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ANALYSIS OF THE ANATOMICAL VARIATIONS OF THE SUPRAORBITAL TRANSCRANIAL PASSAGE IN SOUTHEAST SERBIAN POPULATION ON VOLUME RENDERED CT SCANS

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The aim of this study was to analyze the variability in the shape and number of supraorbital transcranial passages, supraorbital notch or foramen (SON/F) in southeast Serbian population using three-dimensional computer tomography (3D-CT) with the volume rendering and to evaluate these variations in relation to gender and side.

One hundred and fifteen CT scans of adult subjects (59 men and 56 women) without any skull trauma or malformation, aged 21 to 83 years, were analyzed in our study.

Of 230 supraorbital regions, a smooth supraorbital rim with absent SON/F was observed in 37.39%. The most common type of the supraorbital passage was single SON (53.48%). Single SOF was found in 5.22% and incomplete SOF in 0.44%. The frequency of double SON was 1.30%, double SOF 0.87% and SON with SOF on the same side was 1.30%. There was no statistically significant difference between genders and sides ($p>0.05$). Fourteen various combinations of different types were observed in our material. The most common combination was bilateral SON (33.91%) and bilateral absence of SON/F (20.87%). A very frequent combination was SON on one side and the absence of SON/F on the contralateral side (32.17%). Other combinations of types were rare.

The knowledge of the frequency of the types of supraorbital transcranial passages and their bilateral distribution may be helpful for clinicians in anticipating the exit point of the supraorbital neurovascular bundle during surgical procedures and planning of local anesthesia. *Acta Medica Medianae 2017;56(3):81-87.*

Key words: *variations; supraorbital notch; supraorbital foramen; computed tomography; volume rendering*

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Introduction

For a number of years, the studies of the bony structures have been done on cadaveric or macerated skulls. The development of radiological techniques enabled the evaluation of anatomical structures on living subjects. During the last two decades Computed Tomography (CT) techniques were developed, which allow the investigation of fine anatomical details that are difficult to evaluate using only axial reconstructions. Multidetector CT (MDCT) enables visualization of very delicate bony structures due to its ability to produce an enormous amount of volumetric data in a short time, high resolution and reliable multiplanar and three-dimensional (3D) reconstruction. Volume rendering (VR) enables visualization of CT medical data by converting 3D dataset into a relevant two-dimensional (2D) image (1-3). With increasingly better imaging capabilities of CT, the skull foramina and other cranial structures can be seen as never before in living subjects (4).

The supraorbital transcranial passage, supraorbital notch or supraorbital foramen (SON/F), is an important anatomical structure on the frontal bone which represents the exit point of the supraorbital neurovascular bundle. The supraorbital nerve, a branch of the frontal nerve, traverses SON/F and gives off terminal rami to the vertex, thus providing sensory innervations to the upper eyelid and conjunctiva, lateral portion of the forehead, and skin of the anterior scalp nearly as far back as the lambdoid suture. The supraorbital

artery, a branch of the ophthalmic artery, leaves the orbit through SON/F, dividing into superficial and deep branches to supply the skin and muscles of the upper eyelid, forehead and scalp (5, 6). Although SON/F represents an important landmark for regional surgery and local anesthesia, the lack of essential data on anatomical variations of the supraorbital region is present. Published studies reporting the position, shape, size and number of the exit point of the supraorbital neurovascular bundle have been variable and the results conflicting (7-14). Clinically, it is essential to avoid injuries to the neuro-vascular bundle, which helps in decreasing morbidity and provides satisfactory results. Injuries of this region cause bleeding and loss of sensation in the corresponding regions of the face. Furthermore, excessive dissection and retraction near the neurovascular bundles can also cause scarring, leading to neuropathies and painful neuralgias (7, 9).

Aim

Based on the data of numerous studies indicating that skeletal variability can be influenced not only by the reasons like race, genetics, geographical distribution, environmental factors and demographic background, but that there are also individual differences within a population, the aim of this study was to analyze the presence and frequency of anatomical variations of the supraorbital transcranial passage, SON/F, in living adult subjects from southeastern Serbia using VR CT scans and evaluate this variation in relation to gender and side.

Material and methods

The current study included CT scans of the head of 115 adult subjects, aged between 21 and 85 years, who did not have previous medical history of any skull bone trauma, malformation and of surgery of the supraorbital region. Data of the subjects were collected from the patients referred to the Center of Radiology, Clinical Center of Niš, Serbia, between September 2015 and March 2016 for MDCT examination of the skull bones and cranial base. CT examination of the head was performed on a CT scanner with 16 rows of detectors (GE CT/e Dual, GE Lightspeed 16; General Electric Medical Systems, USA). Slice thickness was 0.625 mm with scanning parameters 120 kVp and 210 mA, without overlapping. The heads were imaged beginning superior to the vertex of the skull and extending inferiorly to below the mandible. These 3D-CT images of the skull were obtained with a technique of lighting, removal of the overlying anatomical structures, and rotation. Observation and 3D VR were conducted on the workstation (Advantage Workstation 4.1; General Electric, Waukesha, USA). The presence of SON/F, and its shape, if present, were recorded. The accessory SON/F were also analyzed.

The obtained results were statistically analyzed using the SPSS 15.0 statistical software package. The statistical analysis included calculation of the basic parameters of descriptive statistics. Statistical significance for each of the observed groups was tested with χ^2 test. The Mantel-Haenszel's test was used for analyzing sets of two-by-two tables if the sample size was of a higher frequency and Fisher`s exact test was used for small samples with a frequency of less than five. P values less than 0.05 were considered to be statistically significant.

Results

CT scans of the adult subjects included into the study were obtained from 59 men (51.30%) and 56 women (48.70%). The mean age of the subjects was 63.57±14.09 years (male, 66.59 ±10.61; female, 60.93±16.43). Of the 230 supraorbital regions observed in the scans, a smooth supraorbital rim with absent SON/F was observed in 37.39% of the samples. Other types of the supraorbital transcranial passage were noted in 62.61% of the scans. In the total studied population, the most common presentation of the su-

Table 1. Types of the supraorbital passage between gender and side

Supraorbital transcranial passage	Male (*n* = 59)				Female (*n* = 56)				Total (*n* = 115)			
	Right		Left		Right		Left		Right		Left	
	n	%	*n*	%	*n*	%	*N*	%	*n*	%	*n*	%
Absent SON/F	22 a***	19.13	20 a***	17.39	25 a***	21.74	19 a***	16.52	47 a***	40.87	39 a***	33.91
Single SON	30 a***	26.08	34 a***b*	29.56	28 a***	24.35	31 a***b*	26.96	58 a***	50.43	65 ab***	56.52
Double SON	2	1.74	-	0.0	-	0.0	1	0.87	2	1.74	1	0.87
Single SOF	4	3.48	4	3.48	1	0.87	3	2.61	5	4.35	7	6.09
Incomplete SOF	-	0.0	-	0.0	1	0.87	-	0.0	1	0.87	-	0.0
Double SOF	-	0.0	-	0.0	1	0.87	1	0.87	1	0.87	1	0.87
SON with SOF	1	0.87	1	0.87	-	0.0	1	0.87	1	0.87	2	1.74

a – vs. Double SON, SOF, Incomplete SOF, Double SOF, SON with SOF
b – vs. Absent SON/F
* – p<0.05, *** – p<0.001

Table 2. Bilateral frequency of supraorbital transcranial passage types

Right supraorbital region	Left supraorbital region	Male		Female		Total	
		n	%	*n*	%	*n*	%
Single SON	Single SON	22	19.13	17	14.78	39	33.91
Absent SON/F	Absent SON/F	12	10.43	12	10.43	24	20.87
Absent SON/F	Single SON	10	8.70	13	11.30	23	20.0
Single SON	Absent SON/F	7	6.09	7	6.09	14	12.17
Single SOF	Single SOF	3	2.61	-	0.0	3	2.61
Single SON	Single SOF	1	0.87	2	1.74	3	2.61
Double SON	Single SON	2	1.74	-	0.0	2	1.74
Single SOF	Absent SON/F	1	0.87	-	0.0	1	0.87
Single SON	Double SON	-	0.0	1	0.87	1	0.87
Single SON	Double SOF	-	0.0	1	0.87	1	0.87
Double SOF	Single SOF	-	0.0	1	0.87	1	0.87
Single SOF	SON with SOF	-	0.0	1	0.87	1	0.87
SON with SOF	SON with SOF	1	0.87	-	0.0	1	0.87
Incomplete SOF	Single SON	-	0.0	1	0.87	1	0.87
Total		59	51.31	56	48.69	115	100

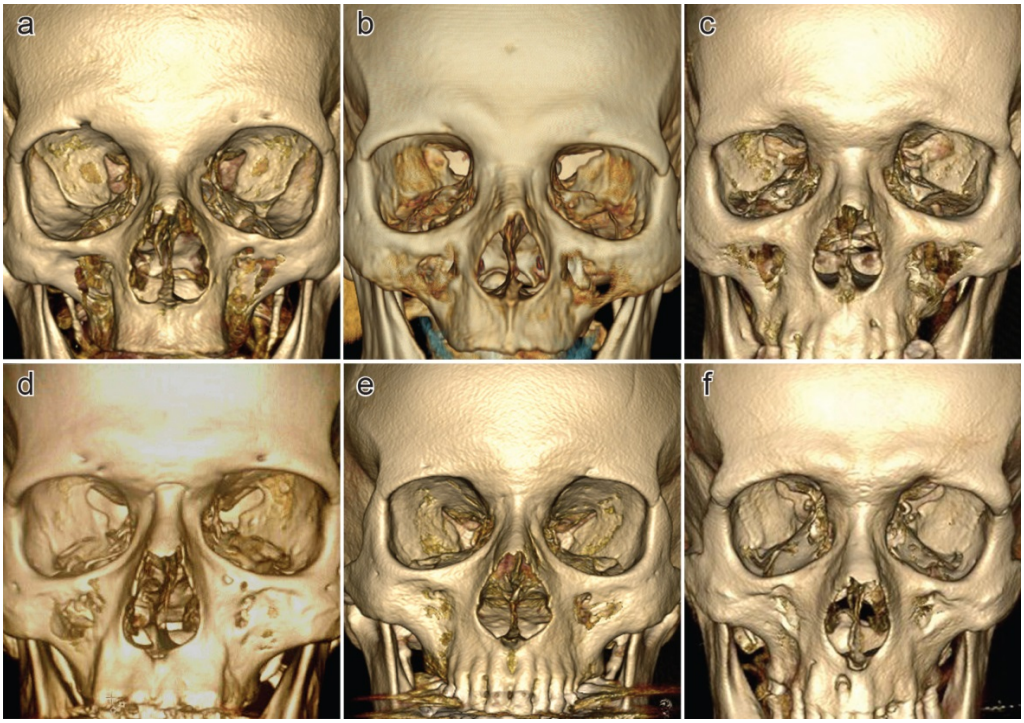

Figure 1. Various combinations of the types of supraorbital transcranial passage: a) single SON on right side and double SOF on left side; b) bilateral single SOF; c) bilateral single SON; d) double SOF on right side and single SOF on left side; e) single SOF on right side and SON with SOF on left side; f) absent SON/F on right side and single SON on left side.

other types for both genders and both sides ($p < 0.001$). Moreover, the χ^2 test showed a statistically significant difference between absent SON/F and other types for both genders and both sides ($p<0.001$). For the comparison of frequency of SON with absent SON/F in both genders and both sides, the χ^2 test showed a statistically significant difference only for the left side for both genders ($p < 0.05$). In the total sample, there was also a statistically significant difference between the two most common types only on the left side ($p < 0.001$). There was no statistically significant difference in the frequency of supraorbital passage types between males and females ($p > 0.05$), as well as between the right and left side ($p > 0.05$).

The bilateral frequency of different types of the supraorbital transcranial passage in the entire studied material is summarized in Table 2 and Figure 1. Fourteen various combinations of different types were noticed in 115 scans of adult

skulls in the studied population. The most common combination was bilateral single SON (33.91 %) and bilateral absence of SON/F (20.87%). Another very common combination was single SON on one side and the absence of SON/F on the contralateral side (32.17%). With regard to the frequency of this combination, 20.0% of the total sample had absent SON/F and single SON and 12.17% had single SON and absent SON/F on the right and left side, respectively. Bilateral single SOF occurred in 2.61% of the skulls. The remaining skulls (10.43%) presented other rare combinations of different types of the analyzed structure. There was no statistically significant difference between males and females ($p > 0.05$).

Discussion

Modern medicine requires more precise knowledge of the morphological variability of humans in order to improve diagnostic and therapeutic procedures. Rapid development of CT imaging and continuous development of the software programs have resulted in some new CT applications. One of these applications, VR, represents a key technique for the visualization of 3D data sets. 3D-CT with VR has become an area of great interest in clinical and fundamental scientific research for the qualitative and quantitative analysis of usual and unusual anatomic structures as well as dismorphological, malformed structures. MDCT and 3D VR have several different clinical applications, such as the evaluation of craniofacial anomalies, fractures and other pathological processes, planning of surgical interventions and evaluation of their outcomes, as well as presurgical planning of dental implants (15-17). It can also be used to define unique individual anatomical variations and in anthropometric studies (18).

Various anatomical studies have been conducted with the aim to describe anatomical variations of SON/F and to examine the exit points of the supraorbital nerve and vessels from the orbit (7-14, 19-23). There are two different approaches to the study of SON/F. The first one involves experimental procedures carried out on dry skulls and cadaveric skulls. The second one involves evaluation of the skull structures by MDCT. Regardless of the approach, the results have shown that the frequency of occurrence of SON and SOF varies in different populations. The findings of previous studies that used dry skulls and cadaveric skulls showed a higher incidence of SON compated to SOF, ranging from 47.50% to 92.5% (13). The frequency of SOF ranged from 8% to 51% depending upon the studied population (20). The exit point of the supraorbital neurovascular bundle has been described in the study of Malet et al. (21). This study was done on 20 fresh cadavers of the European population, showing bilateral SON in 65% of the skulls, bilateral SOF in 20%, and SON and ipsilateral SOF in 10% of the skulls. In the study on 507 adult European macerated skulls, Beer an al. (11) found bilateral SON in 70% of the samples. Of 108 skulls, Webster at al. (10) reported a distribution of 49.07% for bilateral SON, 25.93% for bilateral SOF and 25% for SON and ipsilateral SOF. The study of Cutright et al. (7) conducted on 40 cadaveric heads of white persons and 40 cadaveric heads of black persons showed the highest frequency of SON (92.5%). Cheng at al. (22), in a study of the Chinese population, observed bilateral SON in 40.2%, bilateral SOF in 24.8%, and SON on one side and SOF on the other side in 24.8% of the skulls. In the study on 124 Koreans, Chung et al. (19) reported 69.9% cases of SON and 28.9% cases of SOF. A recent study conducted on the North-West Indian population has revealed a much balanced frequency of SON and SOF, which was 54.4% of SON and 45.6% of SOF (9). The results of the study of adult Asian skulls showed that the frequencies of SON and SOF were equal on the left side, whereas the incidence of SON appeared to be slightly higher than SOF on the right. SOF/N was absent in 5.5% on the right side and 10% on the left (8). As far as we know, there is only one similar study conducted on living subjects. Turhan-Haktanir et al. (23) examined the variations of SON/F on 399 living subjects of the Turkish population using MDCT and evaluated the obtained results according to gender and side. Their results showed that the most common presentation of the supraorbital passage was single SON (69.4% on the right and 68.2% on the left), followed by a single foramen (12.4% on the right and 14.5% on the left). An absence of SON/F was reported in 11.5% on the right and 12.5% on the left side. Tomaszewska et al. (14) proposed that the type and frequency of the supraorbital structures in modern human population may depend on the climatic conditions in which the population lived. Analyzing 1978 orbits from the skulls in anthropological collections from three climatic regions, these authors discovered that the frequency of SON was highest in the samples from warm climates and the highest frequency of SOF was in the skulls from cold climatic conditions. In the samples from temperate climates, a smooth supraorbital rim was most common.

In the present study, we found a higher frequency of SON compared to SOF. In the southeast Serbian population, 53.48% of the supraorbital passages were in fact single SON. The frequency of unilateral SON in the skulls was the highest. Of all the skulls, 33.91% had bilateral SON, 39.12% had SON on one side and some other types on the contralateral side. The frequency of single SOF was lower in our study than in the previous one (23) and it was found in 5.22% of passages. This type of supraorbital passage was present in 2.61% of the skulls bilaterally and in 5.22% unilaterally. A smooth supraorbital margin with an absence of SON/F was found in 37.39% of supraorbital regions. The absence was found in 20.87% of the skulls bilaterally, 30.43% on one side, and some other types on the other side. We compared the results of our CT study with the results of the previous studies and concluded that our findings are generally similar to the study of Tomaszewska et

al. (14). The results of these authors showed that the frequency of SON was 54.5% in the samples from warm climates that came from Syria, Italy and Greece. The lowest frequency of bilateral SOF (6.2%) was in the same samples. In addition to the main SON/F, an extra supraorbital exit in the form of either a notch of a foramen was present in 3.48% of the supraorbital regions in the studied population. The frequency of double SON was 1.30%, double SOF 0.87% and SON with SOF on the same side was present in 1.30%. More than one SON/F have been associated with the branching of blood vessels and nerves during development (24). In the study of Tomaszewska et al. (14), the frequency of multiple SON/F was lower (0.4%) than in other studies. Saylam et al. (12) found multiple types of supraorbital passages in 1.8% and Cheng et al. (22) in 5.7%. The discrepancy between our results and those of the previous study is difficult to explain. These variations might be caused by population differences, which confirmed previous reports.

Evaluation of the SON/F localization enables determination of the position of supraorbital neurovascular bundles with the aim of increasing the proportion of successful interventions and avoiding sequels. The knowledge of the anatomical characteristics of supraorbital structures is crucial for identifying the danger zone in trauma treatment, in surgery as well as in anesthesiology when a regional nerve block is planned (13, 24-27). Open and endoscopic forehead and brow lift techniques have become a standard procedure in esthetic surgery, even though there is a risk of a potential injury of the neurovascular bundle if the exit point and the branching pattern of the supraorbital nerve and vessels are unknown. Traditionally, a forehead flap is designed in the orbitofrontal region based on the dual blood supply provided by the right and left supraorbital arteries. Injuries to the supraorbital neurovascular structures can lead to temporary or permanent loss of sensation in the region innervated by the nerve and partial flap necrosis (28-30). Excessive dissection and retraction close to such neurovascular bundles can cause scarring, whereas compression of the nerve by scar tissue or a connective tissue band, intraneural local anesthetics or nerve retraction during surgery may cause supraorbital neuralgia. Diagnostic and therapeutic nerve blocks are used in hemifacial neuralgia and have been systematically performed in various types of headaches (31-34). SON can be identified by the palpation of the supraorbital margin. However, such palpation is not sufficient in locating the supraorbital neurovascular bundle in all cases. The supraorbital neurovascular bundle might exit through SOF well above the supraorbital rim or below the smooth supraorbital margin. The presence of SOF suggests that the supraorbital neurovascular bundle is relatively fixed in position and therefore at a greater risk to be stretched during surgical dissection. A complete absence of SON/F may deprive the supraorbital neurovascular bundle of the protection given by these and make them more vulnerable to injuries at sharp supraorbital margins (14). The presence of additional exits may be responsible for incomplete analgesia following an injection at the classical anatomical site (9). When SON/F is not palpable, the position of the supraorbital neurovascular bundle can be determined according to other anatomical landmarks. The data about the frequency of supraorbital transcranial passage types and their bilateral distribution may be helpful to the clinicians in anticipating the exit point of the supraorbital neurovascular bundle during routine surgical procedures and planning of local anesthesia.

Conclusion

The present study provides the information about morphology of the exit point of the supraorbital neurovascular bundle in the southeastern Serbian population. The supraorbital passage shows variations in shape and number. SON was observed more often than SOF, though there are numerous variations of the types of this anatomical landmark. The knowledge of these anatomical features might be of great significance in all clinical procedures involving an access to the supraorbital neurovascular bundle or avoiding its injury. 3D-CT with VR enables excellent visualization of all bone structures of the skull. The information are directly relevant to clinical practice and can also assist anthropologists and forensic scientists in the localization and characterization of supraorbital structures.

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ANALIZA ANATOMSKIH VARIJACIJA SUPRAORBITALNOG TRANSKRANIJALNOG PROLAZA U POPULACIJI JUGOISTOČNE SRBIJE NA VOLUMENSKI PRIKAZANIM CT SKENOVIMA

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Cilj rada bio je da se analizira varijabilnost oblika i broja supraorbitalnog transkranijalnog prolaza, supraorbitalnog useka ili otvora (SOU/O) u populaciji jugoistočne Srbije primenom trodimenzionalne kompjuterizovane tomografije sa volumenskim prikazom i proceni njihova učestalost u odnosu na pol i strane.

Analizirani su CT snimci sto petnaest odraslih osoba (59 muškaraca i 56 žena), starosti od 21 do 83 godine, za koje u medicinskoj dokumentaciji nisu postojali podaci o traumi ili malformaciji kostiju lobanje.

Od 230 supraorbitalnih regija, ravna supraorbitalna ivica sa odsutnim SOU/O bila je uočena u 37,39%. Najčešći tip supraorbitalnog prolaza bio je SOU (53,48%). SOO je bio zapažen u 5,22%, dok je inkompletni SOO bio prisutan u 0.44%. Učestalost duplog SOU bila je 1,30%, duplog SOO 0,87%, dok je SOU sa SOO na istoj strani bio prisutan kod 1,30%. Nije postojala statistički značajna razlika između polova i strana (p>0,05). Na našem materijalu uočeno je četrnaest drugačijih kombinacija različitih tipova supraorbitalnog prolaza. Najčešće kombinacije bile su obostrani SOU (33,91%) i obostrano odsustvo SOU/O (20,87%). Veoma česta kombinacija je bila SOU na jednoj strani i odsustvo SOU/O na suprotnoj strani. Ostale kombinacije tipova bile su retke.

Poznavanje učestalosti tipova supraorbitalnog transkranijalnog prolaza i njihove obostrane distribucije može biti korisno za kliničare u anticipiranju izlazne tačke supraorbitalne neurovaskularne peteljke tokom hirurških postupaka i planiranju lokalne anestezije. *Acta Medica Medianae 2017;56(3):81-87.*

Ključne reči: *varijacije, supraorbitalni usek, supraorbitalni otvor, kompjuterizovana tomografija, volumenski prikaz*