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Definition of an Effective Site for Greater and Third Occipital Nerve Block in the Nuchal Region: A Fetal Cadaver Study

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ABSTRACT

AIM: To determine the localization of the greater occipital nerve and the third occipital nerve according to palpable bone landmarks and their relationship with muscles in the suboccipital region and to define an effective zone for clinical approaches.

MATERIAL and METHODS: This study was conducted on 15 fetal cadavers. Bone landmarks to be used as reference were determined by palpation, and measurements were taken before dissection. The location, relationship and variation of these nerves and muscles (trapezius, semispinalis capitis, obliquus capitis inferior) were noted.

RESULTS: It was detected that the nape triangular area formed between the reference points was scalene in males and isosceles in females. It was found that greater occipital nerve pierced aponeurosis of trapezius and passed under obliquus capitis inferior in all fetal cadavers and 96.7% of them had pierced semispinalis capitis. It was determined that the greater and third occipital nerve pierced the trapezius aponeurosis approximately 2 cm below the reference line and 0.5-1 cm lateral to the midline.

CONCLUSION: One of the important factors for the high success rate in suboccipital invasive procedures in the pediatric population is to know the location of the nerves in the region correctly. We believe that the results of this study will contribute to the literature.

KEYWORDS: Greater occipital nerve, Third occipital nerve, Occipital block, Fetal cadaver

INTRODUCTION

The suboccipital region is between the occipital bone and the first two cervical vertebrae. The trapezius and the semispinalis capitis are found superficially in this region, the rectus capitis posterior major, the rectus capitis posterior minor, the obliquus capitis superior and the obliquus capitis inferior in the deep. Just under the skin of the suboccipital region, the greater occipital nerve (GON) and the third occipital nerve (TON) extend (21).

The medial branch of the second cervical dorsal ramus is called the GON; it innervates the semispinalis capitis passing transversely across the inferior oblique side of the muscle. As the superficial medial branch of the third cervical dorsal ramus, the TON extends transversely and deeply into the semispinalis capitis, which it innervates, and it sends a communicating branch to the GON. Just above the second cervical spinal process, the TON turns dorsally to pierce the semispinalis capitis, the splenius capitis, and the trapezius. It becomes cutaneous over a small area immediately below the superior nuchal line (27).

Nerve compression syndrome due to the anatomic position and cervical movements of the GON has been reported in the literature (11,12,22). Paresthesia and pain may occur during flexion of the cervical spine due to the GON passing through the obliquus capitis inferior and compressing the part of the nerve inserted into the semispinalis capitis during cervical extension (11,12,22). It was reported that 53% of whiplash-induced pain cases are caused by affecting the TON (19). Furthermore, some studies have shown that neuralgia of the TON may arise from degenerative disease of the C2-C3 facet

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joint and traumatic arthropathy (3). The symptoms of neuralgia caused by the TON usually mimic neuralgia of the GON (5). Occipital neural blockade procedures are important for the diagnosis and treatment of TON neuralgia (1).

The posterior part of the head and neck are critical anatomical areas, especially for surgical treatment of occipital neuralgia and occipital neural block (18,20,22,31). Fetal and pediatric cadaver studies to support these invasive procedures, which are rarely performed in pediatric age groups, are very limited in the literature. Utilizing imaging methods (e.g., US) during the implementation of invasive procedures is an important method that minimizes the risk of nerve injury. However, in cases where there is no such possibility, determining the safest zones without applying the procedures will help minimize the risk (24).

In this study, we aimed to determine the localization of the superficial nerves and their relationship with the muscles in the suboccipital region (GON and TON) according to the palpable bone landmarks and the lines determined between them and define an effective region for pediatric clinical approaches.

MATERIAL and METHODS

This study was performed on 15 (7 males and 8 females) fetal cadavers without detectable malformations at the 3rd trimester (26–37 gestational weeks). The procedures followed were in accordance with the ethical standards of the Committee on Human Experimentation of the Faculty (approval number 2018/1265), which are based on the Helsinki Declaration. The fetal cadavers were fixated using the immersion method using 10% formalin, and the gestational ages were determined depending on the crown-rump length (13).

Measurements and dissections were performed bilaterally. Bone landmarks to be used as reference were determined by palpation, and measurements were taken before dissection. Then, the scalp and nape skin was elevated through superficial dissection. The nerves and muscles were made visible through deep dissection. The dissections were performed under a microdissection microscope (Carl Caps, Germany) and measurements were taken using electronic calipers (Mitutoyo, Japan, measuring range:0-150 mm, precision:0.01 mm). The location, relationship and variation of the nerves and muscles were noted. The data obtained were compared statistically regarding gender and the right and left sides of the fetal cadaver.

The external occipital protuberance (EOP), the apex of the right and left mastoid process (MP), the midline and the intermastoid line (IML) were marked. To determine the effective zone for the nerves, the reference line (RL) to be used in the measurements was drawn parallel to the IML by passing through the EOP. The intermastoid distance (a), the distance between the right and left MP and the midline (b), the distance between the EOP and the right and left MP (c), and the distance between the EOP and the IML were measured (d) (Figure 1).

The dissections were performed step-by-step from the surface to the deep plane. In the first step, the skin from the scalp and nape of the suboccipital region was elevated by superficial dissection. The aponeurosis of the trapezius, the TON and the GON were made visible. The points where the GON and TON pierced the aponeurosis of the trapezius were determined (Figure 2). The distance from these points to the midline and the RL (GON-Midline, TON-Midline, GON-RL, TON-RL) were measured.

In the second step, the trapezius and the splenius capitis were removed, the semispinalis capitis was revealed, and the GON remained intact during the dissection. It was determined whether the GON punctured the semispinalis capitis and, if it did, which part of the muscle (medial 1/3, middle 1/3, and lateral 1/3) was pierced. It was also noted whether the nerve divided the first branch before or after the muscle was pierced (Figure 3). Furthermore, the distance between the GON and the midline (GON-Midline) was measured.

In the third step, the semispinalis capitis was elevated, and the suboccipital muscles were revealed. The location of the GON (below, above, and pierced) was determined according to the obliquus capitis inferior.

Statistical Analysis

All data were evaluated using SPSS 21.0 (Statistical Package for Social Science; IBM, Chicago, IL, USA). Kolmogorov-Smirnov test was used to reveal whether the data were suitable for normal distribution. Since most of the data showed normal distribution, independent t-test and paired-samples t-test were used in the data analysis. The mean values, standard deviations, maximum and minimum values and percentages were determined. The differences between the morphometric

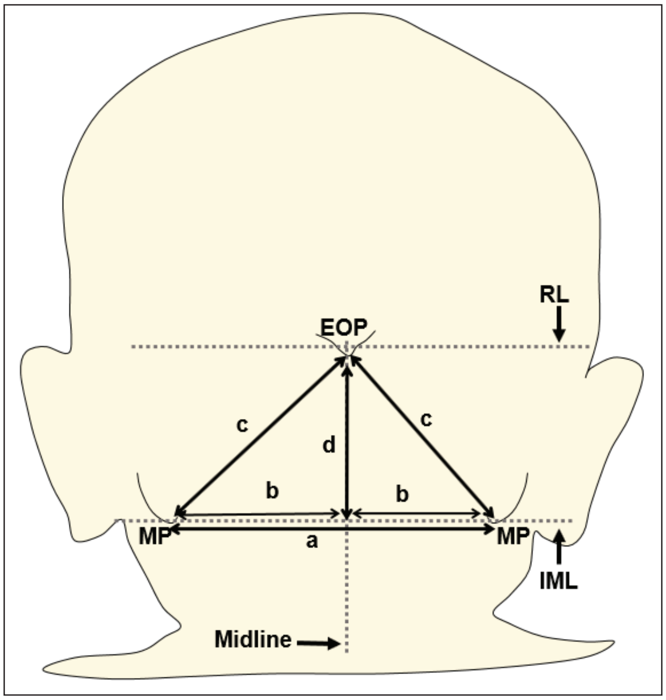

Figure 1: Definitions of distance measurement. **a:** The intermastoid distance, **b:** Distance from mastoid process (MP) to midline. **c:** Distance from MP to the external occipital protuberance (EOP), **d:** Distance from EOP to the intermastoid line (IML).

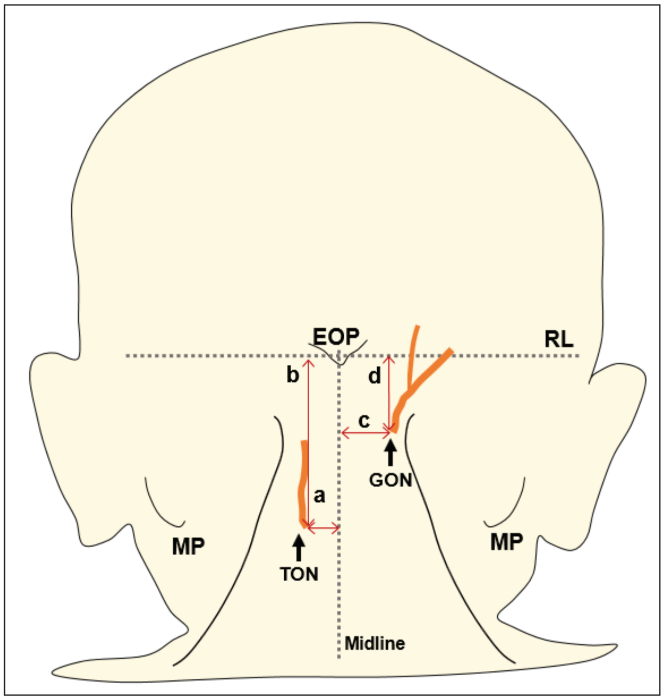

Figure 2: Definitions of measurement for GON and TON on the trapezius. **a:** Distance from TON to the midline. **b:** Distance from TON to RL, **c:** Distance from GON to the midline, **d:** Distance from GON to the RL. **GON:** greater occipital nerve, **TON:** Third occipital nerve, **RL:** Reference line, **EOP:** External occipital protuberance, **MP:** Mastoid process.

values of the male and female were compared using an independent sample t-test. Data from the morphometric measurements from the right and left sides of the fetal cadavers were compared using a paired sample t-test. The 95% confidence intervals were calculated and a p<0.05 was considered statistically significant.

RESULTS

In this study, the distances of bone markers and nerves (GON and TON) extending in the suboccipital regions of third-trimester fetal cadavers to the RL were measured. Among the superficial measurements, only the distance from the EOP to the IML (d) was significantly higher in males than in females (p<0.05) (Figure 1, Table I). The distance between EOP and MP (c) was statistically higher on the right side of males than on the gender and side (p<0.05) (Figure 1, Table II).

In all the fetal cadavers, the GON was observed to pass through the aponeurosis of the trapezius on the superficial plane. In the deep plane, it was observed that this nerve only extended from the medial 1/3 of the semispinalis capitis on one right side without piercing the muscle (3.3%) (Figure 3A) and in 29 of the sides of total fetal cadavers, it pierced the muscle (96.7%) (Figures 3B-D). The GON pierced the semispinalis capitis on 26 of the sides of total fetal cadavers (86.7%) as a single branch (Figure 3B), and it bifurcated into the branches before piercing the muscle in 3 of the sides of total fetal cadavers (10%) (Figures 3C, D).In one case (male, right side), it was observed that the nerve divided into two

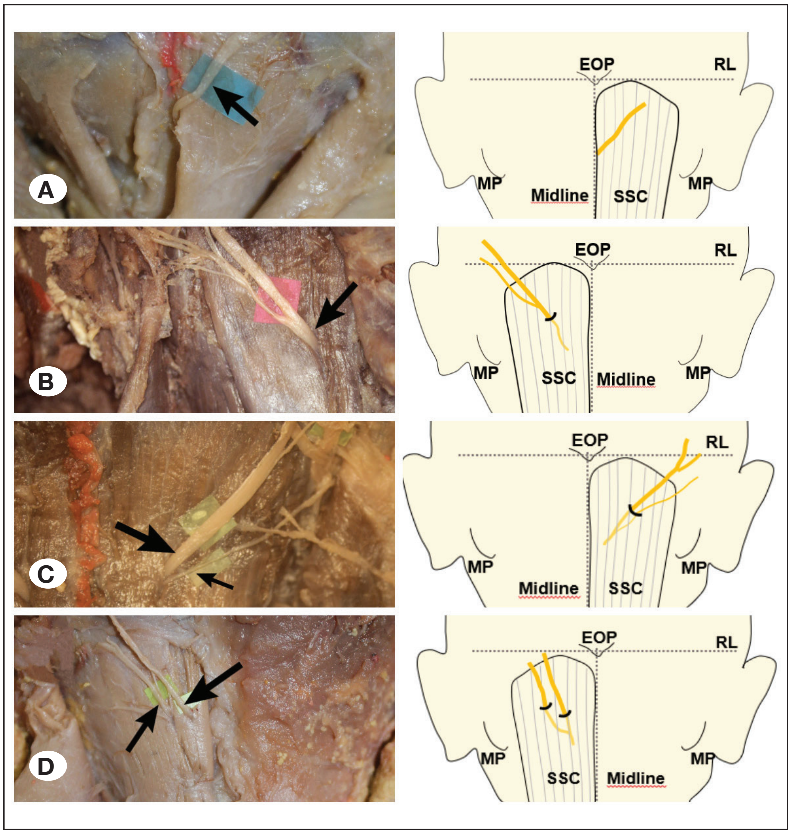

Figure 3: Relationship between the GON branching pattern and the semispinalis capitis (SSC).
A) Course of the nerve without piercing the SSC,
B) The nerve is divided into branches after piercing the SSC, **C)** The nerve splits into two branches before puncturing the SSC and the branches exit through the same hole, **D)** The nerve splits into two branches before puncturing the SSC and the branches exit through the two holes. **Arrows:** GON and its branches, **EOP:** External occipital protuberance, **MP:** Mastoid process, **RL:** Reference line.

branches (thick-thin) before piercing the muscle, and these two branches exited the same hole (Figure 3C). In two cases (one male and one female), it was detected observed that the nerve divided into two branches before piercing the muscle, and these two branches exited the different holes (Figure 3D).

At the deep plane dissection, it was observed that the GON passed below the obliquus capitis inferior and extended to the laterally in all the fetal cadavers (Figure 4).

DISCUSSION

The suboccipital region, located on the posterior side of the head and neck, is an important area due to having intensive anatomical content. Although clinical approaches are commonly performed in this region, studies investigating the bone landmarks needed to preserve the cutaneous nerves are few in the literature (31). An effective zone was defined for clinical procedures in this region by determining the locations of the cutaneous nerves and their relations with the muscles according to the palpable bony landmarks.

This region is important for clinical approaches not only in adults but also in the pediatric age group. Nerve block in this region (especially of the GON) is preferred in pediatric patients after craniotomies, cranioplasties, or ventriculo-peritoneal shunt applications, as the systemic side effects of pain control drugs can be avoided. In addition, diseases, such as occipital neuralgia, chronic migraine, and post-traumatic headache, are suitable indications for nerve blocks (14,15,24,29,30). Due to its proximity to the surface and easy accessibility under the

Table I: Comparison of Distances (mm) Between Bone Structures and the Distance (mm) of the Nerves to the Midline and the Reference Line (RL) by Gender. SD standard deviation, * = p<0.05

Parameters	Male (n = 7)	Female (n = 8)	p
	Mean ± SD	Mean ± SD	
IMD	59.6 ± 14.98	59.67 ± 8.36	0.987
MP-Midline	35.29 ± 8.76	33.54 ± 3.94	0.500
EOP-MP	45.23 ± 7.14	41.71 ± 4.55	0.128
EOP-IML	22.19 ± 4.75	17 ± 7.02	**0.024***
TON- Midline	5.47 ± 3.09	4.77 ± 1.77	0.468
TON-RL	27.51 ± 6.51	26.17 ± 6.51	0.577
*GON- Midline	8.29 ± 6.89	10.78 ± 6.58	0.322
**GON- Midline	4.29 ± 2.46	4.49 ± 2	0.802
GON-RL	20.9 ± 11.29	20.71 ± 8.31	0.960

***IMD:** Intermastoid line, **MP:** Mastoid process, **EOP:** External occipital protuberance, **IML:** Intermastoid line, **TON:** Third occipital nerve, **GON:** Greater occipital nerve, **RL:** Reference line, *: At the level of trapezius aponeurosis, **: At the level of semispinalis capitis.*

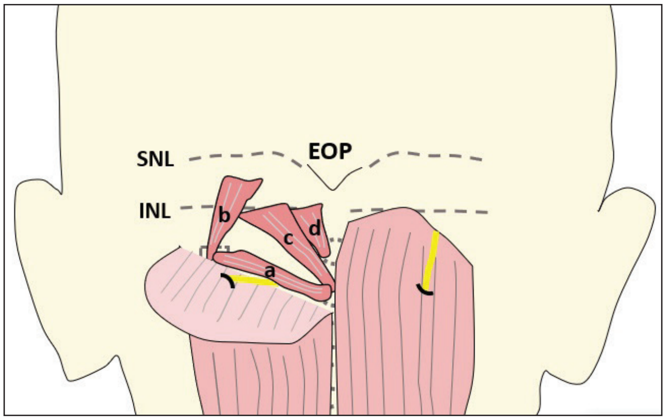

Figure 4: The exit of the GON under the obliquus capitis inferior. **EOP:** External occipital protuberance, **SNL:** Superior nuchal line, **INL:** Inferior nuchal line, **a:** obliquus capitis inferior, **b:** obliquus capitis superior, **c:** rectus capitis posterior major, **d:** rectus capitis posterior minor.

Table II: Comparison of Distances (mm) Between Bone Structures and the Distance (mm) of the Nerves to the Midline and the Reference line (RL) by Gender and Sides. SD standard deviation, * = p<0.05

Parameters	Male			Female		
	Left (n=7) Mean ± SD	Right (n= 7) Mean ± SD	p	Left (n=8) Mean ± SD	Right (n=8) Mean ± SD	p
EOP-MP	47 ± 7.62	43.45 ± 6.7	0.045*	41.42 ± 4.24	42 ± 5.12	0.378
MP-Midline	36.58 ± 8.51	34 ± 9.49	0.238	33.32 ± 4.25	33.76 ± 3.88	0.818
TON- Midline	5.58 ± 3.67	5.35 ± 2.69	0.865	4.58 ± 1.46	4.96 ± 2.12	0.598
TON-RL	28.08 ± 5.72	26.94 ± 7.64	0.463	25.15 ± 5.89	27.18 ± 7.34	0.559
*GON- Midline	7.62 ± 6.19	8.96 ± 7.96	0.165	11.59 ± 6.77	9.97 ± 6.75	0.453
**GON- Midline	3.72 ± 1.92	4.85 ± 2.94	0.499	3.86 ± 2.46	5.13 ± 1.26	0.224
GON-RL	21.12 ± 11.49	20.68 ± 12	0.946	20.35 ± 10.4	21.08 ± 6.28	0.790

***MP:** Mastoid process, **EOP:** External occipital protuberance, **TON:** Third occipital nerve, **GON:** Greater occipital nerve, **RL:** Reference line, *: At the level of trapezius aponeurosis, **: At the level of semispinalis capitis.*

skin, the GON block has been frequently used (8-10,24,28,30). Generally, imaging methods, such as ultrasound, are used for the fast and effective application of nerve blocks (24).However, in conditions where imaging methods are insufficient, nerve blocks are blinded. In this case, the increase in the success rate of the application depends on knowing the relationship between the nerve to be blocked and the palpable points on the skin.

The different areas of GON blocks have been defined using EOP and midline in studies conducted on adults (12,20,22,23). In cadaver studies, it is stated that the GON pierces the aponeurosis of the trapezius approximately 2-5 cm lateral to the midline and 2 cm below the EOP (12,20,22,31). While in clinical studies, it is recommended that nerve block be performed approximately 2 cm lateral to the midline and 2 cm below the EOP (8,23,25).

Since conditions related to the GON are believed to be the most significant cause of 90% of occipital neuralgia cases (6,32),various studies have been conducted in adults to identify the course of this nerve and its relationship with the muscles. In these studies, the GON was shown to pierce the semispinalis capitis bilaterally (90% to 100%) (2,4,7,9,12,16,17,22,26,31).

Ducic et al. reported that 98.5% of the GON pierced the semispinalis capitis, while 1.5% coursed laterally without piercing the muscle (passing through the medial side of the muscle) in their study on 125 individuals (112 live intraoperative measurements and 13 cadavers) (9).

Gelfand et al. are among the first researchers to apply GON block to pediatric patients under 18 years old with chronic headaches. They suggested that 53% of the patients they applied blockage benefited from the treatment, and therefore, this procedure may be appropriate before considering more aggressive interventions (10). Suresh and Bellig reported that they applied GON block in a part of anesthesia before the neurosurgical procedure in very low birth weight neonates (28). In both of these studies, the nerve block was performed blindly. It has been reported that the areas defined in the suboccipital region for nerve block in adults may not be suitable for the pediatric population since bone and muscle development continues in this age group. On the other hand, the MP, the EOP, and the nerve-piercing point are not likely to be altered (24). Suresh and Voronov suggest that the midpoint of the line drawn between the mastoid process and the midline is a good guide for the location of the GON in children (29).

In the studies in the literature, to our knowledge, no data were related to the distance measurements between the palpable bone structures. In our study, the distance between the EOP and the MP and the IMD was measured, similar to the studies performed on adults. As a result of the data analysis, it was determined that the triangle area formed between the bone structures was scalene in males and isosceles in females.

Prigge et al. measured the distance between EOP and GON at approximately 23 mm in five fetal and one infant (2 years old) cadavers (24). They reported that this distance was 44% of the distance between EOP and MP in fetal cadavers and 36.27% in infant cadavers. If it is desired to define a safe area for nerve block in the pediatric population, knowing the distance to the EOP will not be sufficient, considering the course of both GON and TON. Therefore, in this study, the distances to the midline and RL of the GON and TON were measured. It was found that the GON pierced the aponeurosis of the trapezius approximately 1 cm lateral to the midline and 2 cm below the RL. The TON pierced this structure approximately 0,5 cm lateral to the midline and 2,5 cm below the RL.

In this study, the GON pierced bilateral semispinalis capitis in 14 fetal cadavers while it coursed on the medial margin without puncturing the muscle in one fetal cadaver (Figure 2). Newborns up to one year old (especially babies two to four months old) are most at risk of injury from concussion. Shaking them can trigger the “whiplash” effect strongly. This effect may lead to nerve entrapment, where they pass through the muscles or the aponeurosis and to internal injuries, including bleeding in the brain or eyes. As a result of only nerve entrapment, the newborn may constantly cry and be restless. In such cases, the relationship between the superficial nerves in the suboccipital region and the muscles should be kept in mind since the softening of muscle spasms and the relaxation of infants can be achieved with simple manual therapy.

Limitations

This study focused on the procedures in the pediatric age group; the low number of fetal cadavers in the collection and the inability to find pediatric cadavers are the most important limitations of our study.

CONCLUSION

Nerve blocks and other invasive procedures in the suboccipital region are also performed in the pediatric population, although less frequently than in adults. To increase the success of invasive procedures and reduce complications, the localization of the nerves in this region should be well known. In this study, the relationship of nerves with superficial anatomical signs and muscles was revealed, and an effective area was defined, especially for nerve block. As a result, the effective area for nerve block and other invasive approaches in the suboccipital region was approximately 2-2.5 cm below the RL and 0.5-1 cm lateral to the midline. This study aimed to draw attention to the pediatric age group and should be replicated primarily on fetal and pediatric cadavers.

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AUTHORSHIP CONTRIBUTION
Study conception and design: IIU
Data collection: ADAK, UY
Analysis and interpretation of results: ADAK
Draft manuscript preparation: UY, IUU, ADAK
Critical revision of the article: IUU
All authors (IUU, UY, ADAK) reviewed the results and approved the final version of the manuscript.

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