

Presence of Complete or Incomplete Septa in Human Jugular Foramens

Presencia de Septos Completos o Incompletos en Forámenes Yugulares Humanos

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SUMMARY: The objective of this study was to determine the occurrence of anatomical variants in the exocranial surface of the jugular foramen, specifically, the presence of single or double and complete or incomplete septation. A cross-sectional anatomical study was performed using 96 Brazilian dry human skulls (53 male and 43 female). One examiner determined the number (single or double) and type (i.e. complete or incomplete) of osseous septation at the outer surface of jugular foramens. Data went through statistical analysis on GraphPad Prism 6.01. Our results shown that Male individuals were more likely to present normal jugular foramens (male = 71.69%, female = 34.88%; $p = 0.003$). However, one incomplete septation occurred more often on the right side of female individuals (1 incomplete septation, male = 16.98%; 1 incomplete septation, female = 34.88%; $p = 0.044$). Similarly, one complete septation (i.e. the presence of two fully divided jugular compartments) also occurred more often on the right side of female individuals (1 complete septation, male = 9.43%; 1 complete septation, female = 25.58%; $p = 0.038$). Anatomical variants of the jugular foramen regarding single or double complete or incomplete septations were more likely to be found on the right side of female individuals, who also presented a higher rate of jugular foramens with any type of septation than regular non-altered jugular foramens.

KEY WORDS: Anatomy; Jugular foramen; Septa; Compartments.

INTRODUCTION

The jugular foramen (JF) is an opening located at the skull base that provides passage for important neurovascular structures from the cranium cavity to the upper neck region, into the carotid space. The sigmoid sinus passes through the posterolateral portion of the JF, whereas it continues as the internal jugular vein, which receives the inferior petrosal sinus after its passage through the anteromedial portion of the JF. In addition, cranial nerves IX, X, and XI are transmitted through the JF in an intermediate position, between the inferior petrosal sinus and the internal jugular vein (Ayeni *et al.*, 1995; Griessenauer *et al.*, 2016).

Authors have been describing a division of the JF into three compartments, which may be partially or fully divided by one or two bone septa in up to 45% of cases (Vlajkovic *et al.*, 2010). Of these three compartments, the

sigmoid sinus is located at the larger one (sigmoid compartment/larger venous compartment), the inferior petrosal sinus occupies the smaller one (petrosal compartment/smaller venous compartment), and cranial nerves IX to XI are situated in the neural compartment, of intermediate proportions and in between the other two (Tummala *et al.*, 2005; Liu *et al.*, 2009).

The normal and altered anatomy of the jugular foramen is clinically important in neurosurgeries, neuroimaging, and pathologies associated to the internal jugular vein and to the glossopharyngeal, vagus, and accessory cranial nerves. This knowledge may help the clinician into interpreting imaging exams, in providing accurate diagnosis and prognosis, as well as in performing surgical procedures with a higher precision (Liu *et al.*; Wan *et al.*, 2012).

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Despite existing published results regarding the JF and its anatomical variants about number and presence of septations in male and female individuals, scientific literature lacks a complete study that singly provides data from all outcomes that are often analyzed individually in different papers (Vlajkovic *et al.*; Skrsatz *et al.*, 2016; Alabi *et al.*, 2018).

Hence, the aim of the present study was to determine the occurrence of anatomical variants in the exocranial surface of the jugular foramen, specifically, the presence of single or double and complete or incomplete septation.

MATERIAL AND METHOD

Ethical considerations. This study was approved by the institutional ethics committee (Piracicaba Dental School, University of Campinas, Brazil - Protocol: 13197519.8.0000.5418).

Study design and Sample. A cross-sectional *ex vivo* anatomical study was performed using 96 Brazilian dry human skulls (Department of Morphology, Anatomy division, Piracicaba Dental School, University of Campinas, Brazil). Sample size calculation was performed after Alabi *et al.* established the occurrence of anatomical variations of jugular foramens in 36.6% of dry human skulls.

Skulls were considered eligible if pertained to adult individuals (18-80 years old) from both male and female sexes, whereas there was no distinction of ancestralism. The following were excluded: skulls from non-adult individuals; skulls from a different species other than *Homo sapiens*; skulls with injuries to the anatomical structures of interest; and hemi skulls.

Outcomes. One examiner (O.B.O.N., with four years of experience in anatomical studies) performed visual inspections in order to determine the number (single or double) and type (i.e. complete or incomplete) of osseous septation at the outer surface of jugular foramens. These outcomes were only examined at the outer surface (i.e. the exocranial aspect) of the skull base. The occurrence of incomplete bone septa was considered present if they emerged from the margins of the exocranial aspect of the jugular foramen and did not fully divide it into two or three compartments. On the other hand, the occurrence of complete bone septa was considered present if they emerged from the margins of the exocranial aspect of the jugular foramen and fully divided it into two or three compartments.

Statistical analysis. Studied outcomes were reported in absolute values and as percentages. Data were allocated at pre-established sheets and organized on Microsoft Excel. Statistical analysis was performed on GraphPad Prism 6.01 (San Diego, CA, USA), in which the Chi-Square Test was used to compare the occurrence of studied structures between right and left sides of individuals from the same sex, and between the same side (i.e. right versus right and left versus left) of individuals from different sexes. The present study set its confidence level at 95% and its significance level at 5% (0.05).

RESULTS

Comparison between different sides of individuals from the same sex. This analysis showed no statistically significant differences for all comparisons ($p > 0.05$). However, looking at the individual values, one can see that anatomical variants of the JF occurred in both sides of female individuals more often (65.12% on the right side and 51.17% on the left side) than what is considered normal (JF with no septation on the right and left sides, respectively = 34.88% and 48.83%). On the other hand, male individuals presented JF with no anatomical variants in most cases (71.69% on the right side and 64.15% on the left side).

Among the types of septation, in both sexes, incomplete septations occurred more often than complete septations and, between them, a single septation (complete or incomplete) occurred more often than double septation. These data are summarized on Table I.

Comparison between the same side of individuals from different sexes. This analysis revealed statistically significant differences ($p < 0.05$) for comparisons involving the right side of male versus female individuals.

Male individuals were more likely to present normal JF, with no septation, on their right side than female individuals (male = 71.69%, female = 34.88%; $p = 0.003$).

Nevertheless, one incomplete septation occurred more often on the right side of female than in male individuals (1 incomplete septation, male = 16.98%; 1 incomplete septation, female = 34.88%; $p = 0.044$). Similarly, one complete septation (i.e. the presence of two fully divided jugular compartments) also occurred more often on the right side of female than in male individuals (1 complete septation, male = 9.43%; 1 complete septation, female = 25.58%; $p = 0.038$). Figures 1 and 2 show, respectively, cases of complete and incomplete septation of jugular foramens.

Table I: Occurrences of jugular foramina (JF) with no septation and with single or double complete or incomplete septation in 96 dry skulls of Brazilian individuals.

	Male (N=53)					p-value	Female (N=43)					p-value	All (N=96)					p-value
	Right		Left		N		Right		Left		N		Right		Left		N	
	N	%	N	%			N	%	N	%			N	%	N	%		
0 BS/ 1 JF	38	71.69%	34	64.15%	0.40	15	34.88%	21	48.83%	0.18	53	55.21%	55	57.29%	0.70			
1 IBS/ 2 IJC	9	16.98%	13	24.52%	0.33	15	34.88%	12	27.90%	0.48	24	25.00%	25	26.04%	0.86			
2 IBS/ 3 IJC	0	0	0	0	-----	1	2.32%	2	4.65%	0.55	1	1.04%	2	2.08%	0.56			
1 CBS/ 2 CJC	5	9.43%	5	9.43%	1.00	11	25.58%	8	18.60%	0.43	16	16.66%	13	13.54%	0.54			
2 CBS/ 3 CJC	1	1.88%	1	1.88%	1.00	1	2.32%	0	0	0.31	2	2.08%	1	1.04%	0.56			
Total	53	100%	53	100%	-----	43	100%	43	100%	-----	96	100%	96	100%	-----			

Analysis was performed by comparing right versus left sides in individuals from the same sex. BS = bone septum; IBS = incomplete bone septum; IJC; incomplete jugular compartment; CBS = complete bone septum; CJC = complete jugular compartment.

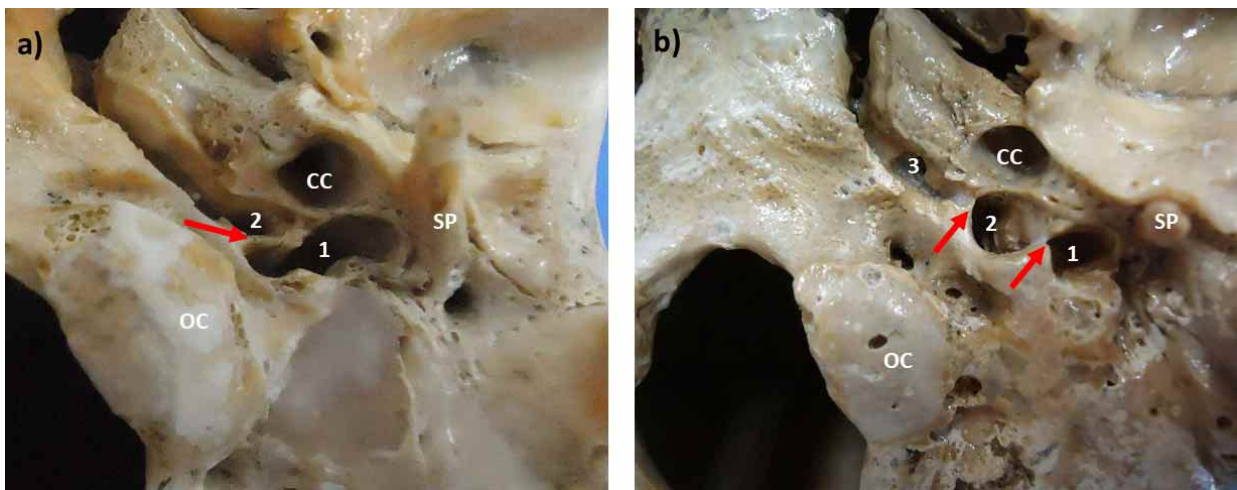


Fig. 1. Inferior view of skull base showing: a) two fully divided jugular compartments (1 and 2) separated by one complete bone septum (arrow); b) three fully divided jugular compartments (1, 2, and 3) separated by two complete bone septa (arrow). CC = carotid canal; OC = occipital condyle; SP = styloid process.

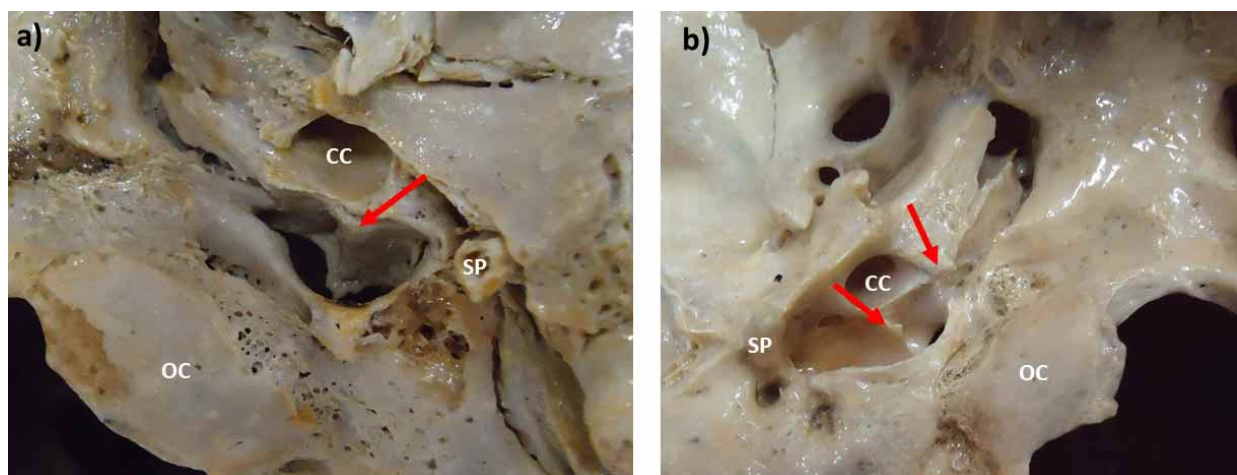


Fig. 2. Inferior view of skull base showing: a) one incomplete bone septum arising from the margins of the jugular foramen (arrow); b) two incomplete bone septa arising from the margins of the jugular foramen (arrow). One can see that incomplete bone septa do not fully divide one jugular foramen into two or three compartments; however, it helps to delineate where the compartments can be found. CC = carotid canal; OC = occipital condyle; SP = styloid process.

Table II. Comparison of anatomical variants of the jugular foramen (JF) between the same side of individuals from different sexes.

	Male (N=53)		Female (N=43)		p-value	Male (N=53)		Female (N=43)		p-value
	Right		Right			Left		Left		
	N	%	N	%		N	%	N	%	
0 BS/1 JF	38	71.69%	15	34.88%	0.003*	34	64.15%	21	48.83%	0.13
1 IBS/ 2 IJC	9	16.98%	15	34.88%	0.044*	13	24.52%	12	27.90%	0.70
2 IBS/3 IJC	0	0	1	2.32%	0.26	0	0	2	4.65%	0.11
1CBS/2 CJC	5	9.43%	11	25.58%	0.038*	5	9.43%	8	18.60%	0.19
2CBS/3 CJC	1	1.88%	1	2.32%	0.88	1	1.88%	0	0	0.36
Total	53	100%	43	100%	-----	53	100%	43	100%	-----

BS = bone septum; IBS = incomplete bone septum; IJC; incomplete jugular compartment; CBS = complete bone septum; CJC = complete jugular compartment; * = indicates a statistically significant value.

DISCUSSION

The present study established the occurrences of jugular foramina (JF) with no septation and with single or double complete or incomplete septation in 96 dry skulls from adult male and female Brazilian individuals.

Two types of analysis were performed: 1) comparison between different sides of individuals from the same sex (Table I); and 2) comparison between the same side of individuals from different sexes (Table II). Considering both analyses altogether, one can see that the likelihood to find septations on the JF was higher in female than in male individuals and that the right side presents a higher rate of anatomical variants than the left side. This may be an indication that female individuals are more likely to present septation on the JF and therefore are more likely to have pathologies associated with this alteration in normal anatomy (Wan *et al.*; Kano *et al.*, 2018).

Table III compares the results from our study with previous studies. It is quite clear that, despite existing literature on this topic, the present study stands out for providing, in a single study, all possible data regarding the occurrence of single or double and partial or full septation of jugular foramina, which is fragmented in various publications (Vlajkovic *et al.*; Pereira *et al.*, 2010; Alabi *et al.*).

The jugular foramen is established, approximately, at 51 days post-ovulation by the union of the otic capsule and the basioccipital plate and is directly related to the development of neurovascular structures that pass through it, especially the cranial nerves IX, X, and XI (Padgett, 1956; O’Rahilly & Müller, 1984). This explains why anatomical variants of this foramen, such as the ones found in our study, may occur.

The present study presents clinical applicability as it adds data to the scientific literature regarding the anatomical explanation behind the morphology of double or triple dumbbell-shaped jugular foramen schwannomas (Wan *et al.*). In addition, it also suggests that female individuals might be more affected by these pathologies than male individuals and that the right jugular foramen might be more affected than the left one. Moreover, these data may also be used by clinicians to interpret more accurately imaging exams.

Therefore, the present paper concludes the following:

1. Anatomical variants of the jugular foramen regarding single or double and complete or incomplete septation were more likely to be found on the right side of female individuals.

Table III. Occurrences of single or double complete or incomplete septations of the jugular foramen in previous papers and in the present study. IBS = incomplete bone septum; IJC; incomplete jugular compartment; CBS = complete bone septum; CJC = complete jugular compartment; NR= non-reported.

Study	Year	Population	N	Septation							
				1 IBS/2 IJC		2 IBS/3 IJC		1 CBS/2 CJC		2 CBS/ 3 CJC	
				Right	Left	Right	Left	Right	Left	Right	Left
Vlajkovic <i>et al.</i>	2010	Serbian	50	NR	NR	NR	NR	55%	60%	45%	40%
Pereira <i>et al.</i>	2010	Southern Brazilian	111	0.9%	0.9%	NR	NR	0.9%	0.9%	NR	NR
Chauhan <i>et al.</i>	2011	Indian	50	NR	NR	NR	NR	6%	8%	NR	NR
Das <i>et al.</i>	2016	Indian	114	3.5%	11.4%	0%	0%	0%	7%	0%	0%
Alabi <i>et al.</i>	2018	Nigerian	93	30.1%	36.6%	NR	NR	30.1%	23.7%	NR	NR
Present study		Brazilian	96	25.00%	26.04%	1.04%	2.08%	16.66%	13.54%	2.08%	1.04%

2. Female individuals presented a higher rate of jugular foramina with any type of septation than regular non-altered jugular foramina.

3. Single complete or incomplete septations of the jugular foramen occurred more often than double complete or incomplete septations in both sexes.

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RESUMEN: El objetivo de la presente investigación fue determinar la presencia de variaciones anatómicas en la superficie exocraneal del foramen yugular, específicamente, la presencia de septos únicos o dobles, completos o incompletos. El estudio fue realizado en 96 cráneos secos (53 masculinos y 43 femeninos) de individuos Brasileños. Se determinaron septos óseos completos o incompletos y número de ellos. Los resultados obtenidos fueron tratados estadísticamente con el programa GraphPad Prism 6.01. Los sujetos de sexo masculino fueron más propensos a presentar forámenes yugulares normales (sexo masculino: 71,69%; sexo femenino: 34,88%, $p=0,003$). Sin embargo, se observaron septos incompletos con mayor frecuencia en el lado derecho y en el sexo femenino (sexo masculino: 16,98%; sexo femenino: 34,88%, $p=0,044$). Adicionalmente, una septación completa (presencia de dos compartimientos yugulares, divididos completamente), se presentaron más frecuentemente en el lado derecho de individuos femeninos (sexo masculino: 9,43%; sexo femenino: 25,58%, $p=0,038$). Las variantes anatómicas del foramen yugular, en relación a septos simples o dobles, completos o incompletos, se encontraron con mayor frecuencia en el lado derecho de las mujeres, las que presentaron un alto rango de forámenes yugulares con algún tipo de septos respecto a los forámenes yugulares regulares no alterados.

PALABRAS CLAVE: Anatomía; Foramen yugular; Septos; Compartimientos.

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