GON.[4,5]

Possible zones of GON irritation and entrapment have been described.[6] These risk zones include the area where the nerve emerges from the C2 dorsal ramus between the atlas and the axis, the area where the GON courses between the obliquus capitis inferior muscle (OCI) and semispinalis capitis (SSC) muscles, the area where it pierces the belly of the SSC, and the point of exit from the tendinous aponeurosis of the trapezius.[6] These entrapment zones have not been well characterized and a causal relationship with occipital neuralgia has not been established in the clinical literature.

When a peripheral nerve becomes entrapped, the cross-sectional area (CSA) increases in comparison to a healthy subject and sometimes its contour is altered. The resultant neuropathy may lead to muscular atrophy. High-resolution sonography is a useful tool for detecting peripheral nerve enlargement as well as neurogenic atrophy and may be able to detect subtle changes associated with acute denervation.[7]

The purpose of this investigation is to measure the CSA of the GON and of the adjacent OCI muscle.

MATERIALS AND METHODS

The research proposal was approved by the Logan University Institutional Review Board,

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FIGURE 1. (A) Probe placement for transverse image of the GON. The probe is aligned with the long axis of the OCI, which courses from the spinous process of C2 to the insertion on the transverse process of C1. The CSA of the GON is measured at this site. (B) Probe placement for transverse image of the OCI. The probe is rotated 90 degrees from the placement in (A) to obtain the CSA of the OCI.

and written informed consent was obtained. Data were collected on 32 asymptomatic subjects, providing a total of 64 examinations. Four examinations were discarded because of poor image resolution due to a thick subcutaneous fat layer in two subjects. There were 10 females (33%) and 20 males (67%). The inclusion criteria were as follows: the absence of symptoms in the head and neck region, the absence of history of primary or secondary headaches within the past 6 months, absence of history of systemic diseases (ie, collagen vascular disease), and no head/neck surgery or cervicocranial trauma within the past 6 months. The examination was performed with the use of an 8- to 13-MHz broadband linear probe on a GE LOGIQ e sonographic scanner (GE Healthcare, Milwaukee, WI). The probe placement for the transverse image of the GON and the OCI are illustrated in Figure 1.

The CSA of the GON was measured at its emergence adjacent to the OCI, with the probe placed along the long axis of the OCI (Figure 2). The probe was then rotated 90 degrees at the same site to image the OCI in cross-section and obtain the CSA measurement (Figure 3). In addition, the suboccipital region of an unembalmed cadaver was dissected to obtain in vitro correlation with the in vivo scans. The GON and OCI were isolated from the trapezius, semispinalis capitis, and splenius capitis muscles. The GE LOGIQ e sonographic unit was utilized to scan the suboccipital region and the sonographic appearance and topographic landmarks for scanning of the GON and OCI were compared (Figure 4).

When the nerve appeared as a solitary hypoechoic oval or circle, all of the abovementioned measurement parameters were obtained. However, when multiple hypoechoic nerves were present or no nerve was observed, the qualifier "multiple branches" was used and the CSA and circumference of the GON could not be obtained in that subject. Arterial or venous branches were frequently noted along the fascial plane of OCI and mimicked the morphology and echotexture of the GON. Therefore, evidence of flow was verified via power Doppler mode. To differentiate arterial versus venous, the subjects were asked to do a Valsalva maneuver and the examiner varied the probe pressure to achieve an effect similar to augmentation. All sonographic images were obtained by a single examiner and were saved to the sonographic system hard drive.

Image analysis, which consisted of measurements of the GON and OCI, was performed on the saved files following completion of the examination on all subjects. All data were recorded in a Microsoft Excel file. The mean and SD were calculated for the collected data. The interexaminer

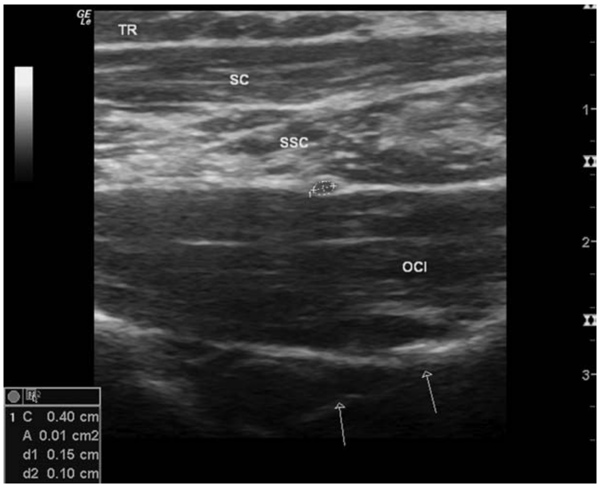

FIGURE 2. Sonogram of greater occipital nerve and obliquus capitis inferior muscle (OCI). The probe is placed along the long axis of the OCI muscle. GON, greater occipital nerve; SC, splenius capitis; SSC, semispinalis capitis; TR, trapezius. Arrows point to the lamina of C2. The ellipse outlines the cross-sectional area of the greater occipital nerve.

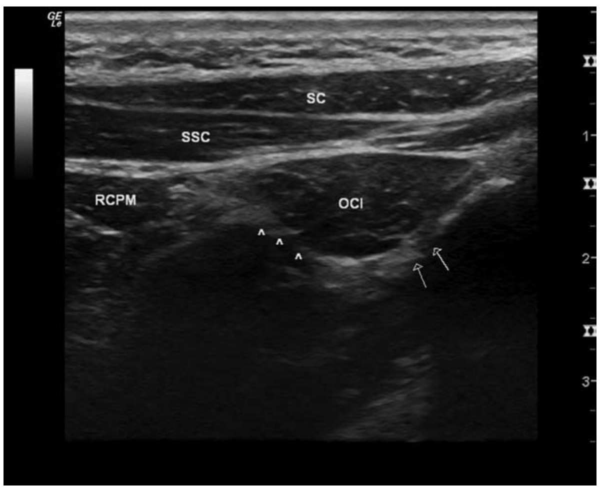

FIGURE 3. Transverse sonogram of obliquus capitis inferior (OCI) muscle. The probe is positioned perpendicular to the OCI muscle. RCPM, rectus capitis posterior major; SSC, semispinalis capitis; SC, splenius capitis. Lamina of C2 (arrows); lamina of C1 (^^^).

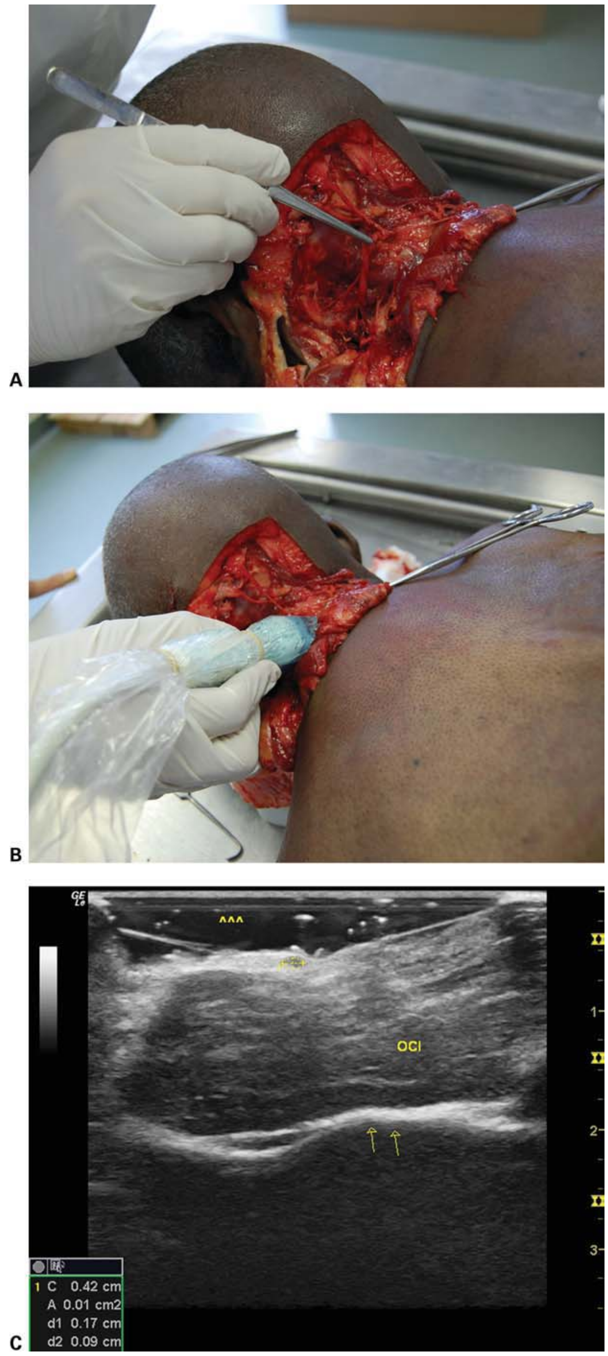

FIGURE 4. Cadaveric study. (A) Photograph shows the forceps holding the greater occipital nerve. Trapezius, semispinalis capitis, and splenius capitis muscles are retracted. (B) Photograph shows the probe parallel to the long axis of OCI, which provides the transverse section of the GON. (C) In vitro sonogram shows images of GON and OCI that are identical to in vivo images demonstrated in Figure 2. From superficial to deep, coupling gel (^^^), GON (ellipse), obliquus capitis inferior (OCI), and lamina of C2 (arrows).

reliability of the measurements was assessed between the primary investigator and a radiologist who had only 3 years of experience in musculoskeletal sonography. Before the reliability data were collected, the less experienced examiner practiced measurements on four sample subjects. Twenty subjects (40 examinations) were then randomly selected and the circumference of the GON and CSA of the GON and OCI were measured by the 2^{nd} examiner who was blinded to the measurements performed by the 1^{st} examiner. Interexaminer reliability analysis was performed using the intraclass correlation coefficient using the software PASW Statistics 17.

RESULTS

In 11 of the 60 examinations, the GON had multiple branches, leaving 49 examinations from which the GON CSA could be measured. Four subjects demonstrated multiple branches bilater-

TABLE 1
Summary of the Measurement Parameters: CSA of the GON, OCI, and Circumference of the GON

ID	Gender	Age	GON CSA-R (mm^2)	GON circumference (mm)	GON CSA-L (mm^2)	GON circumference (mm)	OCI CSA-R (cm^2)	OCI CSA-L (cm^2)
1	M	24	1	3.9	2	5.5	2.88	2.26
2	M	29	3	7.6	3	7.3	1.77	1.29
3	M	27	1	4.0	1	3.5	2.52	2.53
4	F	30	1	3.2	1	3.1	1.95	2.02
5	M	25	1	2.8	1	2.8	2.86	3.15
6†								
7	F	30	1	2.8	1	3.0	2.23	2.33
8	M	26	3	6.8	3	7.8	1.9	1.8
9	M	24	1	4.6	MULTI*		2.66	2.44
10	M	24	MULTI*		1	4.5	2.19	1.96
11	F	22	MULTI*		MULTI*		0.82	0.94
12†								
13	F	24	2	5.0	2	4.8	1.92	2.55
14	M	27	1	3.1	1	3.3	1.52	1.57
15	M	26	2	5.4	2	5.3	1.87	1.99
16	M	27	2	7.1	2	5.8	2.18	2.01
17	M	31	2	5.3	2	5.9	1.59	1.9
18	F	33	2	6.4	2	5.0	1.98	1.64
19	M	29	1	5.6	1	3.9	1.62	1.74
20	M	29	1	4.7	1	5.3	1.32	1.3
21	F	22	2	6.1	2	6.7	1.1	1.23
22	F	23	2	5.4	2	4.7	2.13	2.29
23	M	23	2	5.2	MULTI*		1.22	1.68
24	M	30	MULTI*		MULTI*		2.05	1.89
25	M	23	1	3.6	1	3.3	1.98	1.69
26	M	23	MULTI*		MULTI*		1.48	1.93
27	M	24	1	3.8	1	4.2	1.54	1.77
28	F	32	1	4.0	1	4.3	1.13	1.1
29	M	35	2	5.5	2	5.8	2.4	2.44
30	F	24	2	5.3	1	4.0	1.76	1.39
31	F	28	2	4.9	2	4.7	1.09	1.18
32	M	23	MULTI*		MULTI*		1.98	1.92

Abbreviations: CSA, cross-sectional area; GON, greater occipital nerve; L, left; OCI, obliquus capitis inferior muscle; R, right.
* MULTI = Qualifier to denote the presence of multiple hypoechoic nerves (either an anatomic variation of the GON or anastomoses from sub-occipital, 3rd occipital (least), and/or lesser occipital nerves).
† Data for ID 6 and 12 were discarded due to poor resolution of sonograms from increased thickness of subcutaneous fat.

ally, leaving three subjects with unilateral presentation of multiple branches. The echotexture of either multiple branches or solitary GON was consistently hypoechoic. The morphology was round to oval with no internal fascicles visualized. The CSA of the GON and OCI were 2 mm^2 ± 1 mm^2 and 1.86 cm^2 ± 0.51 cm^2, respectively. The average circumference of the GON was 4.8 mm ± 1.3 mm. The CSA of the GON in males and females was 2 mm^2 ± 1 mm^2 on both the right and the left side. The circumference of GON was 4.8 mm ± 1.3 mm in both males and females. The circumference of OCI in males and females was 1.86 cm ± 0.51 cm and 1.82 cm ± 0.50 cm, respectively. The circumference of OCI on the right side was 1.85 cm ± 0.52 cm in males and 1.79 cm ± 0.50 cm in females. The circumference of OCI on the left side was 1.86 cm ± 0.5 cm in males and 1.84 cm ± 0.5 cm in females (Table 1).

The interexaminer reliability of the measurements was excellent with coefficients of 0.91 and 0.84, for the GON CSA and GON circumference, respectively (Table 2). The cadaveric images were identical to those obtained in vivo.

DISCUSSION

The etiology of occipital neuralgia and its relation to the entrapment syndrome of the GON needs further clarification. Pain usually originates in the suboccipital area with radiation to the skull vertex and temporal areas. In some patients, the pain is described as peri- or retro-orbital.[2] The pain referral is believed to arise from sensory connections between the principal sensory nucleus of the trigeminal nerve and the substantia gelatinosa (located in the posterior gray column of the cervical spinal cord, which is continuous with the inferior end of the nucleus of the spinal tract of the trigeminal nerve).[2,8]

The GON is formed by the medial branch of the dorsal ramus of C2 that runs between the posterior arch of the atlas and lamina of the axis and emerges inferior to the OCI, where it divides

TABLE 2
Interexaminer Reliability Analysis of the Measurements—Intraclass Correlation Coefficient

	Intraclass Correlation	95% Confidence Interval
R GON CSA	0.89	0.71–0.96
L GON CSA	0.93	0.82–0.98
R GON C	0.81	0.55–0.93
L GON C	0.87	0.68–0.95
R OCI CSA	0.78	0.47–0.92
L OCI CSA	0.69	0.31–0.88
Total GON CSA	0.91	0.82–0.95
Total GON C	0.84	0.70–0.92
Total OCI CSA	0.73	0.51–0.86

Abbreviations: C, circumference; CSA, cross-sectional area; GON, greater occipital nerve; L, left; OCI, obliquus capitis inferior muscle; R, right.

into a larger medial branch and smaller lateral branches.[2,6] The medial branch of the 2nd cervical dorsal ramus provides the motor branches to the muscles it traverses and terminates as the GON. Along with the C2 ramus, the C1 ramus of the spinal nerve innervates the OCI muscle.[9] There are several branches of GON that supply the skin of the back of the scalp as far anterior as the vertex of the skull.[2]

When a peripheral nerve becomes entrapped, the CSA increases in comparison to a healthy subject and sometimes its contour is altered. For example, the CSA of the ulnar nerve measured on US is increased in patients with ulnar neuropathy.[10] A similar increased CSA was observed in the median neuropathy of carpal tunnel syndrome.[11,12] At the entrapment sites, however, other sonographic appearances have been described, including flattening, and with progression of the disease, chronic constriction of the nerve.[13] The success of treatment for compression neuropathy is typically dependent on identifying the mechanism and the degree of peripheral nerve compression.

Several different therapeutic approaches have been utilized with various degrees of success.[2] They have included subcutaneous implanted neurostimulation,[14] conservative treatment with a cervical collar, antimigraine drugs, percutaneous nerve blocks,[2,8] chemical and radiofrequency ablation, and surgical sectioning or decompression of the upper dorsal cervical nerve roots.[2]

We have scanned one of the four risk zones where the GON can be irritated and may potentially induce occipital neuralgia. The selection of our measurement site is noteworthy. First, the interexaminer reliability was excellent for GON CSA and total GON circumference, according to the criteria set forth by Rosner.[15] Fair to good reliability was seen with the OCI CSA. Second, this is the site where multiple anastomoses of the occipital nerves may be observed. In 60 samples of measurements, seven subjects (11 samples; four subjects bilaterally and three subjects unilaterally) demonstrated multiple branches of nerves at the level of the OCI. One explanation for the observation of multiple hypoechoic nerves is that there are anatomic variations observed with the GON. Branches occur at different levels, but mostly below the intermastoid line.[16] Furthermore, branches from the suboccipital nerve, 3rd occipital nerve (least), and lesser occipital nerve do anastomose with GON. This provides another potential site for GON nerve block where administration of anesthetic agent in a confluent region of occipital nerves may improve the treatment of occipital neuralgia.

Since not all nerves were circular on cross-section, the range of circumference measurements varied even with the same CSA measurement. For example, a CSA of GON measuring 1 mm^2 demonstrated circumference measures that varied (ie, 3.9 mm, 2.8 mm, 5.6 mm, etc). Addition of the circumference measurement may prove useful in future research where the GON of occipital neuralgic subjects is investigated.

To our knowledge, there has been no sonographic investigation of the GON at the entrapment risk zone where it exits underneath the OCI muscle. To confirm that our sonograms were accurate, a cadaveric correlation was obtained. The sonograms obtained from the dissection of the suboccipital region were identical and supported the accuracy of our in vivo technique.

These results will be used to evaluate a clinical sample of patients with occipital neuralgia. Comparison between normative data and those of a clinical population may demonstrate alterations in the CSA of the GON with entrapment, in a fashion similar to other peripheral nerves. Normal CSA data for the OCI may allow for assessment of denervation atrophy. An intriguing phenomenon related to altered muscle integrity from neurogenic sources is hypertrophy. In a case series, Deffond and colleagues described neurogenic hypertrophy of the tibialis anterior muscle, calf muscles, and global leg muscles in patients diagnosed with common peroneal nerve injury, S1 radiculopathy, and legionella neuropathy, respectively.[17] Although muscular hypertrophy may occur, it is an unusual phenomenon associated with neuropathy.

Limitations of the study include the lack of correlation of the CSA of the GON and OCI with the age and gender of the subjects. Another limitation is the use of the qualifier, “multiple branches,” for either the presence of multiple hypoechoic nerves or the nonvisualization of a solitary or multiple hypoechoic nerves. The nonvisualization of nerves was thought of as multiple smaller branches and anastomoses of occipital nerves that were suboptimally resolved by the sonography system. This qualifier needs to be validated via cadaveric correlation. The measurement of the CSA of OCI demonstrated a large SD and the lowest intraclass correlation coefficient. The measurement was done with the trace function rather than the elliptical trace function, which is simpler and averages the area and may be more appropriate for future measurements. Also, the muscular plane of OCI is difficult to distinguish from the surrounding musculature (ie, rectus capitis posterior major and rotatores cervicis brevis) in static images, which can be facilitated with the use of dynamic cine loop images. Last, the sample was predominantly male, while occipital neuralgia occurs more frequently in females.

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