Adıyaman Üniversitesi Sağlık Bilimleri Dergisi, 2023;9(2):49-58
doi:10.30569.adiyamansaglik.1307038

E-ISSN: 2458-9176

ADIYAMAN ÜNİVERSİTESİ SAĞLIK BİLİMLERİ DERGİSİ
JOURNAL OF HEALTH SCIENCES OF ADIYAMAN UNIVERSITY

Research Article/Özgün Araştırma

Morphometric and clinical importance of the trigeminal nerve and branches in fetal cadavers

Fetal kadavralarda nervus trigeminus ve dallarının morfometrik ve klinik önemi

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Atıf gösterme/Cite this article as: Küçükdemir M, Akın Saygın D, Aydın Kabakçı AD, Büyükmumcu M. Morphometric and clinical importance of the trigeminal nerve and branches in fetal cadavers. *ADYÜ Sağlık Bilimleri Derg*. 2023;9(2):49-58. doi:10.30569.adiyamansaglik.1307038

Abstract

Aim: The trigeminal nerve is the fifth cranial nerve responsible for motor, sensory and autonomic stimulation of the head and neck. The aim of this study was to examine the relationship of the trigeminal nerve and its branches in fetal cadavers.

Materials and Methods: This study was performed on 20 fetal cadavers. The height and width of the trigeminal pore were measured; the trigeminal pore type was determined. The length, width and thickness measurements of the trigeminal nerve, its branches were performed.

Results: The most common trigeminal pore type was cleft type in both male and female fetal cadavers. It was determined that the length on the left side was longer than on the right side.

Conclusion: We believe that the obtained data can provide valuable guidance planning further interventions in that region for current data on the anatomy of the region and for fetuses in the womb.

Keywords: Fetal cadaver; Trigeminal ganglion; Meckel's cave; Trigeminal nerve; Trigeminal pore.

Öz

Amaç: Nervus trigeminus, baş ve boyunun motor, duysal ve otonomik uyarımından sorumlu beşinci kraniyal sinirdir. Çalışmamızda, fetal kadavralarda nervus trigeminus ve dallarının çevre yapılarla olan ilişkisinin incelenmesi amaçlanmıştır.

Gereç ve Yöntem: Bu çalışma 20 fetal kadavra üzerinde gerçekleştirilmiştir. Dura mater'in oluşturduğu trigeminal açıklığın yüksekliği ve genişliği ölçüldü. Ayrıca trigeminal açıklığın tipleri belirlendi. Nervus trigeminus'un uzunluk, genişlik ve kalınlık ölçümleri, dallarının uzunlukları ölçüldü.

Bulgular: Çalışmamızda hem erkek hem de kız fetal kadavralarda en sık gözlenen trigheminal açıklık tipi yarık tip olarak tespit edildi. Sol tarafa ait nervus trigeminus uzunluğunun sağ taraftakine göre daha uzun olduğu belirlendi.

Sonuç: Çalışmadan elde edilen ölçümlerin, bölgenin anatomisine ilişkin güncel veriler sağlayacağı ve anne karnındaki fetüsler için o bölgeye yapılacak ileri müdahalelerin planlanmasında yol gösterici olabileceği kanaatindeyiz.

Anahtar Kelimeler: Fetal kadavra; Ganglion trigeminale; Cavum Meckel; Nervus trigeminus; Trigeminal açıklık.

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Geliş Tarihi/Received:30.05.2023 **Kabul Tarihi/Accepted:**02.08.2023 **Yayım Tarihi/Published online:**30.08.2023

Introduction

The trigeminal nerve is the fifth (V.) cranial nerve and is the largest and thickest of the cranial nerves.[1-4] The nerve extends to the trigeminal ganglion and divides into three branches. These branches are the ophthalmic, maxillary and mandibular nerve. As it is divided into three branches from the trigeminal ganglion, it is named "trigeminus" meaning "triplets".[3,5,6,7,8]

The ophthalmic nerve is the smallest of the three divisions of the trigeminal nerve. This particular nerve extends from the superior orbital fissure (SOF) and distributes somatic general sensory fibers to the skin, nose, conjunctiva and mucous membranes in front of the head. It enters the SOF and is divided into three branches including the lacrymal nerve, frontal nerve, nasociliary nerve. SOF is a small, but topographically important area.[2,9]

The maxillary nerve is located in the middle of the three branches of the trigeminal nerve. It passes through the foramen rotundum (FR) and provides sensory innervation to various structures in and around the midface region including the lower eyelid and upper lip.[1,3,4,10]Additionally, the branches of the, trigeminal nerve, specifically the ophthalmic and maxillary nerves are two important formations that course on the lateral wall of the cavernous sinus.[11]

The mandibular nerve is the largest of the three divisions of the trigeminal nerve. It passes through the foramen ovale (FO) and provides innervation to the region from the sub-ear to the lower part of the face, the lower part of the oral cavity, and the muscles in that area.[1,3]Mandibular nerve is the only branch that supplies both motor and sensory fibers.[12]

The three branches of the trigeminal nerve originated from the trigeminal ganglion are well-developed. The trigeminal ganglion is surrounded by the dorsal side of the eye, the pituitary gland and internal carotid artery. The sensorial root enters the wall of the mesencephalon at the pontin flexure. The motor root is located within the trigeminal nerve and then within the trigeminal ganglion. At this stage, all structures of central nervous system are surrounded by a vascular network called the “pia mater”. Many small vessels may be recognized rostral and dorsally around the ganglion and its branches. The meninges are not differentiated.[13,14]

Cranial nerves may include sensory, motor, or both types of fibers. The somata of motor neuroblasts are derived from the neuroepithelium, while those of sensory neuroblasts are derived from the neural crest with contributions from ectodermal placodes.[15] The trigeminal nerve has four different nuclei. The trigeminal motor nucleus contains motor fibers while the mesencephalic nucleus, main nucleus, and spinal trigeminal nucleus contain sensory fibers.[12] The motor and sensory nuclei of trigeminal nerve exist in the brainstem.[16]

The fibers in the trigeminal nerve exhibit a structure similar to that of peripheral nerves in general. The number of nerve fibers of the trigeminal nerve differs between branches, and the number of motor fibers is less than the number of sensitive fibers.[16] The appearance of the trigeminal ganglion is similar to the peripheral ganglion structure. There are many neuron bodies (ganglion cells) surrounded by satellite cells.[10,18] The trigeminal ganglion contains between 20,000 to 35,000 neurons, while the number of non-neuronal cells is a hundred times higher.[17] The ophthalmic nerve, the maxillary nerve, and the mandibular nerve contain approximately 26,000, 50,000 and 78,000 nerve fibers, respectively.[19]

It is a very important anatomical region. Conditions that affect the trigeminal nerve can lead to a decrease in the quality of life for individuals and cause psychological and social problems. Adult studies related to this subject cover a wide range in the literature.[20] However, the number of studies on the trigeminal nerve in fetal cadavers is limited. Histological and embryological studies have been conducted in general, and anatomical studies have mostly been carried out on adult cadavers. Although it is a nerve that needs to be examined in detail along with the innervation area and complex structure, it holds great significance for clinicians.

The aim of the present study was to determine the morphometric measurements of

the trigeminal ganglion, trigeminal nerve and its branches, to identify the association between the trigeminal nerve and surrounding structures, and to obtain updated data that could guide the clinicians in surgical procedures-related tothe relevant region.

Materials and Methods

Type of the study

This study was performed on 40 fetal cadavers, including 11 (55%) males and 9 (45%) females (40 as right and left) during the second trimester (13-25 weeks).[21] Dysmorphic features of fetal cadavers that were collected were examined in the study. Fetal cadavers with skull pathology or anomalies were excluded from the study, while cadavers without morphological malformation were included.

Data collection tools

A digital caliper (Stainless hardened, Chinese) was used for measurements. Measurements were repeated three times. A surgical microscope (Karl Kaps SOM 62, Germany) was also used in addition to the digital caliper during morphometric measurements of the trigeminal ganglion and trigeminal nerve. All measurements were recorded in millimeters (mm).

The measurements of the trigeminal pore

1. **GT-iw:** The inlet width of the trigeminal nerve into the trigeminal pore
2. **TP-h:** The height of the trigeminal pore
3. **TP-w:** The width of the trigeminal pore

The trigeminal pore was classified into four types according to Öğüt et al.[22] (Figure 1).

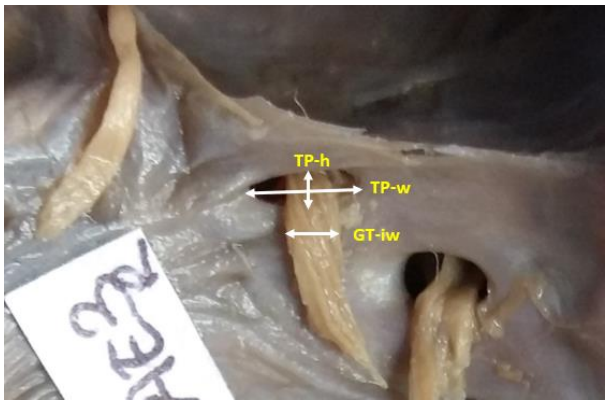

Figure 1. Measurements of trigeminal pore. TP-h: the height of the trigeminal pore, TP-w: the width of the trigeminal pore, GT-iw: the inlet width of the trigeminal pore of the trigeminal nerve.

- **Type 1:** Elliptical
- **Type 2:** Cleft
- **Type 3:** Round
- **Type 4:** Irregular performed

The measurements of between the trigeminal nerve, trigeminal ganglion, branches of trigeminal nerve and the adjacent structures (Figure 2 and 3).

1. **TP-ow:** The outlet width of the trigeminal nerve from the trigeminal pore
2. **MC-l:** The length of the trigeminal nerve in the Meckel's cave
3. **TG-l:** The length of the trigeminal ganglion
4. **TG-w**: The width of the trigeminal ganglion
5. **V_1-l:** The length of the ophthalmic nerve belonging to the branches of the trigeminal nerve up to the SOF
6. **V_1-it:** The inlet thickness of the ophthalmic nerve
7. **V_1-ot:** The outlet thickness of the ophthalmic nerve
8. **V_2-l:** The length of the maxillary nerve up to the foramen rotundum
9. **V_2-it:** The inlet thickness of the maxillary nerve
10. **V_2-ot:** The outlet thickness of the maxillary nerve
11. **V_3-l:** The length of the mandibular nerve up to the foramen ovale
12. **V_3-it:** The inlet thickness of the mandibular nerve
13. **V_3-ot:** The outlet thickness of the mandibular nerve
14. **FR-SOF:** The distance between the foramen rotundum and superior orbital fissure
15. **FO-FR:** The distance between the foramen ovale and foramen rotundum
16. **ZA-MC:** The distance between the zygomatic arch and the Meckel's cave as surrounding tissues of the trigeminal nerve
17. **PB-MC:** The distance between the lateral end of the petros ridge and the Meckel's cave
18. **AE-MC:** The distance between the arcuate eminence and Meckel's cave

19. **IAM-TP:** The distance between the internal acoustic meatus and the trigeminal pore
20. **JF-TP:** The distance between the jugular foramen and the trigeminal pore
21. **AN-TP:** The distance between the abducens nerve and the trigeminal pore
22. **OC-TP:** The distance between the optic canal and trigeminal pore
23. **RTP-LTP:** The distance between the right trigeminal pore and the left trigeminal pore

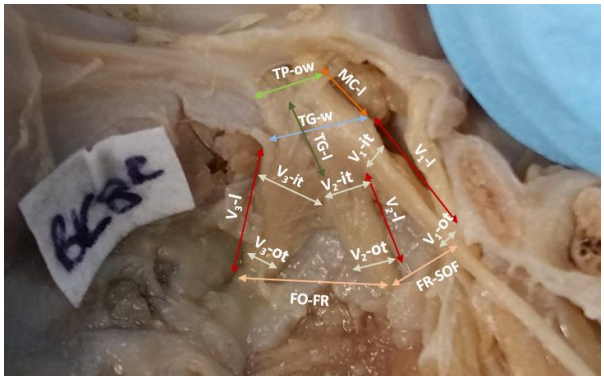

Figure 2. Measurement parameters of trigeminal nerve and ganglion trigeminale.**TP-ow:** the outlet width of the trigeminal pore of the trigeminal nerve TÇG, **TG-w:** the width of the trigeminal ganglion, **TG-l:** the length of the trigeminal ganglion, **MC-l:** the length of the trigeminal nerve in the MC,**V_1-l:** the length of the ophthalmic nerve, **V_1-it:** the inlet thickness of the ophthalmic nerve, **V_1-ot:** the outlet thickness of the ophthalmic nerve, **V_2-l:** the length of the maxillary nerve, **V_2-it:** the inlet thickness of the maxillary nerve, **V_2-ot:** the outlet thickness of the maxillary nerve, **V_3-l:** the length of the mandibular nerve, **V_3-it:** the inlet thickness of the mandibular nerve, **V_3-ot:** the outlet thickness of the mandibular nerve, **FO-FR:** the distance between foramen ovale and foramen rotundum, **FR-SOF:** the distance between foramen rotundum and superior orbital fissure.

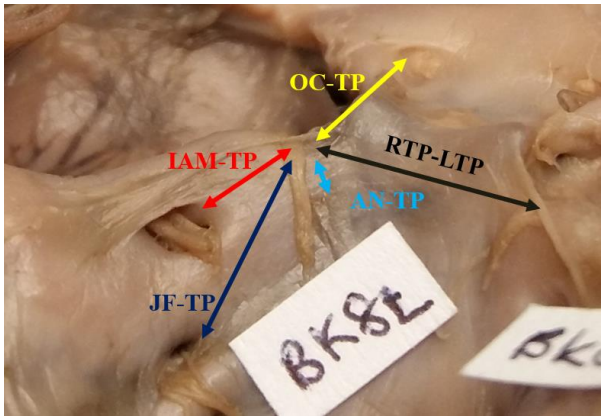

Figure 3. Other parameters related to trigeminal nerve. **OC-TP:** the distance between the optic canal and the trigeminal pore, **IAM-TP:** the distance between the internal acoustic meatus and the trigeminal pore, **AN-TP:** the distance between the abducens nerve and the trigeminal pore, **JF-TP:** the distance between the jugular foramen and the trigeminal pore, **RTP-LTP:** the distance between the right trigeminal pore and left trigeminal pore.

Data analysis

SPSS 21.0 (IBM, USA) was used for the statistical analysis of the data obtained in this study. Normality analysis was performed through the Shapiro-Wilk Test (due to the number of individuals was less than 50), Skewness, Kurtosis, Histogram, and Detrended tests. As our parameters indicated a normal distribution in the normality analysis, parametric tests were employed for statistical analysis.

The descriptive (mean, standart deviation(SD), minimum(min.)-maximum(max.) values) and quantitative statistical methods (Independent T-test and Paired Sample T-test) were used. Results were interpreted statistically in 95% confidence interval and differences were accepted as significant if $p<0.005$.

Ethic committee approval

The ethics committee approval required for the study was obtained by the Committee of Ethics for Non-Pharmaceutical and Medical Device Researches of Medical Faculty within Necmettin Erbakan University with the decision number of 2020/2887 on 06.11.2020. This study conformed to the Helsinki Declaration.

Results

Four types of trigeminal pore were identified, including elliptical, cleft, round, and irregular (Figure 4). Among the trigeminal pore types on the right side of fetal cadavers, the cleft type was the most common, accounting for 45.5% in males and 44.4% in females, based on the data obtained. The cleft type (36.4%) and elliptical type (36.4%) were the most common types on the left side in males, and elliptical type (44.4%) in females. The irregular type of the trigeminal pore was not detected on the left side (Table 1). The difference between both right ($p=0.970$) and left ($p=0.641$) trigeminal pore types was not statistically significant ($p>0.05$).

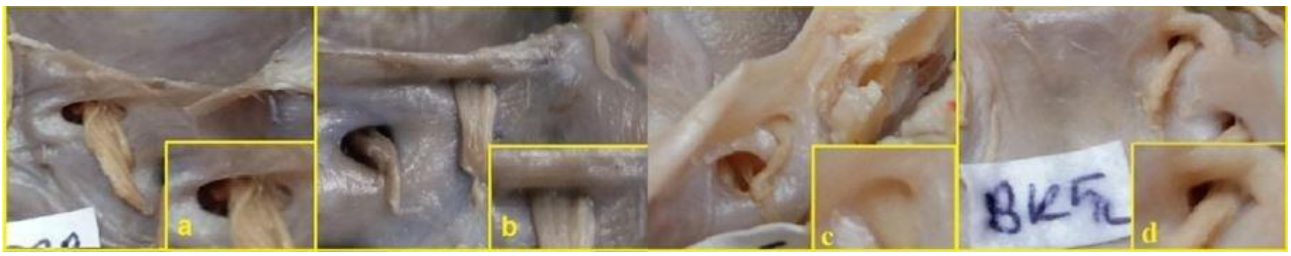

Figure 4. Appearance of trigeminal pore types. (a: elliptical, b: cleft, c: round and d: irregular)

Table 1. Comparison of trigeminal pore (TP) type by gender and both sides

		Males		Females			
		n	**%**	**n**	**%**	***p***	**χ2**
Right	**Round**	2	18.2	1	11.1		
	Cleft	5	45.5	4	44.4		
	Elliptical	3	27.3	3	33.3	0.970	0.247
	Irregular	1	9.1	1	11.1		
Left	**Round**	3	27.3	2	22.2		
	Cleft	4	36.4	2	22.2		
	Elliptical	4	36.4	4	44.4	0.641	0.641
	Irregular	0	0	1	11.1		

(n: fetal cadaver number, %: The percentage, χ2:Chi-square value)

While the length of the MC-l was measured as 2.49±0.83 mm on the right side, with min. and max. values of 1.42 mm and 3.96 mm, respectively, it was found to be 1.98±0.69 mm on the left side, with min. and max. values of 0.64 and 3.03 mm. According to these data, a statistically significant association was found between the right and left sides of the MC-l (*p*= 0.011). The FR-SOF was found 2.9±0.6 mm on the right and 3.24±0.74 mm on the left in males; the min. and max. values were 2.10 mm and 3.66 mm on the right and 1.81 mm and 4.41 mm on the left in females. A statistically significant difference was found between the right and left sides of the FR-SOF (*p*=0.017). In males, the V_1-l, V_2-l, and V_3-l were 4.35±0.87 mm, 3.84±1.12 mm, and 3.18±0.9 mm, respectively on the right; however, it was found 4.23±1.43 mm, 3.44±0.88mm and 2.88±0.88 mm, respectively on the left. In females; the V_1-l, V_2-l, and V_3-l were 5.32±0.8 mm, 4.94±1.28 mm, and 3.92± 0.94, respectively on the right; however, it was found 5.58±2.2 mm, 5.05±1.85mm, and 4.46±1.16 mm, respectively on the left (Table 2). According to these findings, the length of the trigeminal nerve was found more in females than males. The difference between the right side of V_1-l and the left side of V_2-l, V_3-l was found statistically significant according to the data obtained (*p*=0.019, *p*=0.036, *p*=0.004). The ZA-MC parameter was found 13.13±3.45 mm on the right and 12.3±3.21 mm on the left in females (*p*=0.020). This parameter was found 9.31±3.07 mm on the right and 11.09±3.27 mm on the left in males (*p*=0.009). Total p value of the ZA-MC parameter was 0.020 on the right side, which was statistically significant (Table 2).

Discussion

In the literature, there is a limited number of studies on the morphological and morphometric properties of the trigeminal nerve in fetal cadavers. More emphasis has been placed on histological and embryological studies of the trigeminal nerve in fetal cadavers. In addition to histological and embryological studies, morphological and morphometric studies on the trigeminal pore, the trigeminal ganglion, the branches of the trigeminal nerve, and adjacent structures are also available.

Choudhri et al.[23] stated in their clinical study that the detection of the Meckel's cave and agenesis of the trigeminal nerve is very crucialfor the early diagnosis and clinical diagnosis of Gomez-Lopez-Hernandez syndrome. Choudhri et al.[23] detected in their study that the trigeminal nerve and foramen rotundum were not presentin a case with Gomez-Lopez-Hernandez syndrome. Chauvin et al.[24] reported agenesis of the trigeminal

nerve accompanying to Gomez-Lopez-Hernandez syndrome (cerebello-trigeminal dermal dysplasia) in a 19-week-old fetus in their study. This current study includes detailed morphometric measurements of the trigeminal nerve, its branches, and peripheral structures in fetal cadavers during the second trimester are included in this study; however, no agenesis of the trigeminal nerve and Meckel's cave was detected.

Table 2. Comparison of right and left range data of parameters by gender.

	Males					**Females**						
	Right		**Left**			**Right**		**Left**			**Total p**	
P	**Mean±SD**	**Min-Max**	**Mean±SD**	**Min-Max**	***p***	**Mean±SD**	**Min-Max**	**Mean±SD**	**Min-Max**	***p***	**Right**	**Left**
TP-ow	1.43±0.4	0.71-2.05	1.39±0.28	1.01.1989	0.803	1.38±0.44	0.88-2.32	1.4±0.34	0.95-2.12	0.883	0.809	0.954
TP-w	1.89±0.53	1.29-2.63	1.9±0.4	1.15-2.46	0.950	1.98±0.42	1.44-2.68	1.87±0.48	1.18-2.66	0.538	0.666	0.883
TP-h	0.85±0.24	0.43-1.16	1.06±0.51	0.49-2.13	0.218	0.86±0.2	0.54-1.17	0.93±0.31	0.36-1.34	0.184	0.874	0.495
GT-iw	2.06±0.42	1.24-2.44	2.27±0.47	1.39-3.29	0.271	2.3±0.44	1.71-3.07	2.38±0.67	1.65-3.72	0.750	0.241	0.663
MC-l	2.29±0.77	1.42-3.83	1.92±0.77	0.64-2.90	0.184	2.73±0.89	1.62-3.96	2.05±0.63	1.10-3.03	**0.026***	0.262	0.681
TG-l	3.17±0.66	1.90-4.09	3.02±0.73	2.14-4.44	0.462	3.72±0.98	2.22-5.11	3.65±0.87	2.15-5.01	0.795	0.169	0.105
TG-w	4.86±0.94	3.04-6.09	4.64±0.92	3.22-6.69	0.425	5.27±0.78	4.14-6.06	5.06±1.65	3.01-8.18	0.682	0.299	0.508
V_1-l	4.35±0.87	2.68-5.76	4.23±1.43	2.40-7.19	0.764	5.32±0.8	4.53-6.49	5.58±2.2	2.84-8.95	0.709	**0.019***	0.135
V_1-it	1.35±0.42	0.90-2.28	1.23±0.41	0.70-1.95	0.216	1.6±0.48	0.88-2.18	1.54±0.47	0.90-2.27	0.716	0.243	0.137
V_1-ot	1.12±0.43	0.69-2.09	1.04±0.37	0.57-1.72	0.517	1.69±0.83	0.75-3.05	1.57±0.67	0.74-2.73	0.654	0.088	0.056
V_2-l	3.84±1.12	2.23-6.37	3.44±0.88	1.90-5.0	0.274	4.94±1.28	3.31-7.84	5.05±1.85	2.67-7.70	0.837	0.060	**0.036***
V_2-it	1.77±0.4	1.15-2.64	1.51±0.45	0.70-2.0	0.258	1.99±0.39	1.57-2.62	2.09±0.53	1.25-2.87	0.364	0.228	**0.022***
V_2-ot	1.38±0.48	0.51-1.96	1.51±0.36	0.95-2.10	0.435	1.76±0.39	1.40-2.50	1.88±0.7	1.05-3.01	0.456	0.066	0.178
V_3-l	3.18±0.9	1.68-4.55	2.88±0.88	1.42-4.34	0.275	3.92±0.94	3.05-5.85	4.46±1.16	2.41-5.81	0.128	0.092	**0.004***
V_3-it	1.84±0.64	0.90-2.94	1.87±0.42	1.13-2.59	0.840	2.37±0.59	1.64-3.33	2.32±0.59	1.55-3.19	0.779	0.069	0.072
V_3-ot	1.64±0.67	0.90-2.85	1.53±0.32	0.90-1.98	0.538	2.29±0.61	1.60-3.17	2.13±0.71	1.26-3.51	0.378	**0.039***	0.400
FR-SOF	2.9±0.6	2.10-3.66	3.24±0.74	1.81-4.41	**0.017***	3.65±1.33	1.61-5.30	4.06±1.12	2.44-5.56	0.353	0.148	0.080
FO-FR	2.83±0.97	1.08-4.51	3.5±1.42	1.50-6.96	0.083	4.09±1.16	1.84-5.70	3.9±0.88	2.75-5.76	0.580	**0.019***	0.457
ZA-MC	9.31±3.07	2.79-12.65	11.09±3.27	5.12-16.65	**0.009***	13.13±3.45	9.49-18.89	12.3±3.21	8.84-18.12	0.250	**0.020***	0.417
PB-MC	9.97±1.75	6.68-11.97	9.86±1.99	6.74-11.82	0.837	11.33±2.67	7.97-16.64	11.78±3.29	7.94-17.84	0.679	0.209	0.148
AE-MC	4.1±1.54	2.11-7.03	5.15±1.57	3.04-7.15	**0.010***	4.63±1.21	2.20-6.26	4.47±0.99	3.06-5.60	0.703	0.407	0.251
JF-TP	7.43±0.96	6.68-10.06	7.2±0.89	5.52-8.65	0.325	7.42±1.13	5.54-8.68	8.11±1.13	6.68-10.47	0.055	0.988	0.700
AN-TP	2.8±0.88	1.91-4.46	2.84±0.79	2.19-4.49	0.654	2.38±0.45	1.73-2.91	2.51±0.52	1.74-3.32	0.172	0.188	0.280
OC-TP	8.15±1.93	5.50-12.22	8.61±2.64	5.59-12.95	0.500	9.08±1.19	7.07-10.21	8.96±1.38	7.36-11.15	0.525	0.203	0.705
IAM-TP	3.16±0.58	2.37-4.43	3.34±1.19	2.20-6.64	0.641	3.36±0.68	2.25-4.28	3.85±0.95	2.60-5.62	0.173	0.512	0.306
RTP-LTP	9.43±2.28		4.87-12.11			10.08±1.62		8.38-12.23			0.462	

(***P:*** parameters, **SD:** Standart Deviation, **p:** Significance value, ***TP-ow:*** the outlet width of the trigeminal pore of the trigeminal nerve TÇG, ***TP-w:*** the width of the trigeminal pore, ***TP-h:*** the height of the trigeminal pore, ***GT-iw:*** the inlet width of the trigeminal pore of the trigeminal nerve ***TGG, MC-l:*** the length of the trigeminal nerve in the MC, ***TG-l:*** the length of the trigeminal ganglion, ***TG-w:*** the width of the trigeminal ganglion, ***V_1-l:*** the length of the ophthalmic nerve,***V_1-it:*** the inlet thickness of the ophthalmic nerve,***V_1-ot:*** the outlet thickness of the ophthalmic nerve, ***V_2-l:*** The length of the maxillary nerve ,***V_2-it:*** the inlet thickness of the maxillary nerve,***V_2-ot:*** the outlet thickness of the maxillary nerve, ***V_3-l:*** the length of the mandibular nerve, ***V_3-it:*** the inlet thickness of the mandibular nerve,***V_3-ot:*** the outlet thickness of the mandibular nerve, ***FR-SOF:*** the distance between foramen rotundum and fissura orbitalis superior, ***FO-FR:*** the distance between foramen ovale and foramen rotundum, ***ZA-MC:*** the distance between the zygomatic arch and the Meckel's cave, PB-MC: the distance between the lateral edge of the petrous bone and ***MC, AE-MC:*** the distance between the arcuate eminence and ***MC, JF-TP:*** the distance between the jugular foramen and the trigeminal pore, ***AN-TP:*** the distance between the abducens nerve and the trigeminal pore, ***OC-TP:*** the distance between the optic canal and the trigeminal pore, ***IAM-TP:*** the distance between the internal acoustic meatus and the trigeminal pore, ***TP-TP:*** the distance between the right trigeminal pore and left trigeminal pore)

Tubbs et al.[25] reviewed the association between the superior petrous sinus and the trigeminal pore using 25 adult cadavers. In their study, they identified three types of trigeminal pore sections based on the superior petrous sinus. Type 1 represented the superior petrous sinus extending over the trigeminal pore, type 2 represented the superior petrous sinus extending below the trigeminal pore, and type 3 represented a superior petrous sinus surrounding the trigeminal pore. The findings of this study revealed that all trigeminal pores examined were classified as type 1, indicating the superior petrous sinus overlying the trigeminal pore.

Numerous morphological and morphometric studies have been conducted on the trigeminal pore. Öğüt et al.[22] performed a study to address the lack of detailed information about the trigeminal pore, and clarify its association with critical surgical marks on the skull base. In this study, which included 9 female and 10 male adult cadavers, four types of trigeminal pore were identified: elliptical (42.1% left, 36.8% right), oval (52.6% left, 36.8% right), cleft-like (0% left, 5.3% right) and unidentified (5.3% left, 21.1% right). The mean TP-w was 8.02 mm (female) and 9.2 mm (male) on the right side, and 8.26 mm (female) and 8.81 mm (male) on the left side. The mean TP-h is 1.99 mm (female) and 2.65 mm (male) on the right side, 2.42 mm (female) and 2.94 mm (male) on the left side. Ciołkowski et al.[26] performed a study on 20 adult cadavers in order to identify the trigeminal pore, trigeminal nerve, and surrounding structures. They found the mean TP-w to be 7.3±1.0 mm and the mean TP-h 2.2±0.4 mm, and identified the trigeminal pore as an ellipsoid canal. Nestor et al.[27] examined 53 trigeminal pores and reported a mean TP-w of 6.6 ± 2.4 mm on the left side and 7.7 ± 1.6 mm on the right side. They also suggested that that the right trigeminal pore maybe more suitable for surgical approaches. Janjua et al.[28] conducted a study on 10 cadavers (20 sides as right and left) and reported a mean TP-w of 8.6 mm, and a mean TP-h of 4.3 mm. Both Ciołkowski et al.[26] and Nestor et al.[25] found no statistically significant difference between the genders for morphometric measurements of the trigeminal pore. Ajayi et al.[5] reported TP-w as 7.9 mm (ranging from 5.3–10.2 mm) and TP-h as 4.1 mm (ranging from 1.9–5.8 mm) in their study conducted on 30 sagittal cadavers analyzed sagitally. Four types of trigeminal pore were identified, including round (15% right, 25% left), cleft (45% right, 30% left), elliptical (30% right, 40% left) and irregular (10% right, 5% left) TP-w was measured as 1.98±0.42 mm (female) and 1.89±0.53 mm (male) on the right side, and 1.87±0.48 mm (female) and 1.9±0.4 mm (male) on the left side. TP-h was measured as 0.86±0.2 mm (female) and 0.85±0.24 mm (male) on the right side, and 0.93±0.31 mm (female) and 1.06±0.51 mm (male) on the left side. Similar to previous studies, this study also found no statistically significant difference between genders and sides of TP-w and TP-h (p>0.05).

Öğüt et al.[22] conducted a study on peripheral structures of the trigeminal pore, and reported the following measurements: IAM-TP was measured as 6.60 mm (female) and 6.13 mm (male) on the right side, and 6.21 mm (female) and 6.77 mm (male) on the left side. GT-iw was measured as 4.55 mm (female) and 5.38 mm (male) on the right side, 5.06 mm (female) and 5.22 mm (male) on the left side. AN-TP was measured as 6.76 mm (female) on the right side and 6.97 mm (male), and 6.45 mm (female) and 7.04 mm (male) on the left side. Ciołkowski et al.[26] reported the following measurements: IAM-TP was 6.6±1.7 mm, JF-TP was 16.2±1.8 mm and AN-TP was 5.9±1.2 mm. Arslan et al.[29] stated in their study conducted on 15 cadavers that the IAM-TP was 7.11±0.85 mm on the right side, and 7.28±0.80 mm on the left side, with a mean value of 7.19±0.81 mm. In this study, the following measurements were obtained: IAM-TP was measured as 0.68 mm (female) and ± 0.58 mm (male) on the right side, and 0.95 mm (female) and 3.34± 1.19 mm (male) on the left side; however, GT-iw was found 1.38± 0.44 mm (female) and 1.43± 0.4 mm (male) on the right side, 1.4± 0.34 mm (female) and 1.39± 0.28 mm (male) on the left; AN-TP was found 2.38± 0.45 mm (female) on the right and 2.8± 0.88 mm (male), 2.51± 0.52 mm (female) and 2.84± 0.79 mm (male) on the left side. Similar to the study conducted by Öğüt et al.[22], higher

AN-TP values were observed in females compared to males on both the right and left sides. However, this trend was only observed on the right side for IAM-TP values.

Some researchers compared the morphometric measurement parameters of the trigeminal nerve and branches, the trigeminal ganglion and surrounding structures only as the right and left sides[20,29,30], some assessed the measurement parameters through mean values[5,28,31,32]. It was detected that comprehensive parameters were used in previous studies conducted by Arslan et al.[29] on the trigeminal nerve, its branches, and surrounding structures, Öğüt et al.[22] on typing, length and width of the trigeminal pore and the distance to peripheral structures. The measurements and typing of the trigeminal pore, the trigeminal nerve and its branches, the measurements of the trigeminal ganglion, and the distance between the trigeminal nerve and peripheral structures were evaluated, and such measurement parameters determined for the present study were compared for genders and locations.

Janjua et al.[28] conducted a study on the trigeminal ganglion and reported that its width was 15.6 mm. They described the trigeminal ganglion as having a lunar shape and a 45 degrees angle. Soeira et al.[31] reported TG-w as 17±2.4 mm and TG-l as 5.4±1.2 mm in their study involving 10 adult cadavers. Soeira et al.[31] mentioned that different studies may yield varying results, and the largest width measurement can be obtained by measuring the entrance site of the maxillary sinus as the starting point. Henderson[32] detected TG-w between 15 mm and 25 mm, and TG-l between 5mm and 5 mm in the study conducted on the anatomy and injections of the trigeminal ganglion about surgical procedures for trigeminal neuralgia. Arslan et al.[29] measured the right and left sides individually, and reported that the IAM-TG-w was 10.3±1.42 mm on the right side, and 10.6±1.33 mm on the left side with a mean value of 10.5±1.36 mm.

Dimitropoulou et al.[30] examined the morphometric difference between the trigeminal nerve and the trigeminal ganglion on 40 fetal cadavers in second and third trimesters. TG-w was found between 5.5 and 6.8 mm in the fourth and fifth months with a difference of 0 and 0.3 mm between the right and left sides; however, the TG-w was detected between 7.5 mm and 8.5 mm at the end of the fifth and sixth months with a difference of 0mm and 0.5 mm between the right and left sides. In this study; TG-w was found as 5.27±0.78 mm (female) and 4.86±0.94 mm (male) on the right side, and 5.06±1.65 mm (female) and 4.64±0.92 mm (male) on the left side. It was detected that the values measured in this study were consistent with the measurements found by Dimitropoulou et al.[30]

Arslan et al.[29] performed measurements on the trigeminal ganglion, the trigeminal nerve and branches as well as the peripheral structures in their study conducted on 15 adult cadavers. The ZA-MC parameter was found 27.6±1. 84 mm on the right and 25.4±1.76 mm on the left. The AE-MC parameter was measured as 16.1±1.30 mm on the right and 17.1±1.33 mm on the left in females. The IAM-TP parameter was found 7.11±0.85 mm on the right and 7.28±0. 80 mm on the left.

Significant differences were reported between the right and left sides with this measurement (p<0.05). In this study, ZA-MC was found 11.03±3.71 mm on the right and 11.63±3.21 mm on the left, AE-MC was found 4.34±1.39 mm on the right and 4.84±1 on the left; IAM-TP was detected 3.25±0.62 mm on the right side and 3.57±1.09 mm on the left side. The distance between the zygomatic bone and the Meckel's cave was statistically significant on the right side (p=0.020). No statistically significant difference was detected between other measurement parameters. The difference between the study conducted by Arslan et al.[29] and the present study is caused by a predictable difference between adult cadavers and fetal cadavers.

Sabancı et al.[33] carried out a study to obtain detailed information about the microsurgical anatomy of the Meckel's cave. They reported the following measurements: TP-h was 4.2 mm, TP-w was 7.6 mm, IAM-TP was 12 mm, AN-TP was 6.5 mm, and AE-MC was 20 mm. The study emphasized the significance of accurately defining the complex anatomy of the Meckel's cave, which is surrounded by

important structures, by providing detailed and precise information.

Among previous studies on morphometric measurements of the trigeminal nerve branches, Soeira et al.[31] detected V_1 as 27.4 mm, V_2 as 12.5 mm and V_3 6 mm on 10 adult cadavers. Janjua et al.[28] recorded V_1, V_2 and V_3 as 19.4 mm, 12.3 mm and 7.4 mm, respectively. Ajayi et al.[5] reported V_1, V_2 and V_3 as 28 mm, 12.7 mm and 3.6 mm, respectively. The values provided by the previously mentioned researchers are given as an average value without specifying the right and left sides**.** In addition to the studies performed in our study, the inlet and outlet thicknesses were also measured along with the length of the trigeminal nerve and branches. It was detected that the inlet and outlet thicknesses were not measured individually in the previous studies. The V_1 was detected 4.79±0.96 mm on the right, and 4.84±1.9 mm on the left, V_2 was found 4.33±1.29 mm on the rightand 4.17±1.59 mm on the left, V_3 was measured 3.51±0.97 mm on the right and 3.59±1.27 mm on the right. The difference between the right ophthalmic nerve and the left maxillary nerve among branches.

Study limitation

The most important limitation of the study was the low number of fetal cadavers in the collection. We believe that the data obtained from studies with more fetal cadavers will provide more beneficial results in terms of regional interventions.

Conclusion

We believe that the updated data about the length, width, thickness, and distance association of the trigeminal nerve, the trigeminal ganglion, the trigeminal pore, and adjacent structures would be useful to clarify the regional anatomy.

We hope that the data obtained in this study would enlighten other studies related to the trigeminal nerve and better results may be obtained by evaluating it as a whole in detailed studies on other structures in the region.

Ethic Committee Approval

This study was approved by the Committee of Ethics for Non-Pharmaceutical and Medical Device Researches of Medical Faculty within Necmettin Erbakan University with the decision number of 2020/2887 on 06.11.2020. This study conformed to the Helsinki Declaration.

Author Contributions

All authors have participated in the conception and design, or analysis and interpretation of the data; drafting the article or revising it critically for important intellectual content; and approval of the final version.

Acknowledgement

We thank the fetal cadaver donors for contribution to study.

Conflict of Interest

There is no conflict of interest to declare.

Financial Disclosure

The research was not sponsored by an outside organization. We (all of the authors) have agreed to allow full access to the primary data and to allow the journal to review the data if requested. There is no conflict of interest between the authors and this manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.

Peer-review

Externally peer-reviewed.

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