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ORIGINAL ARTICLE
Peripheral Nerve

Feasibility of Ultrasound Measurements of Peripheral Sensory Nerves in Head and Neck Area in Healthy Subjects

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Background: Current diagnostic methods for nerve compression headaches consist of diagnostic nerve blocks. A less-invasive method that can possibly aid in the diagnosis is ultrasound, by measuring the cross-sectional area (CSA) of the affected nerve. However, this technique has not been validated, and articles evaluating CSA measurements in the asymptomatic population are missing in the current literature. Therefore, the aim of this study was to determine the feasibility of ultrasound measurements of peripheral extracranial nerves in the head and neck area in asymptomatic individuals.
Methods: The sensory nerves of the head and neck in healthy individuals were imaged by ultrasound. The CSA was measured at anatomical determined measurement sites for each nerve. To determine the feasibility of ultrasound measurements, the interrater reliability and the intrarater reliability were determined.
Results: In total, 60 healthy volunteers were included. We were able to image the nerves at nine of 11 measurement sites. The mean CSA of the frontal nerves ranged between $0.80 \pm 0.42\,mm^2$ and $1.20 \pm 0.43\,mm^2$, the mean CSA of the occipital nerves ranged between $2.90 \pm 2.73\,mm^2$ and $3.40 \pm 1.91\,mm^2$, and the mean CSA of the temporal nerves ranged between $0.92 \pm 0.26\,mm^2$ and $1.40 \pm 1.11\,mm^2$. The intrarater and interrater reliability of the CSA measurements was good (ICC: 0.75–0.78).
Conclusions: Ultrasound is a feasible method to evaluate CSA measurements of peripheral extracranial nerves in the head and neck area. Further research should be done to evaluate the use of ultrasound as a diagnostic tool for nerve compression headache. *(Plast Reconstr Surg Glob Open 2023; 11:e5343; doi: 10.1097/GOX.0000000000005343; Published online 11 October 2023.)*

INTRODUCTION

For patients with unremitting chronic headaches, compression of peripheral sensory nerves is a possible extracranial origin of their pain.[1] These nerve compression or neuralgic headaches can be caused by compression of several different sensory nerves: most frequently frontal, temporal, and occipital.[2] Possible compression points of these nerves are described in the current literature in anatomical studies.[3–10] Proper diagnosis of headache due to compression neuropathy is currently based on the patient's history, pain sketches, imaging findings, and the presentation of symptoms.[11,12] Additionally, diagnostic nerve blocks or a positive response to botulin toxin type A are used in determining the diagnosis; however, these are invasive procedures.[13,14]

A less-invasive method that can aid in the diagnosis of peripheral nerve disorders is ultrasound. Ultrasound is an excellent tool for nerve imaging, widely available, and easy to learn and perform.[15] Nerves that have undergone mechanical compression show a hypoechogenic aspect and appear enlarged due to swelling when visualized with ultrasound, as studied in other nerve

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compression syndromes.[16,17] For the affected nerves in patients with neuralgia, several articles describe nerves to be thickened on surgical exploration compared with the contralateral side.[18] This change in the nerve could be quantified by measuring the increased cross-sectional area (CSA) at or just proximal or distal to the site of compression.[19] Cho et al used ultrasound to measure the CSA of symptomatic greater occipital nerves (GONs) at its emergence adjacent to the obliquus capitis inferior muscle in patients with unilateral occipital neuralgia and asymptomatic GONs in healthy individuals. They reported sonographic evidence showing an increased CSA at the site of compression of the symptomatic GON in patients with unilateral occipital neuralgia.[20,21] These results suggest that ultrasound could possibly be used as a diagnostic tool for nerve compression headaches. However, only a small cohort was included in this study, and additional articles evaluating CSA measurements by ultrasound in the asymptomatic population are missing in the current literature.

Therefore, this study aimed to determine the feasibility of ultrasound measurements of peripheral extracranial nerves in the head and neck area in asymptomatic individuals. Evaluating the reliability of ultrasound measurements of these sensory nerves is the first step to determine the value of ultrasound as a diagnostic tool for patients with nerve compression headache. Secondary, the goal of this study is to provide reference values for the CSA of these nerves in asymptomatic individuals.

> **Takeaways**
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> **Question:** What is the feasibility of ultrasound measurements of peripheral extracranial nerves in the head and neck?
>
> **Findings:** The nerves of the head and neck in healthy individuals were imaged by ultrasound, and the CSA was measured at anatomical measurement sites for each nerve. We were able to image the nerves and measure the CSA at nine out of 11 sites. The intrarater and interrater reliability of the CSA measurements was good.
>
> **Meaning:** Ultrasound is a feasible method to evaluate CSA measurements of peripheral extracranial nerves in the head and neck area.

METHODS

Study Design

This study is a cross-sectional analysis. Ethical approval for this study was obtained in the two participating centers. Healthy volunteers without a history of headaches in the head and neck region within the past 6 months were imaged by ultrasound during a one-time visit to the outpatient clinic. Exclusion criteria included a history of trauma of the cervical spine or cranial trauma, a history of polyneuropathy, systemic disease potentially associated with polyneuropathy or a neuromuscular disease, prior surgery in the head and neck area and prior injections with a neurotoxin, such as botulin toxin within the past 6 months. Written informed consent of all participants was obtained.

Ultrasound Measurements

The measurements were individually performed by the two authors (M.H. and T.B.), trained on ultrasound nerve assessment. The following nerves were measured: supraorbital nerve (SON), supratrochlear nerve (STN), zygomaticotemporal nerve (ZTN), auriculotemporal nerve (ATN), GON, lesser occipital nerve (LON), and third occipital nerve. The ultrasonographic evaluation was conducted using a Philips iU22 ultrasound system with a 12-MHz linear transducer.

Participants were asked to sit down in a relaxed position, and the array probe was placed directly onto the skin, using sufficient transmission gel. The CSA of the nerves was measured on either the right side of the patient or on the left side of the patient.

To determine the feasibility of ultrasound measurements of the peripheral nerves in the head and neck area, the interrater reliability and the intrarater reliability were determined. A second independent examiner also conducted ultrasound measurements in five healthy volunteers to assess the interrater reliability. The intrarater reliability was determined by a consequent ultrasound measurement of five healthy volunteers perfomed by the first examiner. The CSA and the diameter were measured directly by using the measurement system of the ultrasound machine.

Measurement Sites

The CSA was measured at the site of compression. The possible compression points of the nerves mentioned above are described in the current literature. For the supraorbital and supratrochlear nerves, this is the foramen or notch in the supraorbital rim and the corrugator muscle (SON 1, 2, STN 1, 2).[3,4,22] As the zygomaticotemporal nerve only has one common compression point, the passing through the temporal fascia, only this point is measured (ZTN).[5,23] For the auriculotemporal nerve, the compression point is the preauricular fascial band and the superficial temporal artery (ATN 1, 2).[6,10,24] The most proximal compression point to the origin of the greater occipital artery in its peripheral and noncervical trajectory is a fascial band along the border of the obliquus capitis inferior (GON 1). The most distal compression point crosses the occipital artery at the nuchal ridge (GON 2).[7,9,25] For the lesser occipital artery, this is a fascial band and the border of the sternocleidomastoid muscle crossing with the occipital artery (LON 1, 2).[8,26,27] All peripheral nerve and measurement sites are depicted in Table 1.

Sample Size Calculation

Only data for the GON were available for the sample size calculation. The study by Cho et al measured extracranial nerves in both asymptomatic and symptomatic nerves.[21] The CSA was 2 mm^2 with an SD of 0.7 mm^2. An SD of 35% (found in the pilot study) and an uncertainty of the 95% confidence interval of 25% were used for the sample size estimation. We estimated a sample size of 56,

Table 1. Measurement Sites

Nerve	Measurement Site	Location
Supraorbital nerve	SON 1	Just distal to supraorbital notch/foramen
	SON 2	In the corrugator muscle
Surpratrochlear nerve	STN 1	Just distal to supraorbital notch/foramen
	STN 2	In the corrugator muscle
Zygomaticotemporal nerve	ZTN	Emerge through the temporal fascia
Auriculotemporal nerve	ATN 1	Preauricular
	ATN 2	Near the superficial temporal artery
Greater occipital nerve	GON 1	Near the edge of the obliquus capitis inferior muscle
	GON 2	Near the occipital artery
Lesser occipital nerve	LON 1	Near the border of the sternocleidomastoid muscle
	LON 2	Near the occipital artery

ATN, auriculotemporal nerve; LON, lesser occipital nerve; SON, supraorbital nerve; STN, supratrochlear nerve; ZTN, zygomaticotermporal nerve.

but assumed that there would be measurement errors (quality of artifacts) and therefore added 10% with a total sample size of 60.[21]

Statistical Analysis

The primary outcome of this study was the feasibility of ultrasound measurements of peripheral extracranial nerves in the head and neck area. This is quantified as the interrater and intrarater reliability of the CSA measurements. This was measured by calculating the intraclass coefficient (ICC). The ICC was calculated separately for the frontal and temporal nerves (SON, STN, ZTN, ATN) and the occipital nerves (GON, LON). The analysis was performed in R with the package "IRR" (two-way mixed model, absolute agreement, single measures). An ICC of 0.75 was deemed as reliable.

The mean CSA and diameter for each of the previous described 11 measured sites were calculated. The CSA was expressed in millimeters squared with SD; the diameter was expressed in millimeters with SD.

RESULTS

Demographic Results

A total of 60 healthy volunteers were included. The median age was 27 (IQR: 25.0–36.5) years, and most of them were women (n = 37, 62%). The mean body mass index (BMI) was 24 ± 6.7 (Table 2).

Feasibility

We were able to image the nerves at nine of 11 measurement sites using ultrasound. We managed to image the GON and the LON at the first measurement site. However, it was difficult to follow both nerves to the second measurement sites due to their tortuous course and due to hair growth. Therefore, it was not possible to image the GON and the LON at the second measurement site (GON 2, LON 2).

Table 2. Patient Population

Variable	All Patients (n = 60)
Age, median (IQR), y	27 (IQR: 25.0–36.5)
Male sex, n (%)	23 (38.3)
BMI, mean (SD)	24 (6.7)

The learning curve of the ultrasound examination was short. The examination was not perceived as difficult to conduct by the two examiners. The ultrasound examination took approximately 5 minutes per nerve.

CSA

The mean CSA of the imaged nerves at the measurement sites are depicted in Table 3.

The CSA of the GON 2 and the LON 2 was not determined because the nerve could not be imaged by ultrasound at these measurement sites. The mean CSA of the SON, STN, ZTN, and ATN was similar, and ranged between 0.80 ± 0.42 mm^2 and 1.4 ± 01.11 mm^2. The mean CSA of the two occipital nerves, GON 1 and LON 1, was larger (GON 1: 3.40 ± 1.91 mm^2 and LON 1: 2.90 ± 2.73 mm^2; Fig. 1).

Diameter

The mean diameters of the imaged nerves at the measurement sites are depicted in Table 3. The diameter of the GON 2 and the LON 2 was not determined because

Table 3. Mean Diameter and CSA of the Nerves at the Measurement Sites

Nerve	Mean Diameter (SD), mm	Mean CSA (SD), mm^2
Supraorbital nerve		
SON 1	1.22 (0.28)	1.20 (0.43)
SON 2	0.95 (0.23)	0.93 (1.25)
Supratrochlear nerve		
STN 1	1.15 (0.28)	1.00 (0.44)
STN 2	0.97 (0.21)	0.80 (0.42)
Zygomaticotemporal nerve		
ZTN	1.06 (0.19)	0.92 (0.26)
Auriculotemporal nerve		
ATN 1	1.21 (0.30)	1.40 (0.56)
ATN 2	1.34 (1.12)	1.40 (1.11)
Greater occipital nerve		
GON 1	1.85 (0.55)	3.40 (1.91)
GON 2	ND*	ND*
Lesser occipital nerve		
LON 1	1.60 (0.47)	2.90 (2.73)
LON 2	ND*	ND*

*Value could not be determined by ultrasound.
SON, supraorbital nerve; STN, supratrochlear nerve; ATN, auriculotemporal nerve; ZTN, zygomaticotermporal nerve.

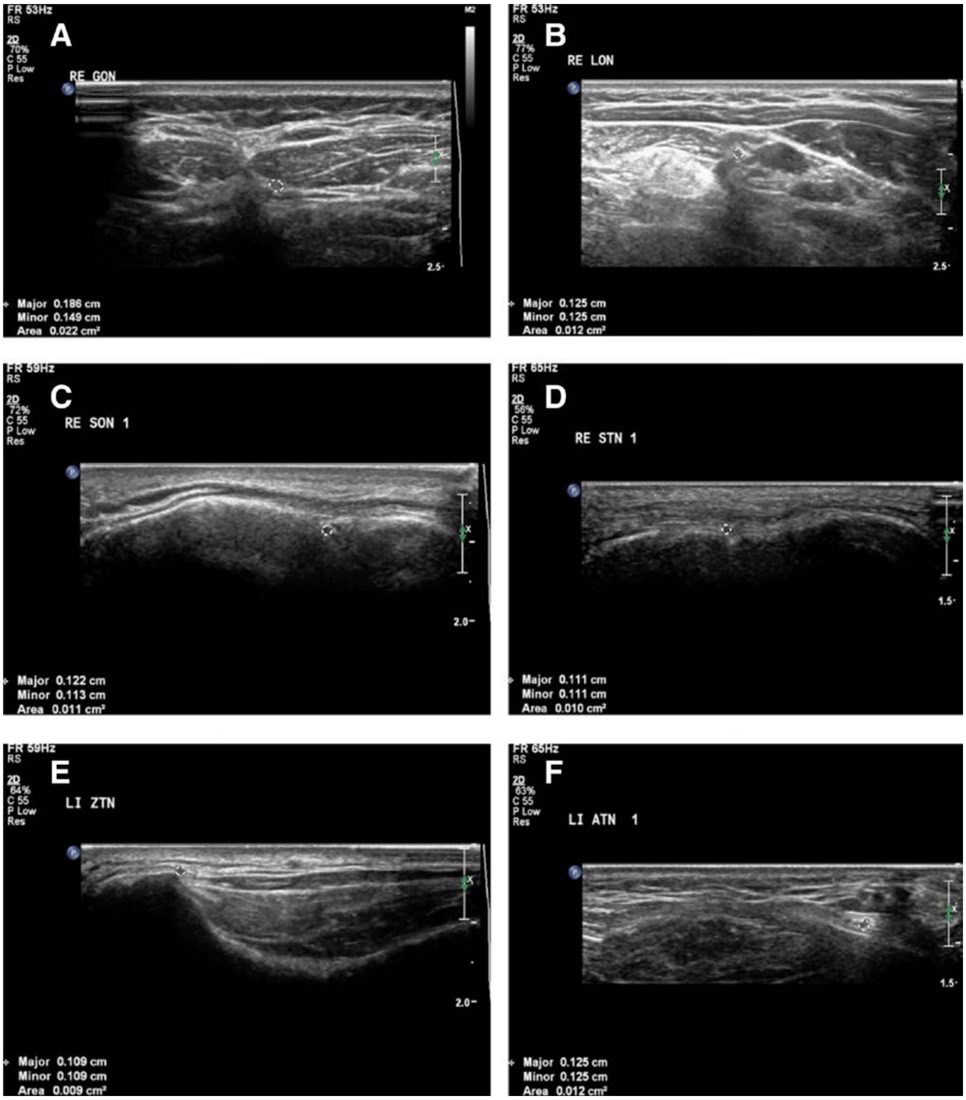

Fig. 1. The visualized nerves and measured CSA. A, Right GON; B, right LON; C, right SON; D, right STN; E, left ZTN; and F, left ATN.

the nerve could not be imaged by ultrasound at these measurement sites. The mean diameter ranged between 0.95 ± 0.23 mm (SON 2) and 1.85 ± 0.55 mm (GON 1).

Table 4. CSA Measurements Reliability

	ICC (95% CI)
Interrater	
Frontal and temporal nerves	0.75 (95% CI: 0.62–0.83)
Occipital nerves	0.76 (95% CI: 0.29–0.93)
Intrarater	
Frontal and termporal nerves	0.78 (95% CI: 0.66–0.86)
Occipital nerves	0.77 (95% CI: 0.32–0.93)

ICC, intraclass correlation coefficient.

Intraclass Correlation Coefficient

The intrarater reliability of the CSA measurements, expressed as an ICC, was good. The ICC of the frontal and temporal nerves was 0.78 (95% CI: 0.66–0.86), and the ICC of the occipital nerves was 0.77 (95% CI: 0.32–0.93). The interrater reliability of the CSA measurements was also good, with an ICC of 0.75 (95% CI: 0.62–0.83) for the frontal and temporal nerves and an ICC of 0.76 (95% CI: 0.29–0.93; Table 4).

DISCUSSION

In this study, we assessed the feasibility of ultrasound measurements of peripheral extracranial nerves in the head and neck area in asymptomatic individuals. We found that the peripheral extracranial nerves were visible with ultrasound at nine of the 11 anatomical determined measurement sites. Only the GON and the LON near the site of the occipital artery (GON 2, LON 2) could not be imaged by ultrasound due to the tortuous course of these nerves and due to hair growth. The mean CSA of the frontal and temporal nerves was similar and ranged between 0.80 ± 0.42 mm^2 and 1.4 ± 01.11 mm^2. The mean CSA of the two occipital nerves, GON 1 and LON 1, was larger and ranged between 3.40 ± 1.91 mm^2 and 2.90 ± 2.73 mm^2. We found good intrarater and interrater reliability of these measurements, proving the feasibility of ultrasound to measure the peripheral extracranial nerves in the head and neck area.

This is the first study that describes the feasibility of ultrasound measurements of peripheral extracranial nerves. We found that it was not possible to image the GON and the LON near the occipital artery (GON 2, LON 2) using ultrasound. Both measurement sites are near the occipital artery and are located below the surface of the hair-bearing scalp. The nerves were difficult to visualize by ultrasound because of the tortuous course of the nerves and due to the thickness of hair. An alternative would be to use Doppler ultrasound because both measurement sites are near the occipital artery.

The interrater and intrarater reliability in this study, expressed as an ICC, are good. The measured interrater and intrarater reliability are slightly lower compared with studies evaluating the reliability of ultrasound measurements in the hand. Mohseny et al measured the CSA of the intrinsic hand muscles using ultrasound and reported an excellent intrarater reliability (ICC range: 0.99–1.00) and a good interrater reliability (ICC range: 0.88–0.95).[28]

This study provides an overview of the reference values for the CSA of peripheral extracranial nerves. We found that the mean CSA of the frontal and temporal nerves was small with a small SD. The mean CSA of the occipital nerves was relatively larger with a wide spread. Concerning this large SD, we recommend to take a critical view of the reported CSA of the occipital nerves when using it as reference value. We suggest to compare the values to the contralateral side of the patient. However, the mean CSA of the frontal and temporal nerves is more precise and reliable and could be used as a reference value.

In the current literature, a study published by Cho et al (2010) is the only publication describing the CSA of the GON in asymptomatic subjects. The authors measured the CSA of the GON in 30 asymptomatic subjects between the ages of 22 and 35. They found that the CSA of the GON was 2 mm^2 ± 1 mm^2.[20] Compared with Cho et al, we found a larger value for the mean CSA of the GON (3.40 ± 1.91 mm^2). Although limited data have been published about the CSA values in cranial nerves, numerous publications report CSA values of the peripheral nerves in extremities and discuss factors that could potentially influence these values. Moreover, evidence shows an association between increased age and decreased CSA values of peripheral nerves in extremities.[29,30] Factors that may contribute include a reduction in the number, diameter, and density of nerve fibers and a reduction in the number of nerve fascicles in elderly patients.[31–33] However, Cho et al included subjects between the ages of 22 and 35, which is similar to our cohort. Furthermore, difference in CSA values could potentially be explained by a discrepancy of the BMI between the subjects. Unfortunately, the authors do not report the BMI of included subjects. Regarding the measurement location, the CSA of the GON was measured by Cho et al. (2010) at the same location as described in our methods. It is important to note that the authors described rotating the probe 90 degrees, resulting in a transverse position, to obtain the CSA measurements. In our study, the direction of the probe placement varied between a horizontal and a transverse position.

We found that the CSA of the frontal nerves, the supraorbital nerve, and the supratrochlear nerve was 0.93 ± 1.25 to 1.20 ± 0.43 mm^2 and 1.00 ± 0.44 to 0.80 ± 0.42 mm^2 respectively. A detailed approach to visualize both the supraorbital and supratrochlear nerves has been published by Berchtold et al. Unfortunately, reference values for the CSA of the frontal nerves were not measured. However, they describe the compression points of the STN and the SON, which could result, if compressed, in frontal headaches.[34]

Headache caused by compression of peripheral sensory nerves is often described in the literature.[35–40] Several articles describe the affected nerves as a thickening, leading to an increased CSA of the nerve at the site of compression.[18] Cho et al (2012) measured the CSA of symptomatic GONs in patients with unilateral occipital neuralgia. They describe that the CSA of the GON was increased (4.1 ± 2.6 mm^2) in symptomatic patients compared with healthy individuals (2.0 ± 0.7 mm^2). No difference was found between male and female subjects. The only parameter positively correlating with CSA was the BMI. The authors suggest that measuring an increased CSA could indicate the diagnosis of nerve compression headaches.[21]

Diagnostic nerve blocks with corticosteroids or anesthetics are currently used to confirm this diagnosis.[41,42] Also, a positive response to botulin toxin type A is used to confirm nerve compression headache.[14] However, these methods are invasive procedures, and using less-invasive methods to diagnose nerve compression headaches would be preferable.[13] This study shows that ultrasound is an easy and fast examination to conduct and that the learning curve of the examination was short. Furthermore, ultrasound is considered a safe and noninvasive method and is easily available and relatively low-priced.[43] Considering these advantages, we think that undergoing ultrasound examination would be a less-invasive method to diagnose nerve compression headaches compared with diagnostic injections that are being used today.

The results of this study need to be interpreted in light of its limitations. During the ultrasound examination, the nerves on the left side or the right side of the patient were measured. The investigation would take approximately 60 minutes if both sides were measured. Therefore, we cannot report values measured on the contralateral side of the patient. Furthermore, in the light of the results in this study and the previous mentioned advantages of ultrasound examination, we think ultrasound could be used as a safe and noninvasive diagnostic tool for nerve compression headaches, which could potentially result in the selection of patients requiring nerve decompression surgery. However, future research should include patients with nerve compression headache to see whether ultrasound is indeed a reliable and valid tool to diagnose patients with this condition.

To conclude, the results of this study show that ultrasound is a feasible method to evaluate the CSA measurements of peripheral extracranial nerves in the head and neck area. The CSA of the nerves can be measured at nine of the 11 measurement sites. The examination is easy to learn and does not take much time to conduct, and the reliability of the CSA measurements is good. Further research should be done to evaluate the use of ultrasound as a diagnostic tool for nerve compression headache. This may result in a less-invasive method to confirm this diagnosis compared with the tools used today.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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