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Original Article

Morphometric Assessment of the Carotid Foramen for Lateral Surgical Approach

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OBJECTIVES: This study aimed to compare the right and left sides of the carotid foramen (CF) to determine its precise location according to certain anatomical landmarks.

MATERIALS and METHODS: Twenty human dry skulls were included in the study. A digital caliper and a digital image analysis software were used to obtain direct anatomical numerical values. Then, the same parameters on dry skulls were assessed with computed tomography (CT).

RESULTS: CF was found to be round shaped (62.5%), oval shaped (32.5%), and tear-drop shaped (5%). In all cases, the position of CF was seen as just postero-laterally of the foramen lacerum. According to the jugular foramen, CF was seen to be anterior in 85% and antero-medial in 15% of the cases. Regarding the morphometric values of the surface area, the length and width of CF were observed to be 37.86±11.24 mm^2, 8.02±1.09 mm, and 6.86±0.90 mm at direct anatomical measurements and 39.69±10.07 mm^2, 7.89±1.14 mm, and 6.41±0.90 mm at CT, respectively. The angles between the supramastoid crest-CF-zygoma root and the supramastoid crest-CF-mastoid process were determined as 37.11±6.87º and 42.22±6.40º at direct anatomical measurements and 36.59±4.94º and 43.71±4.55º at CT, respectively.

CONCLUSION: A significant difference in sides was not observed in relation with the numerical data of CF obtained from CT or from direct anatomical measurements of dry skulls. Moreover, a significant difference was not found between radiological and direct anatomical measurements. Therefore, precise radiological assessment of this region by an experienced neuroradiologist may be assumed as a fundamental need for successful surgeries of the skull base, in addition to thorough anatomical knowledge of neurootologists and neurosurgeons.

KEYWORDS: Carotid canal, carotid foramen, lateral approach, skull base

INTRODUCTION

The carotid foramen (CF, also referred to as the external opening or aperture of the carotid canal), which transmits the internal carotid artery along with the sympathetic nerve plexus and a venous network around the artery, is placed in the inferior surface of the petrous part of the temporal bone within the complex structure of the skull base [1-5]. Taking into account the craniocervical junction where there are entries or exits of some vital structures, such as the internal carotid artery, internal jugular vein, glossopharyngeal nerve, vagus nerve, and accessory nerve, the location and dimensions of CF are important for radiologists and neurosurgeons to prevent any iatrogenic injury during the applications such as the infratemporal fossa and lateral supracondylar approaches [1-3, 6-10]. Since CF, the most important and the most easily monitored structure with angiographic applications such as magnetic resonance tomography angiography and digital substraction angiography, is used as a landmark, [2] its location, shape, and angulation within the skull base is increasingly becoming an important area of interest [2-5, 11, 12].

This study was presented orally on the 1st International Mediterranean Anatomy Congress on September 6, 2018.

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The knowledge of the CF dimensions is essential, first, for the repair of carotid canal fractures, agenesis, or stenosis; second, for the treatment of diseases such as aneurysms or schwannoma of structures passing through the carotid canal; and lastly, for a morphometric distance evaluation with adjacent foraminal regions such as jugular foramen and foramen spinosum.[2, 3, 10, 13-16] From this point of view, the main purpose of this study was to assess the morphometric measurements between CF and certain landmarks on the lower surface of the skull base and to evaluate its shape and dimensions.

MATERIALS AND METHODS

Twenty dry skulls irrespective of gender, age, and race were included in the study. The study was conducted in accordance with the ethical principles stated in the Declaration of Helsinki. The following parameters were measured (Figures 1 and 2):

- The distance between the CF and the foramen magnum/foramen spinosum/foramen ovale/jugular foramen/stylomastoid foramen/styloid process/the apex of the mastoid process/zygoma root/supramastoid crest/occipital condyle/midsagittal plane/external acoustic porous (the nearest distance)
- The surface area of CF

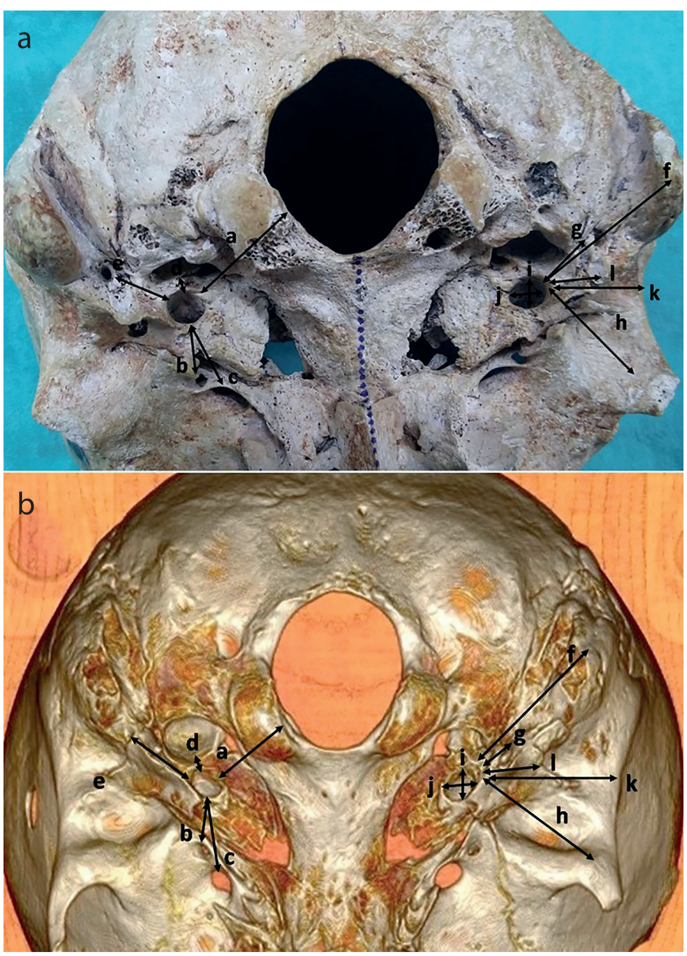

Figure 1. a, b. The photographs show the parameters in (a) dry skulls and (b) CT: the distance between CF and a) foramen magnum, b) foramen spinosum, c) foramen ovale, d) jugular foramen, e) stylomastoid foramen, f) the apex of the mastoid process, g) styloid process, h) zygoma root, i) CF length, j) CF width, k) supramastoid crest, and l) external acoustic porous.

- The length (antero-posterior diameter, at the farthest level) and width (medio-lateral diameter, at the widest level)
- Midline distance (the line between supramastoid crest and middle line of skull passing from middle of CF)
- The angle between the supramastoid crest-CF-zygoma root
- The angle between the supramastoid crest-CF-mastoid process

A digital caliper (0.01 mm precision) was used to measure the length and width of parameters. The measurements were done by the same researchers (GK). The angle between certain landmarks and the surface area of CF was captured under the same position with a millimeter scale and then calculated by a digital image analysis program known as Digimizer Software (MedCalc, Ostend, Belgium). Using a 0.5-mm-thin sections skull algorithm, the raw data were reformatted in the axial, coronal, and sagittal plane, and then three-dimensional images were created at the workstation (Vitrae 2). With a 64-slice scanner (Aquillion 64, Toshiba Medical Systems Tokyo, Japan), a computed tomography (CT) assessment was performed by a radiologist (EK).

Statistical Analysis

The normality of the value sets was checked using the Shapiro–Wilk test. The Levene test was used to test variance homogeneity. The comparisons regarding the side (the paired-samples t-test) were performed. The paired-samples t-test was used to compare the length and width of CF, the angles between the supramastoid crest-CF-zygoma root and supramastoid crest-CF-mastoid process, and the distance

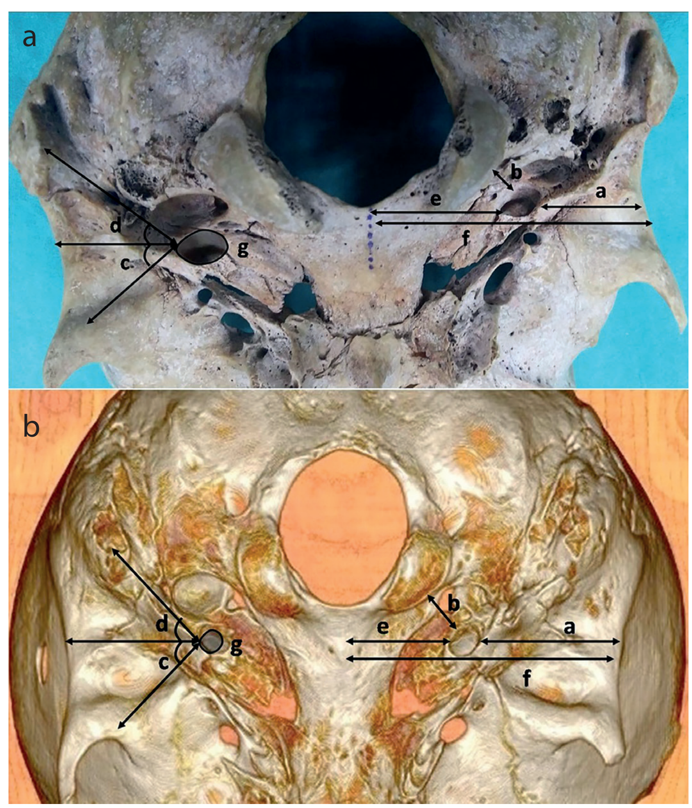

Figure 2. a, b. The photographs show the parameters in (a) dry skulls and (b) CT: a) the distance between CF and supramastoid crest, b) the distance between CF and occipital condyle, c) the angle between the supramastoid crest-CF-zygoma root, d) the angle between the supramastoid crest -CF-mastoid process, e) the distance between CF and midsagittal plane of the skull, f) the midline distance (at passing from middle of CF), and g) CF surface area.

between CF and the supramastoid crest and CF and the midsagittal plane of the skull. In addition, the same test was used to compare the numerical data obtained by direct anatomical measurements and CT. The threshold for statistical significance was set as $p<0.05$.

RESULTS

Considering the right and left sides, the mean±standard deviations related to all parameters obtained from CT or direct anatomical measurements were presented in Tables 1 and 2. The outcomes of our study are as follows:

- Statistical significance was not found between the right and left sides for all parameters and also between two different measurement techniques (CT vs. direct anatomical measurement) ($p>0.05$).
- The length of CF was greater than the width ($p<0.001$).
- The supramastoid crest -CF-mastoid process angle was greater than the supramastoid crest-CF-zygoma root angle ($p=0.011$).
- No statistical difference was found between the CF–supramastoid crest and CF–midline of the skull ($p=0.699$).
- CF was observed to be round shaped, oval shaped, and teardrop shaped in 62.5% (25 sides), 32.5% (13 sides), and 5% (2 sides) of the specimens, respectively (Figure 3).
- The position of CF in relation to the foramen lacerum was found as postero-lateral in all sides.
- The position of CF according to the jugular foramen was anterior in 85% (34 sides) and antero-medial in 15% (6 sides) of the cases (Figure 4).

DISCUSSION

The data obtained from the current study contribute to the limited knowledge in the literature on morphologic anatomy of CF, including the location, dimension, shape, and angulation.

The abnormalities of CF may be associated with aneurysms, clival tumors, carotid sympathetic plexus schwannomas, Crouzon syndrome, carotid canal fractures caused by head traumas, and moyamoya disease [2, 13, 14, 15, 17-19]. In addition, agenesis or stenosis of CF, which especially affects the internal carotid artery, is a vital anomaly that can increase the complications during surgeries in the craniocervical junction [2, 7, 8, 11, 14]. On the other hand, Watanabe et al. [18] studied 60 Japanese adult subjects and 11 Japanese adult patients with moyamoya disease, and they reported that the mean transverse diameter of the carotid canal (5.27±0.62 mm) among the normal subjects was wider than the diameter (3.31±0.44 mm) among anomaly cases. Moreover, Kreiborg and Björk [17] found that CF was

Table 1. Distance Between CF and Certain Anatomic Landmarks

	Skulls			CT			ALL		
Parameters	**Right (N=20)**	**Left (N=20)**	**p**	**Right (N=20)**	**Left (N=20)**	**p**	**Skulls (N=40)**	**CT (N=40)**	**p**
Foramen magnum (mm)	17.64±3.07	17.92±2.79	0.762	18.69±2.68	18.58±3.01	0.869	17.78±2.90	18.63±2.81	0.100
Foramen spinosum (mm)	8.35±1.76	8.53±1.96	0.765	8.59±1.75	8.84±1.45	0.362	8.44±1.84	8.72±1.59	0.098
Foramen ovale (mm)	12.32±1.63	12.83±1.48	0.314	12.31±1.34	12.60±1.36	0.463	12.57±1.56	12.45±1.34	0.290
Jugular foramen (mm)	2.01±0.83	2.09±0.87	0.493	1.91±0.80	1.96±0.73	0.739	2.05±0.84	1.93±0.76	0.063
Stylomastoid foramen (mm)	12.83±1.55	12.68±1.36	0.736	12.71±1.49	12.75±1.50	0.999	12.76±1.44	12.73±1.47	0.826
Styloid process (mm)	10.34±1.75	11.62±6.93	0.429	11.05±3.47	11.66±2.76	0.642	10.98±5.03	11.35±3.11	0.552
Mastoid process (mm)	27.29±2.97	26.13±2.82	0.214	27.55±3.05	27.67±3.26	0.788	26.71±2.92	27.61±3.12	0.076
Zygoma root (mm)	30.24±1.98	30.68±1.94	0.483	30.69±2.49	31.02±2.11	0.440	30.46±1.95	30.85±2.28	0.104
Supramastoid crest (mm)	28.76±2.79	28.62±2.85	0.209	28.49±2.05	29.14±1.95	0.889	28.69±2.84	28.71±1.98	0.820
Occipital condyle (mm)	14.82±2.69	14.23±2.50	0.474	14.31±1.66	14.20±1.69	0.823	14.53±2.58	14.26±1.66	0.530
Midsagittal plane (mm)	26.08±2.03	25.83±2.25	0.713	25.15±2.11	25.96±2.11	0.975	25.95±2.12	25.55±2.13	0.230
External acoustic porous (mm)	17.94±2.67	17.69±2.28	0.749	17.57±3.09	17.74±1.76	0.530	17.82±2.45	17.65±2.52	0.724

Table 2. CF data

	Skulls			CT			ALL		
Parameters	**Right (N=20)**	**Left (N=20)**	**p**	**Right (N=20)**	**Left (N=20)**	**p**	**Skulls (N=40)**	**CT (N=40)**	**p**
SC-CF-ZR angle (°)	35.87±6.53	38.36±7.13	0.256	36.73±5.18	36.44±4.81	0.935	37.11±6.87	36.59±4.94	0.702
SC-CF-MP angle (°)	43.46±6.06	40.97±6.63	0.222	43.73±2.90	44.69±5.65	0.235	42.22±6.40	43.71±4.55	0.225
Surface area (mm2)	38.11±10.82	37.61±11.93	0.891	39.59±10.60	39.78±9.79	0.556	37.86±11.24	39.69±10.07	0.476
Length of CF (mm)	8.17±1.05	7.87±1.14	0.385	7.90±1.08	7.87±1.23	0.877	8.02±1.09	7.89±1.14	0.414
Width of CF (mm)	6.95±0.91	6.76±0.90	0.513	6.34±0.91	6.49±0.91	0.852	6.86±0.90	6.41±0.90	0.071
Midline distance (mm)	57.98±3.55	56.25±4.11	0.247	57.92±3.09	58.01±3.56	0.688	57.36±3.86	57.96±3.31	0.145

MP: mastoid process; SC: supramastoid crest; ZR: zygoma root

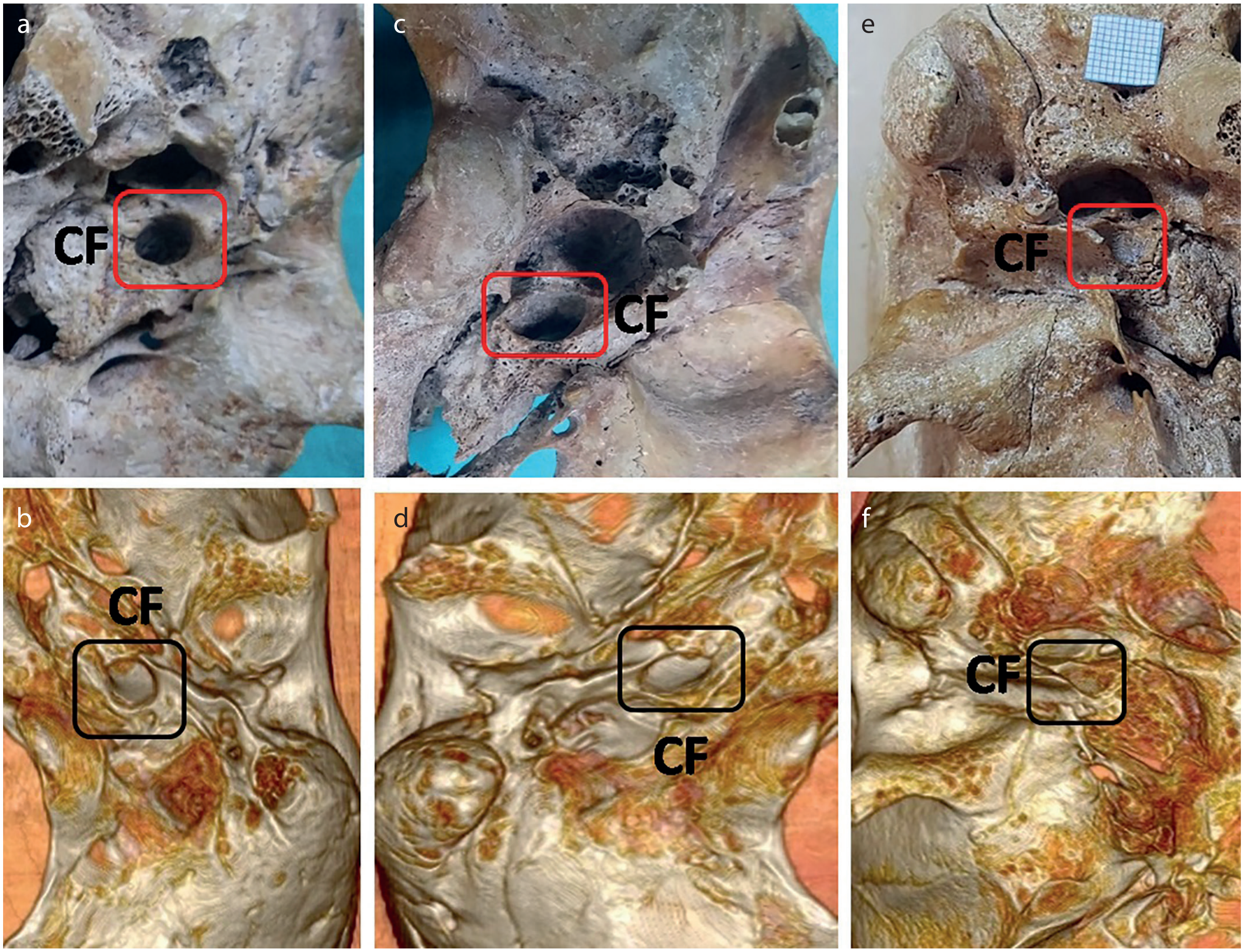

Figure 3. a-f. The photographs show the shape of CF in dry skulls and CT. a, b) round shaped, c, d) oval shaped, and e, f) tear-drop shaped.

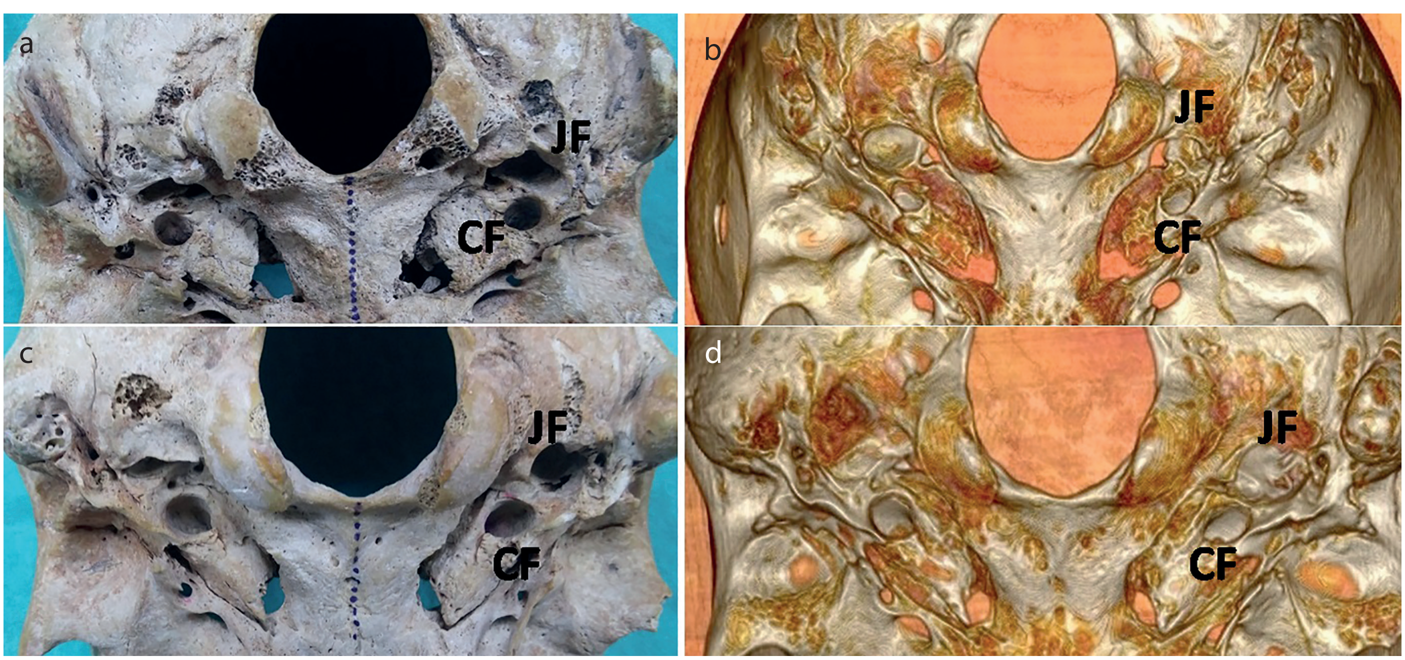

Figure 4. a-d. The photographs show the position of CF according to the jugular foramen in dry skulls and CT. a, b) anterior and c, d) antero-medial.

Table 3. The length, width and surface area of CF in the current literature

Studies	N	Length (antero-posterior) of CF (mm) Right	Length (antero-posterior) of CF (mm) Left	Width (medio-lateral) of CF (mm) Right	Width (medio-lateral) of CF (mm) Left	Surface area of CF (mm2) Right	Surface area of CF (mm2) Left
		Male Female	Male Female	Male Female	Male Female	Male Female	Male Female
Ahmed et al. [1]	100	6.79 (5-8.50)	6.28 (5-8)	5.54 (4-7.50)	5.27 (4-7)	30.02	26.89
Naidoo et al. [4]	81	5.41	7.52	-	-		
Shaikh and Kulkarni [5] (Fetus)	235	2.40±1.20	2.60±1.30	1.80±0.90	1.80±0.40	-	-
Shaikh and Kulkarni [5] (Young)		7.50±1 7±0.90	7.50±1.20 7±0.70	5.30±0.60 5.40±0.60	5.20±0.90 5.10±0.60	-	-
Shaikh and Kulkarni [5] (Adult)		7.60±1.10 7.20±1.10	7.50±0.90 7.30±1	5.30±0.80 5.30±1.20	5.50±0.80 5.30±0.80	-	-
Aoun et al. [6]	150	7.96±0.89 7±0.65	6.77±0.80 6.77±0.60	5.70±0.69 5±0.50	5.58±0.67 4.86±0.44	-	-
Berlis et al. [9]	60	7.81±1.16 (skulls), 7.91±1.13 (CT)	5.69±0.35 (skulls), 5.88±0.64 (CT)	-	-		
Sharma and Garud [11]	50	5.42 (3.20-8.14)	7.01(4.50-9.52)	-	-		
Somesh et al. [12]	82	8.13±0.99 (6-10)	8.16±1 (6.50-10.50)	6.31±0.64 (5-8)	6.19±0.80 (5-8.50)	40.61±7.79	40.03±8.10
The current study (Skulls)	20	8.17±1.05	7.87±1.14	6.95±0.91	6.76±0.90	38.11±10.82	37.61±11.93
The current study (CT)	20	7.90±1.08	7.87±1.23	6.34±0.91	6.49±0.91	39.59±10.60	39.78±9.79

CT: computed tomography; N: Number of skulls

placed much closer to the midline than normal in a dry skull with Crouzon syndrome. They also observed that the distance between CF and the foramen ovale was short bilaterally [17]. Considering these previous articles, [2, 7, 8, 16-18] a comprehensive anatomical perspective including quantitative features of CF with adjacent structures can provide more insights to radiologists, neurootologists, and neurosurgeons during the applications of surgical procedures such as infratemporal fossa approach and lateral supracondylar approach for skull base surgeries.

In the present study, CF was observed to be round shaped (62.5%), oval shaped (32.5%), and tear-drop shaped (5%), just postero-laterally of the foramen lacerum. According to the jugular foramen, CF was seen to be anterior in 85% and antero-medial in 15% of the cases. Aoun et al. [6] stated that CF was round shaped or oval shaped, just in front of the jugular foramen. Somesh et al. [12] classified the shape of CF and reported the incidences as 52.14% (85 sides), 30.67% (50 sides), and 17.17% (28 sides) for rounded, oval shaped, and almond shaped, respectively. In our study, it was determined that CF was mostly round shaped. Positionally, they expressed that CF was postero-lateral to the foramen lacerum and antero-lateral to the jugular foramen [12]. However, Naidoo et al. [4] classified the shape of CF as round, oval shaped, and tear-drop shaped, and found in 28.4%, 49.4%, and 22.2% of cases, respectively. On the other hand, in their study, the position of CF according to the jugular foramen was presented to be antero-medial in 12.3%, antero-lateral in 11.7%, and anterior in 75.9%, and according to the foramen lacerum, it was reported to be postero-lateral in 93.8%, lateral and diagonal in 3.1%, and lateral in 3.1% of cases, respectively.

Considering the current literature, a plexus of the existing reports belonging to the length, width, and surface area of CF is summarized in Table 3. In this study, the surface area, length (antero-posterior diameter) and width (medio-lateral diameter) of CF were observed to be 37.86±11.24 mm^2, 8.02±1.09 mm, and 6.86±0.90 mm at direct anatomical measurements and 39.69±10.07 mm^2, 7.89±1.14 mm, and 6.41±0.90 mm at CT, respectively. In adults, the data range is wider in the studies where the lengths (3.20-10.5 mm), widths (4-8.5 mm), and surface areas (26.89-48.13 mm^2) of CF were given [1, 4-6, 9, 11, 12]. Although our findings are available within these ranges, it is observed that the data regarding the length, width, and surface area of CF are quite various in the the literature. The reasons for this difference may be due to the use of sample groups with different characteristics such as race, region, age, side, and gender [2, 4, 6]. Naidoo et al. [4] stated that the length of CF was typically longer on the left side than on the right side. However, similarly to our study, no right/left significant statistical difference was reported by Aoun et al. [6] and Çalgüner et al. [2] Another reason may stem from methodological approaches used in the studies [1, 12]. The authors calculated the surface area of CF using the formula (π×Length×Width)/4; [1, 12] however, it was calculated by a digital image analysis program in the present study.

On the other hand, a plexus of the existing reports related to the distance from CF to certain landmarks is summarized in Table 4. The distance from the medial edge of CF to the midsagittal plane in the present study is compatible with the data from the previous studies [1, 2, 6, 11, 12, 19]. Similarly, the distance from the lateral edge of CF to the supramastoid crest in our study is compatible with the data of the

Table 4. The distance from CF to certain landmarks in the literature

				The distance from CF to				
Studies	**N**	**Sides**	**Sex**	**Midsagittal plane**	**Supramastoid crest**	**External acoustic porous**	**Mastoid process**	**Zygoma root**
Çalgüner et al. [2]	307	Right	Male	25.63±3.60	31.16±2.62	23.50±3.12	-	-
		Left	Male	25.67±2.88	31.36±2.87	24.29±3.16	-	-
		Right	Female	25.01±3.59	29.77±3.12	22.72±3.42	-	-
		Left	Female	24.92±2.45	31.13±2.74	22.90±3.45	-	-
Çiçekcibaşı et al. [3]	60	Right	Male	-	-	-	31.83±3.52	-
		Left	Male	-	-	-	31.53±3.28	-
		Right	Female	-	-	-	30.55±2.59	-
		Left	Female	-	-	-	30.41±2.58	-
Naidoo et al. [4]	81	Unknown	Unknown	-	-	-	27.94	-
Aoun et al. [6]	150	Right	Male	28.78±2.15	31.1±3.10	-	-	-
		Left	Male	28.19±1.97	30.9±3.06	-	-	-
		Right	Female	26.40±1.40	28.60±2	-	-	-
		Left	Female	25.99±1.50	28.37±1.99	-	-	-
Sharma and Garud [11]	50	Right	Unknown	25.31	-	-	-	-
		Left	Unknown	24.88	-	-	-	-
Somesh et al. [12]	82	Right	Unknown	25.42±0.25	-	-	-	30.96±0.23
		Left	Unknown	24.97±0.25	-	-	-	30.78±0.21
Zhong et al. [19]	120	Unknown	Unknown	24.50±1.26	-	-	-	-
The current study (Skulls)	20	Right	Unknown	26.08±2.03	28.76±2.79	17.94±2.67	27.29±2.97	30.24±1.98
		Left	Unknown	25.83±2.25	28.62±2.85	17.69±2.28	26.13±2.82	30.68±1.94
The current study (CT)	20	Right	Unknown	25.15±2.11	28.49±2.05	17.57±3.09	27.55±3.05	30.69±2.49
		Left	Unknown	25.96±2.11	29.14±1.95	17.74±1.76	27.67±3.26	31.02±2.11

CT: Computed tomography; N: Number of skulls

past studies [2, 6]. However, our findings related to the distance from the lateral edge of CF to the external acoustic porous is shorter than the data by Çalgüner et al. [2] The distance from CF to the apex of the mastoid process in this study is compatible with the outcome in Naidoo et al., [4] but it is shorter than the findings by Çiçekcibaşı et al. [3] Somesh et al. [12] found a similar distance concordant with our data for the distance from the lateral edge of CF to the root of the zygoma. In addition to all these data, the distance from CF to the foramen magnum, foramen spinosum, foramen ovale, stylomastoid foramen, jugular foramen, styloid process, and occipital condyle were determined to prevent any iatrogenic injury during the lateral surgical approaches. In addition, the angles between the supramastoid crest-CF-zygoma root and the supramastoid crest -CF-mastoid process were determined in terms of these surgical approaches.

CONCLUSION

All data in our study obtained from CT or direct anatomical measurements of dry skulls did not differ statistically in terms of the sides. In addition, a significant difference was not found between radiological and direct anatomical measurements.

Precise radiological assessment of this region by an experienced neuroradiologist may be assumed as a fundamental need for successful surgeries of the skull base.

Our data can be used by neurosurgeons to prevent any iatrogenic injury during the lateral surgical approaches.

Ethics Committee Approval: The study was conducted in accordance with the ethical principles stated in the "Declaration of Helsinki".

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – H.Ö., O.B., V.H., Y.V., A.D., A.H.Ö., D.Ü.T.; Design - H.Ö., O.B., Y.V., A.D., A.H.Ö., D.Ü.T.; Supervision - H.Ö., V.H., E.K., Y.V., A.D., A.H.Ö., D.Ü.T.; Resource - H.Ö., O.B., V.H., Y.V., A.D., A.H.Ö., D.Ü.T.; Data Collection and/or Processing - H.Ö., O.B., O.E., E.K., T.K., G.K., V.H.; Analysis and/or Interpretation - – H.Ö., O.B., O.E., E.K., T.K., D.Ü.T.; Literature Search - H.Ö., O.B., O.E., T.K., G.K., D.Ü.T.; Writing - H.Ö., O.B., T.K., E.K., D.Ü.T.; Critical Reviews - H.Ö., O.B., V.H., Y.V., A.D., A.H.Ö., D.Ü.T.

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REFERENCES

1. Ahmed MM, Jeelani M, Tarnum A. Anthropometry: A Comparative Study of Right and Left Sided Foramen Ovale, Jugular Foramen and Carotid Canal. Int J Sci Stud 2015; 3: 88-94.
2. Calgüner E, Turgut HB, Gözil R, Tunç E, Sevim A, Keskil S. Measurements of the carotid canal in skulls from Anatolia. Acta Anat (Basel) 1997; 158: 130-2. [CrossRef]
3. Cicekcibasi AE, Murshed KA, Ziylan T, Şeker M, Tuncer I. A morphometric evaluation of some important bony landmarks on the skull base related to sexes. Turkish J Medical Science 2004; 34: 37-42.
4. Naidoo N, Lazarus L, Ajayi NO, Satyapal KS. An anatomical investigation of the carotid canal. Folia Morphol (Warsz) 2017; 76: 289-94. [CrossRef]
5. Shaikh VG, Kulkarni PR. A study of morphology, morphometry, symmetry and development of external opening of carotid canal with comparison in male, female and foetus. Int J Anat Res 2014; 2: 797-805. [CrossRef]
6. Aoun MA, Nasr AY, Aziz AMA. Morphometric study of the carotid canal. Life Science J 2013; 10: 2559-62.
7. Aslan A, Balyan FR, Taibah A, Sanna M. Anatomic relationships between surgical landmarks in type b and type c infratemporal fossa approaches. Eur Arch Otorhinolaryngol 1998; 255: 259-64. [CrossRef]
8. Babu RP, Sekhar LN, Wright DC. Extreme lateral transcondylar approach: Technical improvements and lessons learned. J Neurosurg 1994; 81: 49-59. [CrossRef]
9. Berlis A, Putz R, Schumacher M. Direct and CT measurements of canals and foramina of the skull base. Br J Radiol 1992; 65: 653-61. [CrossRef]
10. George B, DeMantos C, Cophignon J. Lateral approach to the anterior portion of the foramen magnum. Surg Neurol 1988; 29: 484- 90. [CrossRef]
11. Sharma NA, Garud RS. Morphometric evaluation and a report on the aberrations of the foramina in the intermediate region of the human cranial base: A study of an Indian population. Eur J Anat 2011; 15: 140-9.
12. Somesh MS, Sridevi HB, Murlimanju BV, Pai SR. Morphological and morphometric study of carotid canal in Indian population. Int J Biomechanical Res 2014; 5: 455-60.
13. Goudihalli SR, Goto T, Bohoun C, Nagahama A, Tanoue Y, Morisako H, et al. Sympathetic plexus schwannoma of carotid canal: two cases with surgical technique and review of literature. World Neurosurg 2018; 118: 63-8. [CrossRef]
14. Orakdöğen M, Berkman Z, Erşahin M, Biber N, Somay H. Agenesis of the left internal carotid artery associated with anterior communicating artery aneurysm: case report. Turk Neurosurg 2007; 17: 273-6.
15. Resnick DK, Subach BR, Marion DW. The significance of carotid canal involvement in basilar cranial fracture. Neurosurgery 1997; 40: 1177-81. [CrossRef]
16. York G, Barboriak D, Petrella J, DeLong D, Provenzale JM. Association of internal carotid artery injury with carotid canal fractures in patients with head trauma. AJR Am J Roentgenol 2005; 184: 1672-8. [CrossRef]
17. Kreiborg S, Björk A. Description of a dry skull with Crouzon syndrome. Scand J Plast Reconstr Surg 1982; 16: 245-53. [CrossRef]
18. Watanabe A, Omata T, Koizumi H, Nakano S, Takeuchi N, Kinouchi H. Bony carotid canal hypoplasia in patients with moyamoya disease. J Neurosurg Pediatr 2010; 5: 591-4. [CrossRef]
19. Zhong S, Ren J, Zhang Y, Li W, Li H, Song S, et al. Anatomic Study of Craniocervical Junction and Its Surrounding Structures in EndoscopicTransoral-Transpharyngeal Approach. J Craniofac Surg 2018; 29: 1973-7. [CrossRef]