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An anatomical analysis of the occipital nerve complex: an essential tool for the application of occipital nerve blocks

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Abstract

Background Occipital nerve blocks are essential in diagnosing and treating headache disorders such as migraine, cervicogenic headache, occipital neuralgia, and cluster headache. In this study, we aimed to investigate the potential compression points of the greater occipital nerve (GON), third occipital nerve (TON), and lesser occipital nerve (LON) which are targeted to block in occipital nerve blocks and to develop a method to detect these points easily.

Methods To identify potential compression points of the GON, TON, and LON, we dissected 43, 41, and 26 cadavers, respectively. A rigid, transparent tool divided into 1 × 1 cm sections was placed on the external occipital protuberance to measure the determined points. The cadaveric head was viewed from above, vertically, and the coordinates corresponding to each point were noted separately.

Results Six, four, and one potential entrapment points were detected for the GON, TON, and LON, respectively. The distances of the point where the GON arose from the lower border of the obliquus capitis inferior muscle and the emerging point of the TON from the C2-C3 vertebrae to the posterior midline were statistically significant in terms of the sides ($p = 0.040$). Similarly, there was a statistical significance between genders for the distance of the point where the LON arose from the posterior edge of the sternocleidomastoid muscle to the posterior midline ($p = 0.002$).

Conclusions We believe that with the method developed, the GON, TON, and LON compression points can be easily localized and blocked in diagnosing and treating patients experiencing headaches such as migraines, cervicogenic headaches, occipital neuralgia, and cluster headache.

Keywords Occipital nerve, Headache, Block, Method, Anatomy

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Background

The utilization of occipital nerve blocks (ONB), a component of peripheral nerve blocks, has continued with increasing momentum in the last 50 years. This technique is used not only for treating headaches but also for diagnostic purposes [1, 2].

ONB is applied according to certain landmarks and the success of ONB may depend on factors including the timing of the injections, the sensitization (tenderness) of the peripheral nerve or central sensitization, the agents used, the indication, the localization as well as to the landmark techniques used [3–6]. Some studies recommend for intervention a point 2 cm inferior and 2 cm lateral to the external occipital protuberance (EOP) [7, 8], as well as publications that offer a point 3 cm inferior and 1.5 cm lateral to this prominence [1, 9]. Even previous studies have shown that the point between 1/3 medial and 1/3 middle section of the designed line between the EOP and mastoid process (MP) or between 1/2 medial and 1/2 lateral section of this line can also be used [10, 11].

ONB is considered safe, but complications such as Cushing's syndrome [12], and neck muscle weakness can develop from repeated corticosteroid injections [13]. Other complications are more common including hematoma, swelling, and dizziness/vagal reactions and other more rare including hair loss [5]. Therefore, the ONB should be applied precisely and accurately to the target point.

Among the headache causes for which ONB is efficient, migraine, cervicogenic headache, occipital neuralgia, and cluster headache come to the fore [13–20]. Although ONB is effective in the treatment of migraine, cervicogenic headache, occipital neuralgia, and cluster headache, there are some patients in which satisfactory results cannot be achieved [21–23]. One of the most important reasons for this issue is undoubtedly the anatomical variations of the occipital nerves [13, 24–27].

It can be assumed that there are 2 important issues to be handled here. The first is the anatomical analysis of the occipital nerves and the second is the discussion of the block technique used with different methodologies. To address these two important points, we aimed to investigate the anatomy of the occipital nerves to assert the potential compression points of these nerves and to develop a method to identify these points in the easiest and fastest way. This method describes a way to perform ONB fastest, taking as reference EOP, which is the landmark frequently used in invasive interventions.

Methods

The success of the ONBs may be directly related to the detailed knowledge of the anatomy of the nerves and the applied block technique. This study aims to investigate potential compression points of the occipital nerves previously described in the existing literature and to develop a method to find these points easily. With this purpose, the greater occipital nerve (GON), third occipital nerve (TON), and lesser occipital nerve (LON), 43 (27 males and 16 females), 41 (25 males and 16 females), and 26 (14 males and 12 females) cadaveric specimens, aged between 35 and 88 years, respectively, were dissected bilaterally at different times in the Department of Anatomy, Istanbul, Faculty of Medicine. There were no visible signs of pathology, malformation, and/or trauma in the head and neck region of any of the cadavers and none of the heads included dolichocephaly. Cadaver dissections were carried out by two experienced anatomists (L.S. and O.G.). The ethical approval was granted by the Clinical Research Ethical Committee of the Istanbul, Faculty of Medicine (IRB (institutional review board) number: 2024/03). All cases were dissected similarly to the previous study by Saglam et al. [27]. GON, TON, and LON were carefully followed throughout their course.

The relationship of the GON with the muscles and occipital artery (OA), the relationship of the TON with the C2-C3 vertebra and the muscles, and lastly the relationship of the LON with the sternocleidomastoid muscle (SCM) were carefully examined and based on the points previously defined as potential compression points in the literature [25–31], the following points related to these nerves were determined.

Point 1 GON The point where the GON curves around the lower border of the obliquus capitis inferior muscle (OCI) (Figs. 1 and 2).

Point 2 GON and Point 3 GON Points where the GON enters semispinalis capitis muscle (SS) and exits from the SS, respectively (Figs. 1 and 3).

Point 4 GON and Point 5 GON Points where the GON enters the trapezius muscle (TM) and exits from the TM, respectively (Figs. 1, 3 and 4).

Point 6 GON The first point where the GON and OA cross each other (Fig. 4).

Point 1 TON The point where the TON arises from the C2 and C3 vertebrae (Figs. 2 and 5).

Point 2 TON The point where the TON perforates the SS (Figs. 3 and 5).

Point 3 TON The point where the TON pierces the splenius capitis muscle (SC) (Figs. 5 and 6).

Point 4 TON The point where the TON pierces the TM (Figs. 4 and 5).

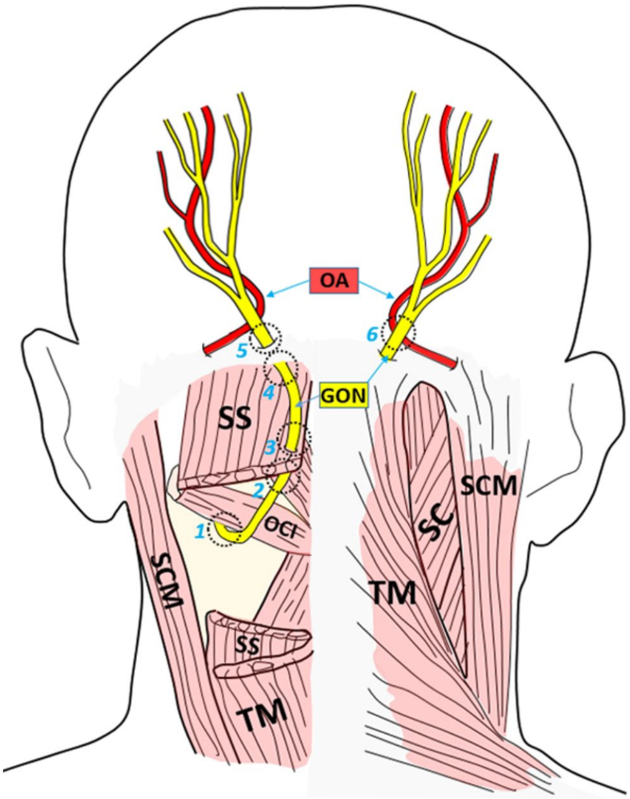

Fig. 1 Schematic illustration of the potential compression points of the greater occipital nerve (posterior view). *Abbreviations* TM, trapezius muscle; SC, splenius capitis muscle; SCM, sternocleidomastoid muscle; SS, semispinalis capitis muscle; OCI, obliquus capitis inferior muscle; GON, greater occipital nerve; OA, occipital artery. *1*, the point where the GON curves around the lower border of the OCI. *2* and *3*, points where the GON enters SS and exits from the SS, respectively. *4* and *5*, points where the GON enters TM and exits from the TM, respectively. *6*, the first point where the GON and OA cross each other. The dotted black circles show the potential compression points of the greater occipital nerve

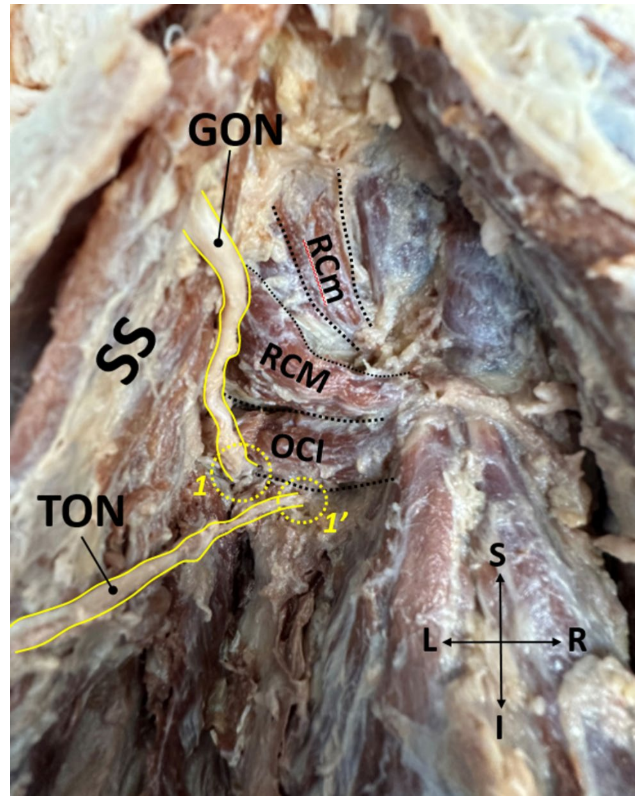

Fig. 2 The first potential compression points of the greater and third occipital nerves on the cadaver (posterior view, left). *Abbreviations* SS, semispinalis capitis muscle; OCI, obliquus capitis inferior muscle; RCM, rectus capitis posterior major muscle; RCm, rectus capitis posterior minor muscle; GON, greater occipital nerve; TON, third occipital nerve; S, superior; I, inferior; R, right; L, left. *1* = Point 1 GON, the first potential compression point of the GON where it curves around the lower border of the OCI. *1′*= Point 1 TON, the first potential compression point of the TON where it emerges from the C2 and C3 vertebrae

Point 1 LON The point where the LON emerges from the posterior border of the SCM (Fig. 7).

Each specimen was placed in the prone position. A rigid, transparent material divided into 1×1 cm sections was used to measure the determined points. The exact midpoint of the measurement material (each unit refers to cm) was placed on the EOP, and the material was carefully positioned so that the x-axis passed transverse from the specimen and the y-axis coincided with the posterior midline (Fig. 8). The cadaveric head was viewed from above, vertically, and the coordinates corresponding to each point were noted separately in cm.

Statistical evaluation

The obtained data were evaluated using IBM SPSS (The Statistical Package for the Social Sciences) version 21.0 package program. Descriptive analyses were expressed as frequency (n) and percentage (%) for categorical variables and mean and standard deviation or median [minimum (min)-maximum (max)] for continuous variables. The Kolmogorov-Smirnov test was applied to evaluate the normal distribution of continuous variables. A comparison of normally distributed continuous variables of two independent groups was performed by the Independent groups t-test, and the Mann-Whitney U test made a comparison of non-normally distributed variables. The degree of statistical significance was determined as $p<0.05$.

Results

In a total of 86 sides, Point 1 GON was a median of 3 cm (min-max: 2–4 cm) to the x-axis and 5 cm (min-max: 3–8) to the y-axis, and Point 2 GON was a median of 2 cm (min-max: 1–3 cm) to the x-axis and 4 cm (min-max: 2–6 cm) to the y-axis. Similarly, Point 3 GON was a median of 2 cm (min-max: 1–4 cm) to the x-axis and 3 cm (min-max: 2–6 cm) to the y-axis, and Point 4 GON was a median of 3 cm (min-max: 1–4 cm) to the x-axis and 3 cm (1–6 cm) to the y-axis. Point 5 GON was

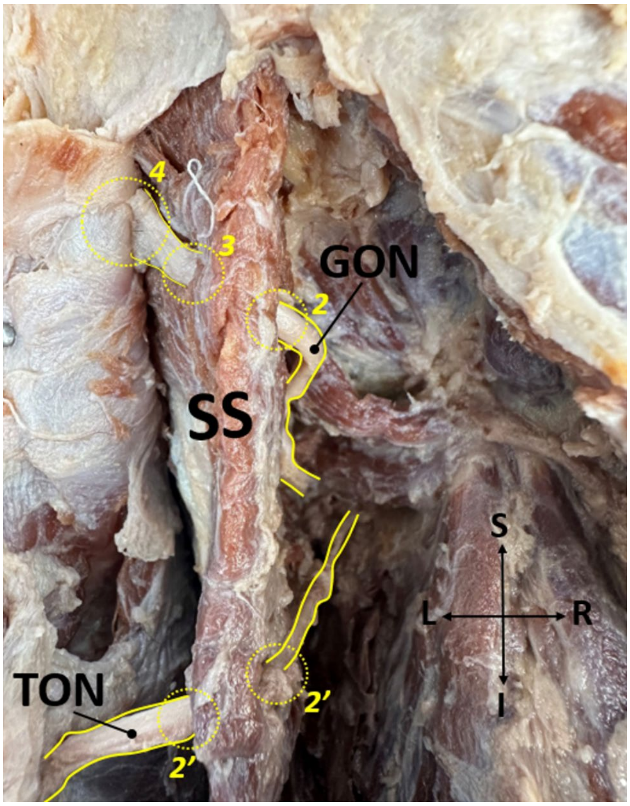

Fig. 3 The second, third, and fourth potential compression points of the greater occipital nerve and the second potential compression point of the third occipital nerve on the cadaver (posterior view, left). *Abbreviations* SS, semispinalis capitis muscle; GON, greater occipital nerve; TON, third occipital nerve; S, superior; I, inferior; R, right; L, left. *2* = Point 2 GON, the second potential compression point of the GON, where it enters the semispinalis capitis muscle. *3* = Point 3 GON, the third potential compression point of the GON, where the GON exits from the semispinalis capitis muscle. *4* = Point 4 GON, the fourth potential compression point of the GON where it enters the trapezius muscle. *2′* = Point 2 TON, the second potential compression point of the TON where it pierces the SS

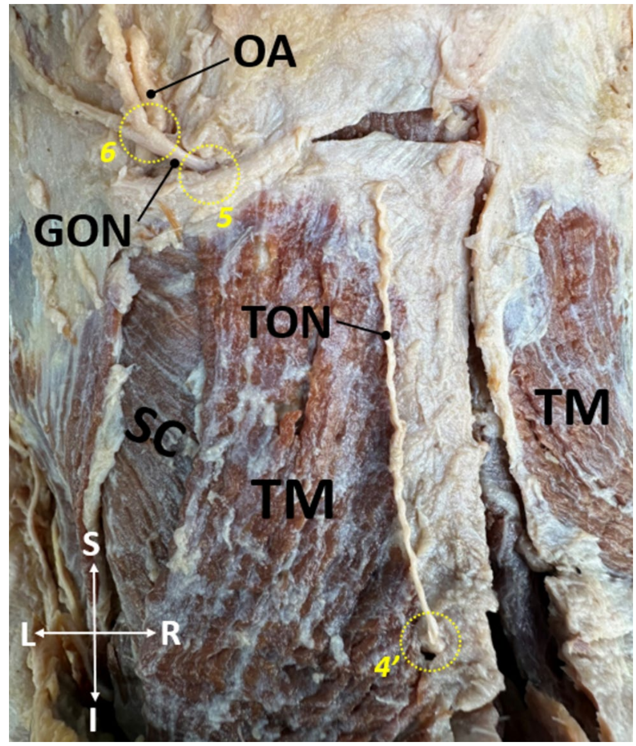

Fig. 4 The fifth and sixth potential compression points of the greater occipital nerve and the fourth potential compression point of the third occipital nerve on the cadaver (posterior view, left). *Abbreviations* TM, trapezius muscle; SC, splenius capitis muscle; GON, greater occipital nerve; TON, third occipital nerve; OA, occipital artery; S, superior; I, inferior; R, right; L, left. *5* = Point 5 GON, the fifth potential compression point of the GON, where the GON exits from the trapezius muscle. *6* = Point 6 GON, the sixth potential compression point of the GON (the first point where GON and OA cross each other). *4′* = Point 4 TON, the fourth potential compression point of the TON where it pierces the TM

obtained as a median of 3 cm (min-max:2–5 cm) to the x-axis and 2 cm (1–4 cm) to the y-axis. Point 6 GON, that is, the first point where GON and OA cross each other, was observed on a total of 77 sides. This point was calculated as a median of 4 cm (min-max:3–6 cm) to the x-axis and 1 cm (min-max:1–4 cm) to the y-axis.

In a total of 82 sides regarding TON analyzed, Point 1 TON was measured as a median of 3 cm (min-max:1–3 cm) to the x-axis and 7 cm (min-max:4–9 cm) to the y-axis, and Point 2 TON was a median of 2 cm (min-max:1–3 cm) to the x-axis and 6 cm (min-max: 4–9 cm) to the y-axis. Similarly, Point 3 TON was obtained as a median of 2 cm (min-max:1–3 cm) to the x-axis and 6 cm (min-max: 2–9 cm) to the y-axis, and Point 4 TON was obtained as a median of 2 cm (min-max:1–3 cm) to the x-axis and 5 cm (min-max: 2–9 cm) to the y-axis.

Lastly, a total of 52 sides concerning LON were evaluated, Point 1 LON was calculated as a median of 7 cm (min-max:1–10 cm) to the x-axis and 8 cm (min-max: 1–12 cm) to the y-axis. The general analysis results obtained according to the identified points are summarized in Fig. 9.

Distribution and statistical comparison of determined points in terms of side and gender are tabulated in Tables 1 and 2, respectively. The distances of Point 1 GON and Point 1 TON from the x-axis were statistically significantly different between the sides ($p = 0.040$). Moreover, a statistically significant difference between the genders regarding Point 1 LON to the x-axis ($p = 0.002$) was found.

Discussion

In the existing literature, 6 potential compression points for GON [27–29], 4 potential compression points for TON [26, 30], and 1 potential compression points for LON [25, 31] have been previously identified. These potential entrapment points may be caused by the occipital nerves penetrating the muscles and where they bend,

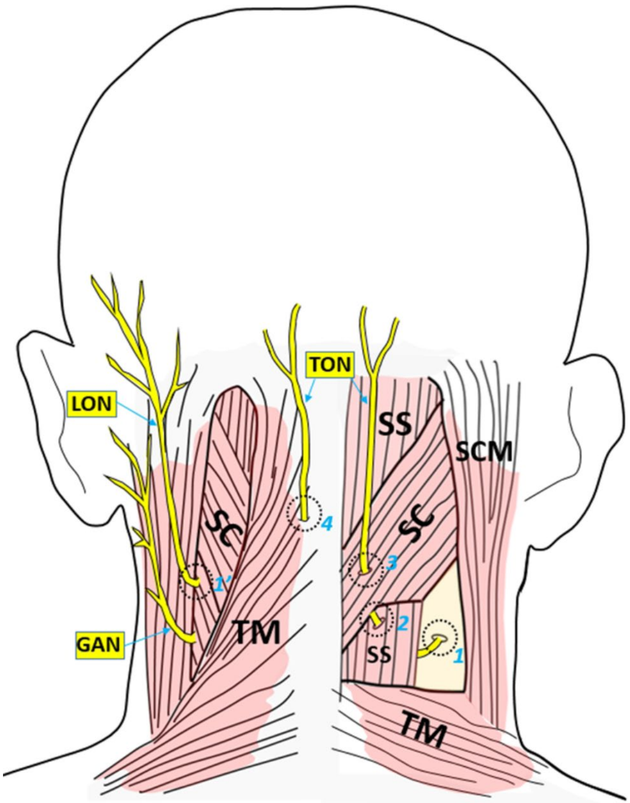

Fig. 5 Schematic illustration of the potential compression points of the third occipital nerve (posterior view). *Abbreviations* TM, trapezius muscle; SC, splenius capitis muscle; SCM, sternocleidomastoid muscle; SS, semispinalis capitis muscle; TON, third occipital nerve; LON, lesser occipital nerve; GAN, great auricular nerve; *1*, the point where the TON arises from the C2 and C3 vertebrae. *2* and *3*, the points where the TON pierces SS and SC, respectively. *4*, where the TON pierces the TM. The dotted black circles show the potential compression points of the third occipital nerve

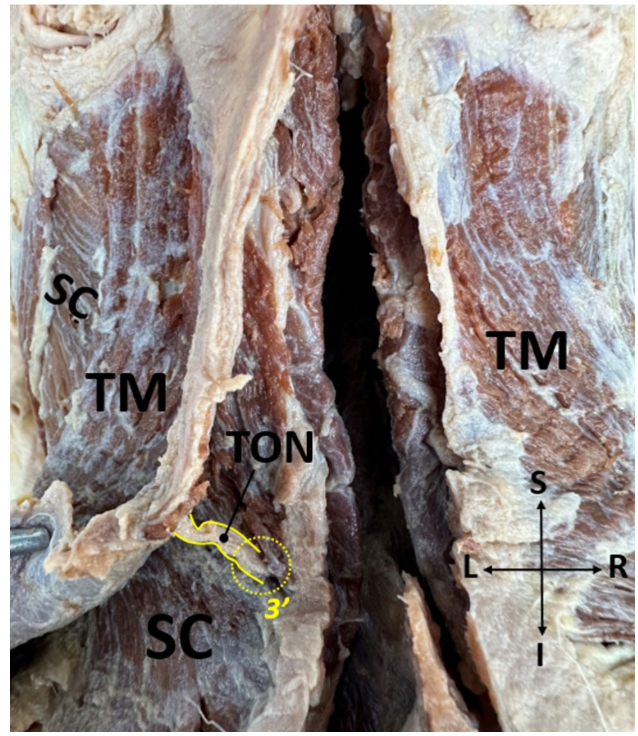

Fig. 6 The third potential compression point of the third occipital nerve on the cadaver (posterior view, left). *Abbreviations* TM, trapezius muscle; SC, splenius capitis muscle; TON, third occipital nerve; S, superior; I, inferior; R, right; L, left. *3'*= Point 3 TON, the third potential compression point of the TON where it pierces the SC

nerve and artery crossing, fascial bands, and tendinous or aberrant structures (lymph nodes, etc.) [25–32].

Point 1 GON

The point where the GON emerges from the lower edge of the OCI has been identified as its first potential impingement point [28]. Janis et al. [28] reported the mean Point 1 GON as 20.13 mm and 77.38 mm according to the x-axis (the perpendicular distance of the point to the transverse line that passes through EOP) and y-axis (the perpendicular distance of the point to the posterior midline that passes through EOP), respectively, in their study on 25 fresh cadaveric heads. Güvençer et al. [33] mentioned only the Point 1 GON relative to the x-axis in their research on 6 cadavers (12 sides) and reported this value as meanly 19.1 ± 1.3 mm. Similarly, in their study performed on 20 (40 sides) fresh cadaveric heads, Scherer et al. [34] calculated Point 1 GON only according to the x-axis and recorded it as meanly 3.56 ± 0.36 cm. In our study, Point 1 GON was a median of 3 cm (min-max: 2–4 cm) to the x-axis and 5 cm (min-max: 3–8) to the y-axis (Fig. 9). While our Point 1 GON according to the x-axis is compatible with the studies of Janis et al. [28], the values obtained according to the y-axis are inconsistent between these two studies. This difference may be explained by different sample sizes, racial differences, and/or different measurement techniques.

Point 2 GON and Point 3 GON

The point where the GON enters the SS is identified as the second potential compression point and the point where the GON exits from the SS is depicted as the third potential pinch point [28]. Previous studies have generally reported this point, which they describe as the point where the GON pierces the SS, according to the x and y axis [9, 30, 32, 35]. Only Janis et al. [28] calculated Point 2 GON and Point 3 GON values. In their study, the Point 2 GON value was recorded as meanly 17.46 mm and 59.71 mm according to the x and y axis, respectively, and the Point 3 GON was recorded as meanly 15.52 mm and 34.52 mm according to the x and y axis, respectively. In our study, we obtained Point 2 GON was a median of 2 cm (min-max: 1–3 cm) to the x-axis and 4 cm (min-max: 2–6 cm) to the y-axis, and Point 3 GON was a median of 2 cm (min-max: 1–4 cm) to the x-axis and 3 cm (min-max: 2–6 cm) to the y-axis (Fig. 9). Our

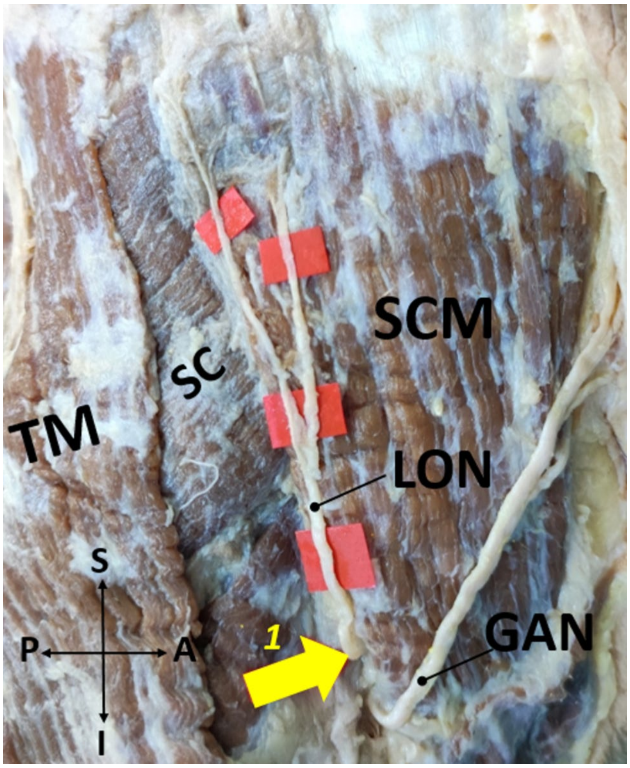

Fig. 7 The potential compression point of the lesser occipital nerve on the cadaver (lateral view, right). *Abbreviations* TM, trapezius muscle; SC, splenius capitis muscle; SCM, sternocleidomastoid muscle; LON, lesser occipital nerve; GAN, great auricular nerve; S, superior; I, inferior; A, anterior; P, posterior. *1* = Point 1 LON, the potential compression point of the LON where it emerges from the posterior border of the SCM

results are not consistent with Janis et al. [28]. This may be due to different sample sizes and/or methodologies.

Point 4 GON and Point 5 GON

The point where the GON enters the TM is pointed out as the fourth potential compression point and the point where the GON exits from the TM is stated as the fifth potential compression point [28]. Similar to Point 3 GON, the vast majority of the researchers only evaluated this point as its piercing point of TM [30, 35–37]. Janis et al. [28] reported the Point 4 GON value as 24 mm and 21 mm on average according to the x and y axis, respectively, and the Point 5 GON value as meanly 37.7 mm and 43.6 mm, respectively, according to the same axes. In our study, we calculated Point 4 GON was a median of 3 cm (min-max: 1–4 cm) to the x-axis and 3 cm (1–6 cm) to the y-axis and similarly, Point 5 GON was obtained as a median of 3 cm (min-max:2–5 cm) to the x-axis and 2 cm (1–4 cm) to the y-axis (Fig. 9). Our results are incompatible with those reported by Janis et al. [28] and the possible reason is the previously said reasons.

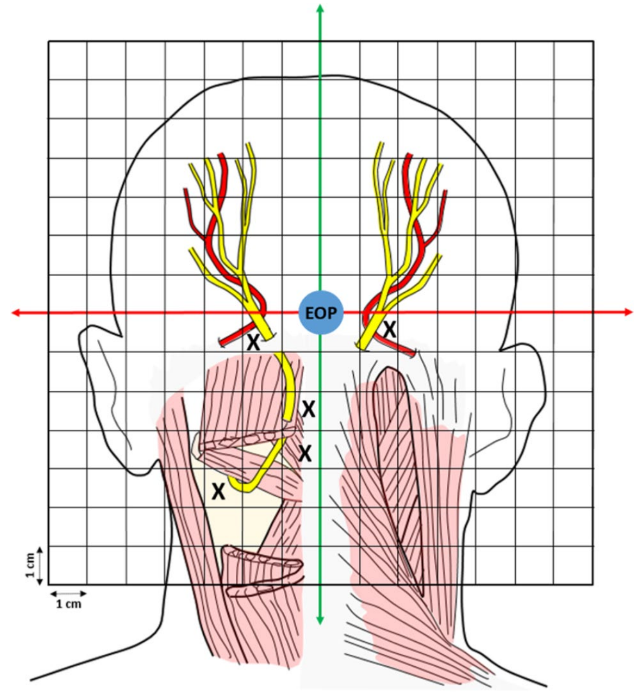

Fig. 8 An example demonstration of marking potential entrapment points of the GON with transparent material. *Abbreviations* EOP, external occipital protuberance; cm, centimeter. Each 'X' shows the example of the potential compression point of the GON

Point 6 GON

The point where the GON and OA cross each other is the sixth potential impingement point of the GON [28]. Janis et al. [29] categorized the GON and OA relationship as 2 types in their study using 25 (50 sides) fresh cadaveric heads. They reported that GON and OA had a single-crossed (crossed each other) morphology on 8 sides, a spiral-shaped morphology on 19 sides, and no intersection on 23 sides. They noted that in the single-cross morphology, the perpendicular distances of the crossing point to the x- and y-axis averaged 30.27 mm and 10.67 mm, respectively. In spiral-shaped morphology, they used as reference the perpendicular distances of the caudal and cranial points of the spiral relative to the x and y axes. They reported the mean perpendicular distances of the caudal point according to the x and y axis as 25.34 mm and 24.91 mm, respectively, and similarly, the mean perpendicular distances of the cranial point according to the x and y axis as 42.09 mm and 0.97 mm, respectively. In our study, we observed the Point 6 GON value on 77 sides and this point was calculated as a median of 4 cm (min-max:3–6 cm) to the x-axis and 1 cm (min-max:1–4 cm) to the y-axis (Fig. 9). The results seem inconsistent with those reported by Janis et al. [29] and are probably due to different measurement methods.

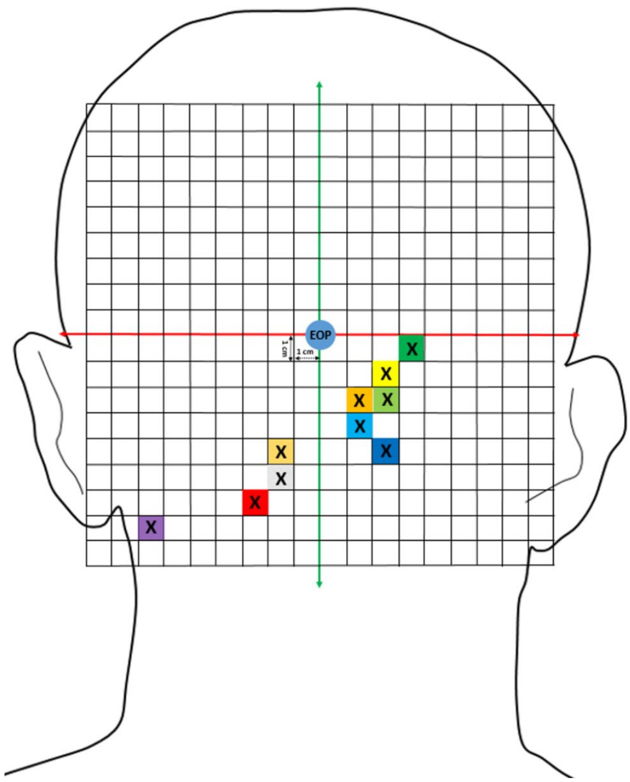

Fig. 9 Summary representation of identified potential compression points on the coordinates related to greater, third, and lesser occipital nerves. *Abbreviations* EOP, external occipital protuberance. Each 'X' shows the potential compression points of the greater, third, and lesser occipital nerves. The dark blue box shows the first (the point where the GON curves around the lower border of the obliquus capitis inferior muscle) potential compression point of the greater occipital nerve (GON). Light blue and orange boxes show the second (the point where the GON enters the semispinalis capitis muscle) and third (the point where the GON exits from the semispinalis capitis muscle) potential compression points of the GON, respectively. Light green and yellow boxes show the fourth (the point where the GON enters the trapezius muscle) and the fifth (the point where the GON exits from the trapezius muscle) potential compression point of the GON. The dark green box shows the sixth (the first point where the GON and occipital artery cross each other) potential compression point of the GON. The red box shows the first potential compression point of the third occipital nerve (TON) where it emerges from the C2 and C3 vertebrae. The gray box shows the second and third (the points where the TON pierces semispinalis capitis and splenius capitis muscles, respectively) potential compression points of the TON. The golden-yellow box shows the fourth potential compression point of the TON where it pierces the trapezius muscle. The purple box indicates the potential compression point of the lesser occipital nerve where it emerges from the posterior border of the sternocleidomastoid muscle

Point 1 TON

This point refers to the point where TON emerges from C2 and C3 vertebrae. Only a recent study which has been published by Saglam et al. [26] measured this point according to the x and y axes. They found the perpendicular distances of Point 1 TON to the x and y axes as meanly 20.25±4.37 mm and 61.29±9.68 mm, respectively. In the present paper, Point 1 TON was measured as a median of 3 cm (min-max:1–3 cm) to the x-axis and 7 cm (min-max:4–9 cm) to the y-axis in a total of 82 sides (Fig. 9). The results of both studies are in agreement.

Point 2 TON

The point where the TON perforates the SS is Point 2 TON. Dash et al. [38] studied 13 cadavers and found a total of 22 TONs. They reported that the perpendicular distances of this point to the midline on the right and left sides were meanly 13.3±5.8 mm and 13.0±5.0 mm (overall 13.2 mm), respectively. Kim et al. [30] calculated the mean perpendicular distances of the Point 2 TON to the x and y axes as 11.5±9.9 mm and 61.4±15.3 mm, respectively. Saglam et al. [26] detected the mean perpendicular distance of the Point 2 TON to the x and y axes was 11.93±5.27 mm and 57.79±10.76 mm, respectively. In the present study, Point 2 TON was a median of 2 cm (min-max:1–3 cm) to the x-axis and 6 cm (min-max: 4–9 cm) to the y-axis (Fig. 9). Our results are consistent with the results of the Saglam et al. [26].

Point 3 TON

Point 3 TON depicts the point where the TON pierces the SC. Research that investigates the morphometric data of the piercing point of the SC is quite scarce. Kim et al. [30] reported that the mean distances of the Point 3 TON to the x and y axes were 10.0±5.3 mm and 59.2±19.8 mm, respectively. Similarly, Saglam et al. [26] stated that the mean distances of the Point 3 TON to the x and y axes were 12.04±4.74 mm and 55.87±14.74 mm, respectively. In the current study, Point 3 TON was obtained as a median of 2 cm (min-max:1–3 cm) to the x-axis and 6 cm (min-max: 2–9 cm) to the y-axis (Fig. 9).

Point 4 TON

The last point is the TON puncturing the TM and represents the Point 4 TON in this study. Tubbs et al. [39] emphasized that this point was settled down approximately 5 cm below and 3 cm lateral to the EOP. Kim et al. [30] reported that the perpendicular distance of Point 4 TON to the x and y axes was meanly 12.9±9.3 mm and 44.2±21.4 mm, respectively. Saglam et al. [26] obtained similar results to Kim et al. [30]. They measured the Point 4 TON to the vertical and transverse lines passing through the EOP as meanly 11.07±5.14 mm and 46.55±15.71 mm, respectively. We obtained the Point 4 TON was a median of 2 cm (min-max:1–3 cm) to the x-axis and 5 cm (min-max: 2–9 cm) to the y-axis (Fig. 9). Our results confirm the previous studies.

Point 1 LON

Point 1 LON refers to the point where LON arises from the posterior edge of the SCM. Dash et al. [38] examined 20 cadaveric heads and observed a total of 30 LONs.

Table 1 Analysis results regarding the greater, third, and lesser occipital nerves in terms of side

Parameters	Right side			Left side			*p* Value†	
	n	Median (cm)		*n*	Median (cm)			
		x-axis (min.-max.)	y-axis (min.-max.)		x-axis (min.-max.)	y-axis (min.-max.)	x-axis	y-axis
Point 1 GON	43	3 (2–4)	5 (3–8)	43	3 (2–4)	5 (3–8)	**0.040***	0.519
Point 2 GON	43	2 (1–3)	4 (2–6)	43	2 (1–3)	4 (2–6)	0.267	0.817
Point 3 GON	43	2 (1–3)	3 (2–6)	43	2 (1–4)	3 (2–6)	0.911	0.387
Point 4 GON	43	2 (1–4)	3 (1–6)	43	3 (1–4)	3 (1–6)	0.156	0.207
Point 5 GON	43	3 (2–5)	2 (1–4)	43	3 (2–5)	2 (1–4)	0.394	0.641
Point 6 GON	38	4 (3–6)	1 (1–4)	39	4 (3–5)	1 (1–4)	0.348	0.753
Point 1 TON	41	3 (2–3)	7 (5–9)	41	2 (1–3)	7 (4–9)	**0.040***	0.423
Point 2 TON	41	2 (1–3)	6 (4–9)	41	2 (1–3)	6 (4–9)	0.660	0.732
Point 3 TON	41	2 (1–3)	6 (2–9)	41	2 (1–3)	6 (3–9)	0.775	0.657
Point 4 TON	41	2 (1–3)	5 (2–9)	41	2 (1–3)	5 (3–9)	0.595	0.592
Point 1 LON	26	7 (1–9)	8 (1–12)	26	7 (1–10)	9 (1–11)	0.749	0.760

Min, minimum; **Max**, maximum. † Mann-Whitney U test was applied. * Statistically significant difference was observed

Point 1 GON: The point where the greater occipital nerve (GON) curves around the lower border of the obliquus capitis inferior muscle

Point 2 GON and Point 3 GON: Points where the GON enters semispinalis capitis muscle (SS) and exits from the SS, respectively

Point 4 GON and Point 5 GON: Points where the GON enters trapezius muscle (TM) and exits from the TM, respectively

Point 6 GON: The first point where the GON and occipital artery cross each other

Point 1 TON: The point where the third occipital nerve (TON) arises from the C2 and C3 vertebrae

Point 2 TON: The point where the TON perforates the SS

Point 3 TON: The point where the TON pierces the SC

Point 4 TON: The point where the TON pierces the TM

Point 1 LON: The point where the lesser occipital nerve (LON) emerges from the posterior border of the sternocleidomastoid muscle

Table 2 Analysis results regarding the greater, third, and lesser occipital nerves in terms of gender

Parameters	Male			Female			*p* Value†	
	n	Median (cm)		*n*	Median (cm)			
		x-axis (min.-max.)	y-axis (min.-max.)		x-axis (min.-max.)	y-axis (min.-max.)	x-axis	y-axis
Point 1 GON	54	3 (2–4)	5 (4–8)	32	3 (2–4)	5 (3–7)	0.371	0.280
Point 2 GON	54	2 (1–3)	4 (2–6)	32	2 (1–3)	4 (3–6)	0.607	0.822
Point 3 GON	54	2 (1–4)	3 (2–6)	32	2 (1–3)	3 (2–5)	0.689	0.945
Point 4 GON	54	3 (1–4)	2 (1–6)	32	2 (1–4)	3 (2–4)	0.528	0.095
Point 5 GON	54	3 (2–5)	2 (1–4)	32	3 (2–5)	2 (1–4)	0.280	0.158
Point 6 GON	52	4 (3–5)	1 (1–4)	25	4 (3–6)	1 (1–3)	0.454	0.632
Point 1 TON	50	3 (1–3)	7 (5–9)	32	2 (2–3)	6 (4–8)	0.156	0.299
Point 2 TON	50	2 (1–3)	6 (4–9)	32	2 (1–3)	6 (4–9)	0.961	0.283
Point 3 TON	50	2 (1–3)	6 (2–9)	32	2 (1–3)	6 (3–9)	0.859	0.353
Point 4 TON	50	2 (1–3)	5 (2–9)	32	2 (1–3)	5 (2–8)	0.329	0.258
Point 1 LON	28	7 (5–10)	9 (4–11)	24	6 (1–8)	8 (1–12)	**0.002***	0.468

Min, minimum; **Max**, maximum. † Mann-Whitney U test was applied. * Statistically significant difference was observed

Point 1 GON: The point where the greater occipital nerve (GON) curves around the lower border of the obliquus capitis inferior muscle

Point 2 GON and Point 3 GON: Points where the GON enters semispinalis capitis muscle (SS) and exits from the SS, respectively

Point 4 GON and Point 5 GON: Points where the GON enters trapezius muscle (TM) and exits from the TM, respectively

Point 6 GON: The first point where the GON and occipital artery cross each other

Point 1 TON: The point where the third occipital nerve (TON) arises from the C2 and C3 vertebrae

Point 2 TON: The point where the TON perforates the SS

Point 3 TON: The point where the TON pierces the SC

Point 4 TON: The point where the TON pierces the TM

Point 1 LON: The point where the lesser occipital nerve (LON) emerges from the posterior border of the sternocleidomastoid muscle

They calculated the perpendicular distance of the Point 1 LON to the y-axis was meanly 65.4±11.6 mm. Tubbs et al. [39] dissected 12 adult formalin-fixed cadavers and found the main LON trunk was meanly 7 cm lateral to the EOP. Lee et al. [31] dissected a total of 10 fresh cadavers and reported that the perpendicular distance of the point to the y-axis was 6.4±1.4 cm. Peled et al. [40] studied eight fresh frozen cadavers and detected a total of 15 LONs. They described as Zone 1, Zone 2, and Zone 3 referred to the arising point of the LON from deep to or behind the SCM, the cephalic ascent of the LON along or posterior to the SCM, and the crossing point of the LON at the nuchal line, respectively. They found the mean perpendicular distances of these points to the x-axis as 7.8±1.84 cm, 5.5±1.38 cm, and 3.8 cm, respectively. They also measured the mean perpendicular distances of Zone 1, Zone 2, and Zone 3 to the y-axis as 6.3±1.37 cm, 6.2±1.10 cm, and 5.9 cm, respectively. Similarly, Tubbs et al. [41] dissected 10 adult formalin-fixed cadaveric heads and the LON was on meanly 6.8 cm lateral to the EOP. Amirlak et al. [42] examined six cadaver necks and measured the average perpendicular distances of the Point 1 LON to the x-axis and y-axis were 8.47±1.11 cm and 7.5±1.31 cm, respectively. Saglam et al. [25] dissected 24 cadavers and reported that the perpendicular distances of the Point 1 LON to the x and y-axes were calculated as 63.69±11.28 mm and 78.83±17.21 mm, respectively. In the current study, Point 1 LON was calculated as a median of 7 cm (min-max:1–10 cm) to the x-axis and 8 cm (min-max: 1–12 cm) to the y-axis in a total of 26 specimens (Fig. 9).

Clinical relevance

ONB is highly reliable and effective in headache management [43–45]. It has therefore become an indispensable tool in invasive interventions for headaches. Being as close as possible to the target nerve during ONB is important for the success of the relevant block [1]. In this context, the target points related to ONB should be identified accurately and precisely. Recent evidence suggests that the use of ultrasound to target the occipital nerves could perhaps be a more safe and effective strategy [46, 47]. Therefore, we believe that using non-invasive imaging to obtain a better response may yield better results.

In our study, potential compression points of GON, TON, and LON were determined in detail from proximal to distal. The distances of Point 1 GON and Point 1 TON from the x-axis were statistically significantly different between the sides ($p=0.040$). Moreover, a statistically significant difference between the genders regarding Point 1 LON to the x-axis ($p=0.002$) was calculated. The fact that there is a statistically significant difference between the sides in the perpendicular distances of Point 1 GON and Point 1 TON to the x-axis indicates that the distances of these points to the midline are statistically significantly different. Although Point 1 GON is not targeted as the block point in clinical practice, and blocking the TON at Point 1 TON is technically difficult due to its deep location and small size, there may be a technical change in clinical practices in the future. In this context, we think that the blocks to be applied to Point 1 GON and Point 1 TON may differ between sides, and clinicians may plan their applications according to this difference. Similarly, the fact that the perpendicular distance of Point 1 LON to the x-axis was found to be statistically significant between genders shows that the distance of this point to the midline is statistically significantly different. In this case, we believe that just like the blocks to be applied to Point 1 GON and Point 1 TON, the blocks to be applied to Point 1 LON may differ between genders so this difference should be taken into consideration. Apart from these, since there are very few studies on Point 1 TON, our study emphasizes both the anatomical localization of this point and shows the block location according to the lines passing through the EOP. We think that this information may aid clinicians during block applications related to Point 1 TON. The fact that Point 2 TON and Point 3 TON were obtained as the same points may indicate that a single block application may be sufficient to block the relevant points. Therefore, we think that there is no need for additional blocks for these points.

Collectively, we think that our morphometric data can be used as a guide in the process of blocking the occipital nerves. In addition, we believe that the technique we use has the advantages of being able to quickly identify all potential points where GON, TON, and LON can compress, being a practical method and being able to be applied quickly, and being an inexpensive method. Of course, this method needs to be tested in clinical practice and therefore some further studies are needed.

Limitations

This study has certain limitations. First, the tool used in this study only offers a measurement method according to EOP as a landmark. Second, this method can be applied in the prone position. Third, the results may be different for those with a dolichocephalic head structure. Fourth, this method has not been clinically tested. Finally, since we did not have data on the clinical history of the specimens, we could not comment at this point.

Conclusion

In this study, the potential compression points of GON, TON, and LON were investigated in detail. Similar to previously reported in the literature, six potential impingement points related to GON, four potential pinch points related to TON and finally one point related to LON were identified. A method was developed to detect these points simultaneously and quickly. We believe that with this method we have developed, the relevant points may be easily localized and blocked in both the diagnosis and treatment of patients who experience headaches such as migraine, cervicogenic headache, occipital neuralgia, and cluster headache.

Abbreviations

ONB	Occipital nerve blocks
EOP	External occipital protuberance
MP	Mastoid process
GON	Greater occipital nerve
TON	Third occipital nerve
LON	Lesser occipital nerve
IRB	Institutional review board
OA	Occipital artery
SCM	Sternocleidomastoid muscle
OCI	Obliquus capitis inferior muscle
SS	Semispinalis capitis muscle
TM	Trapezius muscle
SC	Splenius capitis muscle

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Author contributions
L.S. and O.G. contributed to the conceptual design of the study, network analysis, data interpretation, and manuscript preparation. M.G.G contributed to the statistical analysis of the data. O.C. contributed to the acquisition of data and manuscript preparation. A.K. contributed to the data analysis/interpretation, and critical revision of the manuscript.

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Data availability
The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval
This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Clinical Research Ethical Committee of Istanbul Faculty of Medicine, Istanbul University (Date: 02/09/2024, No: 03).

Consent to participate and/or Consent to publication
Not applicable.

Competing interests
The authors declare no competing interests.

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