The anatomical descriptive pattern of the greater occipital nerve in identified Brazilian cadavers and its clinical implications for scalp anesthesia and migraine treatment

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SUMMARY

Among the measures instituted for the treatment of migraine, the greater occipital nerve (GON) block is described as being an effective, safe, easy to perform and useful technique for the treatment of this condition. However, the measures used to block the GON vary, and there is a lack of information data about the Brazilian population. Therefore, a morphometric study was carried out on 22 identified cadavers, in which the distances were measured on both sides of the following anatomical points: EOP, MP, and GON with anatomical references of the nuchal ligament, Trapezius muscle aponeurosis and MSEC perforation. ANOVA was used for statistical analysis, with Tukey post-hoc and Eta Square (η2) for effect size. Significance was adopted when $p \leq 0.05$. The ANOVA found a significant effect of ethnicity regarding the distances in the GON measurements of the EOP on the line between the EOP and MP – Left antimere; subsequent univariate analysis showed differences between white and oriental ethnicity (pTukey= 0.02); horizontal distance of the GON about the nuchal line – Right antimere; Subsequent univariate analysis showed differences between white and brown ethnicities (pTukey= 0.02); horizontal distance of the GON about the nuchal line – Left antimere. Subsequent univariate analyses showed differences between white and brown ethnicities (pTukey= 0.02). There are morphometric differences in some anatomical points used to block the GON when comparing the two antimeres, as well as in white, brown, and oriental ethnicities.

Keywords: Migraine - Scalp anesthesia - Greater occipital nerve

ABBREVIATIONS

EOP: External occipital protuberance

GON: Greater Occipital Nerve

MD: Midline

MP: Mastoid process

MSEC: Musculus Semispinalis capitis

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INTRODUCTION

The International Classification of Headache Disorders, third edition (ICHD-3; beta version) in 2013 described migraine as a common and disabling type of primary headache. Among the measures instituted for the treatment of migraine, the block of the greater occipital nerve (GON) is described as being an effective, safe, easy to perform, and useful technique for the treatment of this condition (Castillo-Álvarez et al., 2023; Chowdhury et al., 2021). The GON originates from fibers of the dorsal primary branch of the second cervical nerve and, to a lesser extent, from fibers of the third cervical nerve. The GON provides cutaneous innervation to most of the posterior scalp (Shin et al., 2018). Along its path, it is closely related to the rectus capitis posterior major and semispinatus capitis muscles. It becomes superficial at the level of the superior nuchal line medially to the occipital artery and follows together (Kwon et al., 2018), piercing the aponeurosis of the trapezius muscle to then emerge on the scalp (Choi and Jeon, 2016). According to Santos et al. (2017) and Stern et al. (2022), the location of the GON is based on drawing an imaginary line between the occipital protuberance and the mastoid process, locating the exit of the nerve at the point that joins the medial third of this line with the two most lateral thirds (Fig. 1).

Uyar Türkyilmaz et al. (2018) described in their study that the treatment of occipital neuralgia with GON block appears to be a minimally invasive, easy, and effective method. In their research, bilateral blockade of the GON was performed using a method based on anatomical landmarks, in which the GON is located approximately two-thirds of the way along a line drawn from the center of the mastoid process to the external occipital protuberance.

However, this method is challenging to obtain significant results due to the variations in distances and perforations that the GON may have during its anatomical course (Tubbs et al., 2014).

The external occipital protuberance (EOP), mastoid process (MP), and midline (ML) corresponding to the nuchal ligament are important topographic references for analgesia (Choi and Jeon, 2016; Simon et al., 2023). Natsis et al. (2006) emphasized in their work that simple palpation of the occipital region as a method to anesthetize the GON is an inadequate way, as in their results important variations of the peripheral path of the GON were identi-

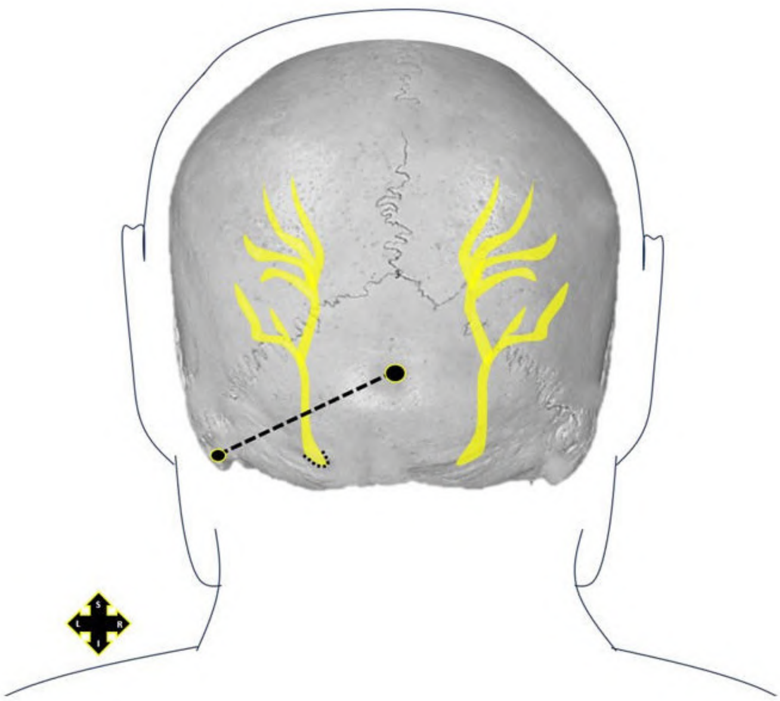

Fig. 1.- Representation of the EOP and MP anatomical points as well as the usual location of GON emergence in the subcutaneous tissue, according to Santos et al. (2017) and Stern et el. (2022).

fied, including significant changes on the right and left sides of the neck of the same cadaver.

Therefore, the use of accurate anatomical parameters proves to be essential in the treatment of migraines, as well as in scalp anesthesia. In this sense, in a scenario in which we have a lack of studies that analyzed identified Brazilian cadavers, this work seeks to analyze the path of the GON in different sexes and ethnicities to find possible correlations as well as anatomical variations and morphological disparities in the two antimeres, thus promoting a standard to be followed by clinicians working in the areas of anesthesiology and neurology.

MATERIALS AND METHODS

A morphometric study was carried out on 22 identified corpses, 13 of which were female, 9 were male, 17 were white, 3 were mixed-race, one was black and one was Asian, with no history of trauma in the region studied. All cadavers were donated for study and scientific research to the descriptive and topographic human anatomy laboratory at the Federal University of São Paulo (Brazil), the ages ranging between 39 and 88 years with an average of 69 years. The study was submitted to the ethics and research committee of the Federal University of São Paulo, Brazil, and had its opinion approved under no. 6,062,607. The distances on both sides of the neck of the following anatomical points were measured using a Mitutoyo® 150 mm Digital Caliper – 150 mm capacity, 0.01 mm resolution, accuracy +/- 0.03 mm: EOP, MP and GON with ML anatomical references, point of perforation of the GON in the aponeurosis of the Trapezius muscle and point of perforation of the GON in the semispinalis capitis muscle (MSEC) (Fig. 2). Two main groups of measurements were carried out on both sides, right and left. In the first, the horizontal distance between the GON, at the point where it pierces the MSEC, and the LM was measured, taking the nuchal ligament as a reference. The vertical distance, parallel to the nuchal ligament, between the GON, at the point where it pierces the MSEC, and the EOP was also measured. In the second group, a line was drawn between the EOP and the MP, and the distance from the GON at the point where it pierces the trapezius aponeurosis in relation to the EOP was obtained. Data were tabulated for descriptive and statistical analyses using Jamovi software (version 2.3). The descriptive data for the categorical variables, age group, race, and gender, were described with frequency (%). Data on continuous variables of measured distances were described with mean ± standard deviation. The age variable was categorized into 'elderly and non- elderly', according to the IBGE age classification – the Brazilian Institute of Geography and Statistics (2023), with ≤ 59 years old being considered 'non-elderly' and ≥ 60 years old 'elderly'. A one-way ANOVA was used to ver-

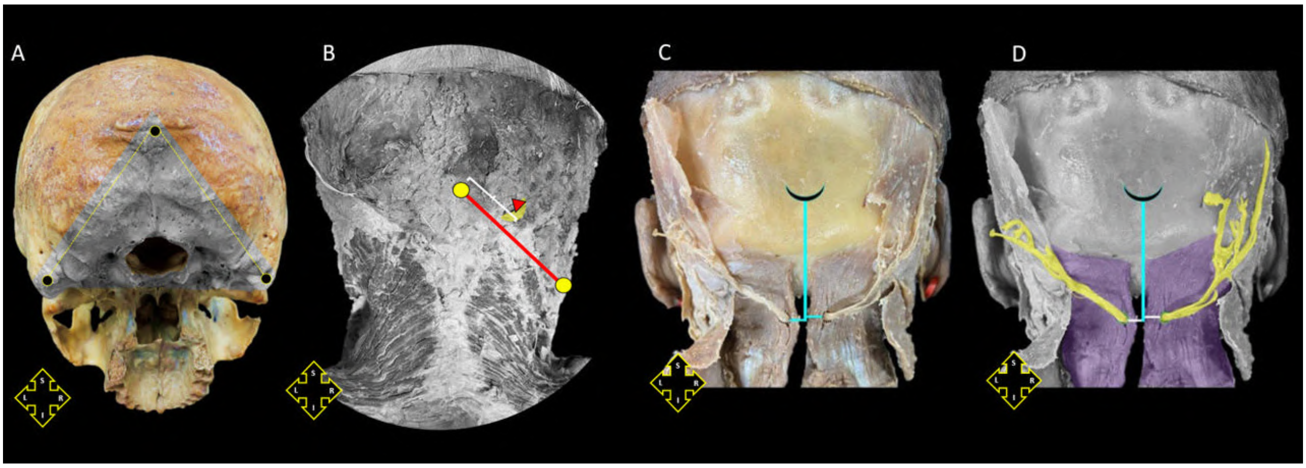

Fig. 2.- Suboccipital region in dissected planes demonstrating the anatomical reference points for analyzing the appearance of the greater occipital nerve. **A**: in skull posterior view, external occipital protuberance in the upper marking and bilateral mastoid process in the lower markings. **B**: dissection at the superficial muscular level demonstrating the identification and measurement of the appearance of the greater occipital nerve. **C-D**: bilateral measurement between the appearances of the greater occipital nerves with standardization to the midline and external occipital.

ify the effect of gender, ethnicity and age groups on the distance measurements taken as a basis in relation to the position of the GON. The Shapiro-Wilk and Levene tests were applied to test the requirements for normality and homogeneity respectively. The data presented normality and homogeneity, so no correction was necessary. Univariate 2 to 2 comparisons were made using Tukey's post-hoc; and to report the magnitude of differences, the Cohen's d effect size measure was used for post hoc and Eta Square ($\eta 2$) for ANOVA. Significance levels were accepted when $p \leq 0.05$.

RESULTS

Table 1 presents the descriptive data of the categorical variables: gender, age group and ethnicity. The values of the distances measured in relation to the anatomical points are described in Table 2, with mean ± standard deviation and minimum and maximum values.

Table 1. Sample description.

Sex	Age Group	Ethnicity	Counts	% of Total
Male	Non-elderly	White	3	13.6 %
		Asian	0	0.0 %
		Black	1	4.5 %
		Brown	1	4.5 %
	Elderly	White	2	9.1 %
		Asian	0	0.0 %
		Black	0	0.0 %
		Brown	2	9.1 %
Female	Non-elderly	White	0	0.0 %
		Asian	0	0.0 %
		Black	0	0.0 %
		Brown	0	0.0 %
	Elderly	White	12	54.5 %
		Asian	1	4.5 %
		Black	0	0.0 %
		Brown	0	0.0 %

Table 3. ANOVA distance and ethnicity.

Distance GON (EOP) line EOP MP - Left			
	F	p	η^2
Ethnicity	4.92	0.01*	0.451
Horizontal distance GON in relation ML - Left			
	F	p	η^2
Ethnicity	3.01	0.05*	0.334
Horizontal distance GON in relation ML - Right			
	F	p	η^2
Ethnicity	4.16	0.02*	0.409

*significant differences between ethnicity in relation to the distances of anatomical points

The main results of the analysis of variance (ANOVA) are described in Table 3. ANOVA found a significant difference in the categories of the ethnicity variable depending on the distances in the GON measurements from the EOP and the line between the EOP and MP – Left antimere F= (3.18) 4.92, p= 0.01, η^2p= 0.45, subsequent univariate analysis showed differences between white and brown ethnicities (pTukey =0.02); Horizontal Distance of the GON in relation to the ML – Right antimere F= (3.18) 4.16, p= 0.02, η^2p= 0.40, subsequent univariate analysis showed differences between white and oriental ethnicity (pTukey = 0.02); Horizontal Distance of the GON in relation to the ML – Left antimere F= (3.18) 3.01, p=0.05, η^2p= 0.33, subsequent univariate samples showed differences between white and brown ethnicities (pTukey =0.02). Two anatomical variations were found during the study: in one of the cases, the GON passed medially to the MSEC, without perforating it, and in the other case there was a double perforation of the MSEC (Fig. 4).

Figure 3 presents the confidence intervals of the univariate analysis showing the statistically significant differences between the groups. There are morphometric differences in some anatomical points used to block the GON when comparing the two antimeres, as well as in white, brown and oriental ethnicities.

Table 2. Distances from anatomical points.

	N	Mean	SD	Minimum	Maximum
Distance between the EOP and MP	22	98.8	8.91	74.00	115.4
Distance of the GON from the EOP on the line between EOP and MP - right	22	35.2	7.62	19.58	49.9
Distance from the GON to the EOP on the line between EOP and MP - left	22	34.7	10.56	17.02	61.5
Vertical distance of the GON from the EOP (in relation to the ML) - right	22	36.2	12.21	15.72	55.1
Vertical distance of the GON from the EOP (in relation to the ML) - left	22	35.8	10.50	16.40	55.1
Horizontal distance of the GON in relation to ML - right	22	14.9	4.65	7.81	26.1
Horizontal distance of the GON in relation to ML - left	22	15.0	5.71	3.76	26.1

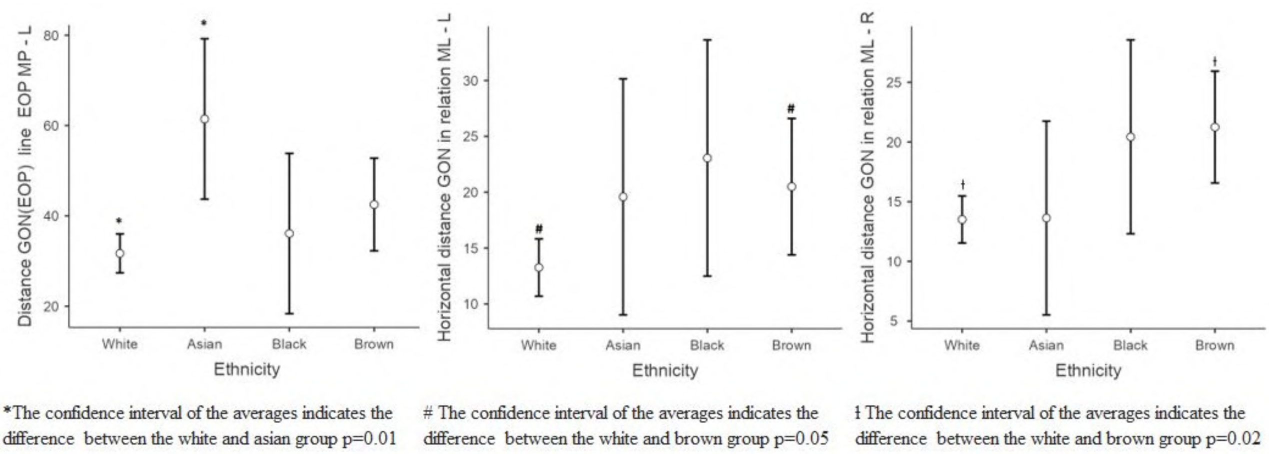

Fig. 3.- Confidence intervals of univariate analysis – Ethnicity.

Fig. 4.- Suboccipital regions in dissected planes demonstrating the anatomical variations of the appearance of the greater occipital nerve. A: anatomical variation in which the nerve passes medial to the MSEC without piercing. B: anatomical variation with double perforation of the m. semispinalis capitis (plane of the MSEC). C: anatomical variation with double perforation of the MSEC (plane of the suboccipital triangle – point where the nerve passes below the inferior oblique capital muscle).

DISCUSSION

This study aimed to analyze the morphological distribution of GON in the most superficial plane in the necks of identified Brazilian cadavers. In addition to this, statistical analysis was carried out to verify possible associations between the ethnicities, sex, and antimeres studied to generate a descriptive, pattern-safe anatomical approach to GON.

According to Stern et al. (2022) and Pingree et al. (2017), there are several techniques for blocking the GON, generally with the patient sitting and facing away from the doctor. The block can occur based on distances of 1.5 to 2 cm lateral and 2 to 3 cm inferior to the occipital protuberance, At a deeper level, the block can be performed at the C2 level, by ultrasonographic localization of the GON nerve over the inferior oblique muscle of the head. In both cases, it must be remembered that the occipital artery runs laterally to the GON. Therefore, it is advisable to perform aspiration before infusing the medication to avoid perfusing the anesthetic into the bloodstream.

Regarding the distances between GON and EOP, Guvençer et al. (2011) found a distance between the GON at the point where it pierces the semispinalis capitis in relation to the EOP of 53.6 ± 5.0 mm on the right and 53.3 ± 6.1 mm on the left, without differentiation between sexes. Mosser et al. (2002), in turn, described a distance of 29.1 ± 7.8 mm on the right and 28.7 ± 6.6 mm on the left, without also differentiating genders. In our findings, on the other hand, we found, on the right, a distance of 40.7 ± 8.37 in females and 47.6 ± 13.26 in males and, on the left, 39.6 ± 9.91 in females and 43.1 ± 5.45 in males. Therefore, there are significant differences in the distances of our sample, derived from Brazilian cadavers, in relation to those measured in cadavers of other nationalities in the aforementioned studies. It is worth mentioning that the point at which the nerve is measured finds its importance in the fact that the GON trunk anesthesia is performed in this location.

Huanmanop et al. (2021) reported that the number of specimens and ethnicity can influence the prevalence of different routes of the GON throughout its course. These data are in line with ours, as we noticed significant differences in the emergence pattern, and distances from pre-defined anatomical points for measurements, especially between white, brown, and Asian ethnicities, as there was a significant effect of ethnicity in terms of distances in measurements of the GON of the EOP and the line between the EOP and MP in the left antimere.

When we took the inter mastoid line as a reference, our data revealed that in none of the cases did the GON perforate the most superficial plane of the neck, below it, this finding is in line with the work of Loukas et al. (2006). The perforation point in the subcutaneous region, taking the aponeurosis of the trapezius muscle as a reference, was 44% (44.36 ± 4.52%) of the distance along the MD of the ipsilateral MP with an average vertical distance of about 18 mm (17.97 ± ± 5.80 mm) (Fig. 2B). No statistically significant difference was found between sexes and sides.

Furthermore, it was demonstrated that the GON perforated the MSEC in 98%, a result similar to that of Huanmanop et al. (2021), where it was reported that this perforation occurred in 95% of cases.

Finally, it should be mentioned that, in relation to the anatomical variations found in our work (Fig. 4), the non-perforation of the MSEC by the GON was also described by Bovin et al. (1990), in a case in which the GON evaded the muscle bilaterally and in two others where penetration was present on one side and absent on the other. In the work of Huanmanop et al. (2020), in 33% of cases, the GON ran between the most medial fibers of the MSEC and the nuchal ligament, and, finally, in the work of Ducic et al. (2009), in 1.5% of cases, the GON ran medially to the MSEC.

The present study has some limitations. The first is that the measurements were carried out by a single researcher. We suggest that researchers who may want to repeat our method use two researchers to carry out the measurements. Secondly, 22 samples could be included in the study, because it was carried out with donated and identified cadavers. In this sense, we did not have homogeneity between the samples, especially in the ethnicities that were compared. We encourage that, in another opportunity, anatomists can repeat our method with equality between sexes and compared ethnicities.

Finally, we know that cadaveric tissues are essential for the evolution of research into human tissues, as well as for human anatomy teachers around the world. We agree in all aspects with the manuscript by Iwanaga et al. (2020): "The results of this research can potentially increase humanity's overall knowledge, which can then improve patient care. Therefore, these donors and their families deserve our utmost gratitude" .

Knowledge of the distribution of the GON and its trajectory, as well as its anatomical variations, is of great clinical importance, since the definition of accurate anatomical parameters for carrying out procedures involving the GON is essential. We observed that there is homogeneity in the distribution of GON, with no significant differences in sex and laterality. Differences in the perforation patterns and path of the GON were observed in studies carried out in Asia, Central America, and Europe. In this sense, we need more studies in the Latin American continent to define whether the anatomical points commonly used in other continents can be reproduced with security in the Brazilian population.

REFERENCES

BALLESTEROS-DEL RIO B, ARES-LUQUE A, TEJADA-GARCIA J, MUELA-MOLINERO A (2003) Occipital (Arnold) neuralgia secondary to greater occipital nerve schwannoma. *Headache*, 43(7): 804-807.

BIGAL ME, LIPTON RB (2009) The epidemiology, burden, and comorbidities of migraine. *Neurol Clin*, 27: 321-334.

BRESLAU N, SCHULTZ L, LIPTON R, PETERSON E, WELCH KM (2012) Migraine headaches and suicide attempt. *Headache*, 52: 723-731.

BUSE D, MANACK A, SERRANO D, REED M, VARON S, TURKEL C, LIPTON R (2012) Headache impact of chronic and episodic migraine: results from the American Migraine Prevalence and Prevention study. *Headache*, 52: 3-17.

CASTILLO-ÁLVAREZ F, BÁRCENA IH, MARZO-SOLA MEM (2023) Greater occipital nerve block in the treatment of headaches. Review of evidence. *Med Clin (Barc)*, 161(3): 113-118.

CESMEBASI A, LOUKAS M, HOGAN E, KRALOVIC S, TUBBS RS, COHEN-GADOL AA (2015) The Chiari malformations: a review with emphasis on anatomical traits. *Clin Anat*, 28(2): 184-194.

CHOI I, JEON SR (2016) Neuralgias of the head: occipital neuralgia. *J Korean Med Sci*, 31(4): 479-488.

CHOWDHURY D, DATTA D, MUNDRA A (2021) Role of greater occipital nerve block in headache disorders: a narrative review. *Neurology India*, 69: 228-259.

DUCIC I, HARTMANN EC, LARSON EE (2009) Indications and outcomes for surgical treatment of patients with chronic migraine headaches caused by occipital neuralgia. *Plast Reconstr Surg*, 123(5): 1453-1461.

DUCIC I, MORIARTY M, AL-ATTAR A (2009) Anatomical variations of the occipital nerves: implications for the treatment of chronic headaches. *Plast Reconstr Surg*, 123: 859-863.

GÜVENÇER M, AKYER P, SAYHAN S, TETIK S (2011) The importance of the greater occipital nerve in the occipital and the suboccipital region for nerve blockade and surgical approaches – an anatomic study on cadavers. *Clin Neurol Neurosurg*, 113: 289-294.

HECHT JS (2004) Occipital nerve blocks in postconcussive headaches: a retrospective review and report of ten patients. *J Head Trauma Rehabil*, 19(1): 58-71.

HEADACHE CLASSIFICATION COMMITTEE OF THE INTERNATIONAL HEADACHE SOCIETY (IHS) (2018) The International Classification of Headache Disorders. 3rd ed. *Cephalalgia*, 38(1): 1-211.

HUANMANOP T, ISSARA I, AGTHONG S, CHENTANEZ V (2021) Evaluations of the greater occipital nerve location regarding its relation to intermastoid and external occipital protuberance to mastoid process lines. *Folia Morphol*, 80(3): 533-541.

IWANAGA J, SINGH V, OHTSUKA A, HWANG Y, KIM HJ, MORYŚ J, RAVI KS, RIBATTI D, TRAINOR PA, SAÑUDO JR, APAYDIN N, ŞENGÜL G, ALBERTINE KH, WALOCHA JA, LOUKAS M, DUPARC F, PAULSEN F, DEL SOL M, ADDS P, HEGAZY A, TUBBS RS (2020) Acknowledging the use of human cadaveric tissues in research papers: Recommendations from anatomical journal editors. *Clin Anat*, 34(1): 2-4.

JANIS JE, HATEF DA, REECE EM, MCCLUSKEY PD, SCHAUB TA, GUYURON B (2010) Compressão neurovascular do nervo occipital maior: implicações para enxaquecas. *Plast Reconstr Surg*, 126(6): 1996-2001.

KEMP WJ, TUBBS RS, COHEN-GADOL AA (2011) The innervation of the scalp: A comprehensive review including anatomy, pathology, and neurosurgical correlates. *Surg Neurol Int*, 2: 178.

KWON HJ, KIM HS, KANG HJ, WON JY, YANG HM, CHOI Y (2018) Anatomical analysis of the distribution patterns of occipital cutaneous nerves and the clinical implications for pain management. *J Pain Res*, 11: 2023-2031.

LOUKAS M, EL-SEDFY A, TUBBS RS, LOUIS RG JR, WARTMANN CHT, CURRY B, JORDAN R (2006) Identification of greater occipital nerve landmarks for the treatment of occipital neuralgia. *Folia Morphol (Warsz)*, 65(4): 337-342.

MEGAN Y, WANG SM (2022) Anatomy Head and Neck, Occipital Nerves. *StatPearls Publishing [Internet]*.

MOSSER SW, GUYURON B, JANIS JE, ROHRICH RJ (2004) The anatomy of the greater occipital nerve: implications for the etiology of migraine headaches. *Plastic Reconst Surg*, 113(2): 696-697.

MUELLER O, HAGEL V, WREDE K, SCHLAMANN M, HOHN HP, SURE U, GAUL C (2013) Stimulation of the greater occipital nerve: anatomical considerations and clinical implications. *Pain Physician*, 16(3): E181-189.

NATSIS K, BARALIAKOS X, APPELL HJ, TSIKARAS P, GIGIS I, KOEBKE J (2006) The course of the greater occipital nerve in the suboccipital region: A proposal for setting landmarks for local anesthesia in patients with occipital neuralgia. *Clin Anat*, 19(4): 332-336.

PERELSON HN (1947) Occipital nerve tenderness: a sign of headache. *South Med J*, 40(8): 653-656.

PINGREE MJ, SOLE JS, O'BRIEN TG, ELDRIGE JS, MOESCHLER SM (2017) Clinical efficacy of an ultrasound-guided greater occipital nerve block at the level of C2. *Reg Anesth Pain Med*, 42: 99-104.

SANTOS LASAOSA S, CUADRADO PÉREZ ML, GUERRERO PERAL AL, HUERTA VILLANUEVA M, PORTA-ETESSAM J, POZO-ROSICH P, PAREJA JA (2017) Consensus recommendations for anaesthetic peripheral nerve block. *Neurologia*, 32: 316-330.

SIMON SK, ROUT S, LIONEL KR, JOEL JJ, DANIEL P (2023) Anatomical considerations of cutaneous nerves of scalp for an effective anesthetic blockade for procedures on the scalp. *J Neurosci Rural Pract*, 14(1): 62-69.

SHIMIZU S, OKA H, OSAWA S, FUKUSHIMA Y, UTSUKI S, TANAKA R, FUJII K (2007) Can proximity of the occipital artery to the greater occipital nerve act as a cause of idiopathic greater occipital neuralgia? An anatomical and histological evaluation of the artery-nerve relationship. *Plast Reconstr Surg*, 119(7): 2029-2034.

SLAVIN KV, NERSESYAN H, WESS C (2006) Peripheral neurostimulation for treatment of intractable occipital neuralgia. *Neurosurgery*, 58(1): 112-119.

SHIN KJ, KIM HS, JEHOON O, KWON HJ, YANG HM (2018) Anatomical consideration of the occipital cutaneous nerves and artery for the safe treatment of occipital neuralgia. *Clin Anat*, 31(7): 1058-1064.

STERN JI, CHIANG C, KISSOON NR, ROBERTSON CE (2022) Narrative review of peripheral nerve blocks for the management of headache. *Headache J Head Face Pain*, 62: 1077-1092.

THIEL W (2004) Atlas Fotográfico Colorido de Anatomia Humana: Cabeça e Pescoço. Revinter, Rio de Janeiro, p 372.

TUBBS RS, SALTER EG, WELLONS JC, BLOUNT JP, OAKES WJ (2007) Landmarks for the identification of the cutaneous nerves of the occiput and nuchal regions. *Clin Anat*, 20(3): 235-238.

TUBBS RS, WATANABE K, LOUKAS M, COHENGADOL AA (2014) The intramuscular course of the greater occipital nerve: novel findings with potential implications for operative interventions and occipital neuralgia. *Surg Neurol Int*, 5: 155.

UYAR TÜRKYILMAZ E, CAMGÖZ ERYILMAZ N, AYDIN GÜZEY N, MORALOĞLU Ö (2016) Bilateral greater occipital nerve block for treatment of post-dural puncture headache after caesarean operations. *Braz J Anesthesiol*, 66(5): 445-450.

WON HJ, JI HJ, SONG JK, KIM YD, WON HS (2018) Topographical study of the trapezius muscle, greater occipital nerve, and occipital artery for facilitating blockade of the greater occipital nerve. *PLoS One*, 13(8): e0202448.