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ORIGINAL ARTICLE

Evaluation of Cross-Sectional Areas of the Sigmoid Sinus, Jugular Bulb and Internal Jugular Vein: A Cadaver Study

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Background: Dural venous sinuses need further attention either for its anatomical structure or relationship to its neighborhood neurovascular formations in and around the temporal bone. In this study, the widths of the sigmoid sinus-jugular vein complex are measured in five different levels. The distances between this complex two some of the important temporal bone landmarks are also evaluated.

Materials and Methods: Eight adult male cadavers (6 right, 8 left side) fixed with formaldehyde were used in this study. Mastoidectomy was performed under a surgical microscope (Zeiss Opmi 99, Germany). The distances between the Henle spine to the middle fossa dura, the sigmoid sinus to the facial nerve, the jugular bulb to the second genus of facial nerve and the crista fenestrae cochlea were measured. Received total 5 levels of cross-sectional areas were calculated that were established at five different levels of sigmoid sinus-jugular vein complex by point counting method. The differences between levels and the sides were evaluated with the Wilcoxon signed-rank test. The relationship amoung the about mention factors was evaluated with Spearman's correlation test.

Results: Differences between levels and correlation characteristics have been introduced in tabular form. Correlation between the levels was found only on the left side. Regarding the landmarks of the temporal bone, positive correlation was found between the cross-sectional area of the jugular bulb with the 'distance between the Henle spine to the middle fossa dura' and negative correlation was found between the ' distance of the jugular bulb to the crista fenestrae cochlea.

Conclusion: Important correlations were found between the anatomical structure and the dimensions of the sinus-vein complex to the important landmarks of the temporal bone affecting the appropriate surgical approach to this area.

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Introduction

Surgical approaches to or through the temporal bone are to be chosen according to the size and venous flow characteristics of the sigmoid sinus besides other factors, preoperatively. Dominance of the vein and presence or absence of adequate intracranial venous connections are important to predict the possible consequences of venous occlusion [1,2]. During surgery, destruction of the venous structure, especially at the dominant side, may lead to cerebral hemorrhage, infarct and dural arteriovenous malformations [1,3-5]. Also, the distances of the sigmoid sinus (SS), superior bulb of jugular vein (BJ) and facial nerve to the some reference points, such as spina suprameatica (Henle spine) and the crista fenestrae cochlea (round window niche) may be a guide during the planning and execution of the temporal bone surgery at presigmoidal-transpetrosal approaches [6-10]. Anatomical changes, such as extremely anterior

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location of the SS and high BJ make surgery difficult to achieve to petrous apex with infralabrynthine approach and mastoidectomy and retrosigmoid tumor surgery [1,3-5,10].

Our previous study revealed that the distances between the SS-facial nerve and BJ-round window were evaluated as important in temporal bone surgery [10]. The data obtained from this study provided important clues for the position of the SS-BJ complex and the surgical corridors in the internal structure of the temporal bone. The present study aimed to measure the cross-sectional area of main venous structures (SS-BJ -internal jugular vein (VJI)) located in the intracranial venous drainage pathway on different levels. In addition, we also plan to evaluate whether or not the width of certain levels of venous structures have correlation with some of the distances in temporal bone for successful surgery.

Materials and Methods

Fourteen temporal bone of eight male, adult cadavers (6 right, 8 left side) fixed with formaldehyde were enrolled to the study. The mean age was 66 with the range 52-86. Lateral jugular foramen dissection was performed under a surgical microscope (Zeiss Opmi 99, Germany) with using surgical drills in the laboratory of Anatomy, Mersin University School of Medicine. Then, the measurements of I, III were performed and II and IV were taken from our previous study [10] (Figures 1-5).

I. The nearest distance between the middle fossa dura and Henle spine (spina suprameatica),
II. The nearest distance between SS and the facial nerve,
III. The nearest distance between the BJ and the second genu of facial nerve,
IV. The nearest distance between the BJ and the crista fenestrae cochlea (round window niche).

All measurements on the temporal bone were carried out by the same investigator.

The whole sigmoid sinus-jugular bulb-internal jugular vein complex was dissected completely. Then, sections were obtained in thickness and perpendicular to the lumen from 5 levels of these venous structures which are defined below (Figure 6);

A1 level: The level of the beginning of SS,

A2 level: The level of the midpoint of the distance between A1 and A3,

A3 level: The level of the internal opening of the jugular foramen of SS,

A4 level: The level of the largest diameter of the BJ,

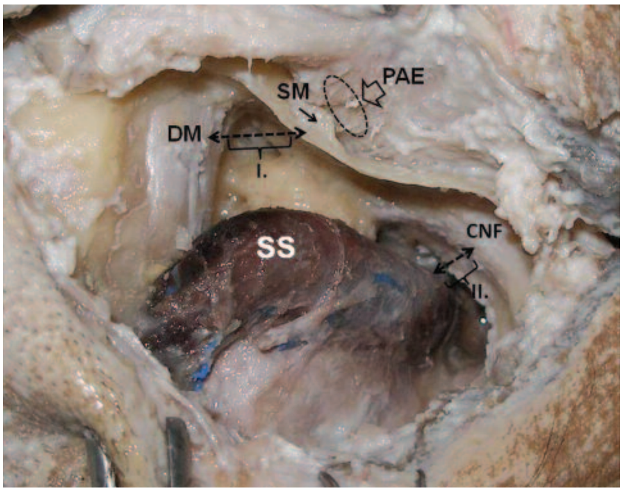

Figure 1. Postero-lateral view of the temporal bone dissection. SM: spina suprameatica (Henle spine), DM: dura mater, PAE: porus acusticus externus, SS: sinus sigmoideus, CNF: canalis nervi facialis, I. The distance between the spina suprameatica with the middle fossa dura mater, II. The distance between the facial nerve with the SS.

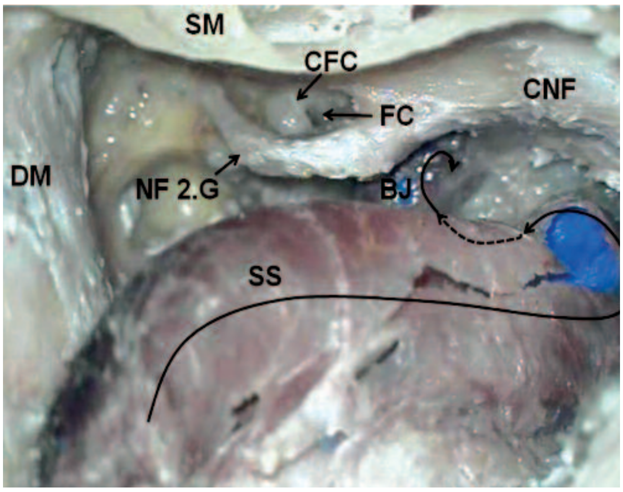

Figure 2. Postero-lateral view of the temporal bone dissection. SM: Spina suprameatica, DM: dura mater, SS: sinus sigmoideus, BJ: superior bulb of jugular vein, CNF: canalis nervi facialis, NF 2.G: second genu of the facial nerve, FC: fenestra cochlea, CFC: crista fenestra cochlea.

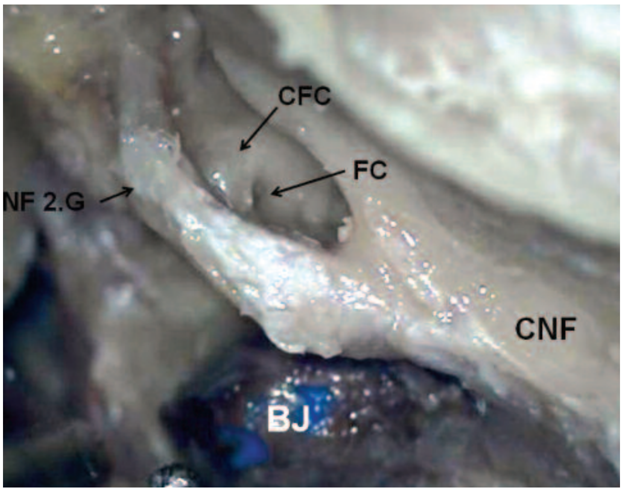

Figure 3. Postero-lateral view of the temporal bone dissection. BJ: superior bulb of jugular vein, CNF: canalis nervi facialis, NF 2.G: second genu of the facial nerve, FC: fenestra cochlea, CFC: crista fenestra cochlea.

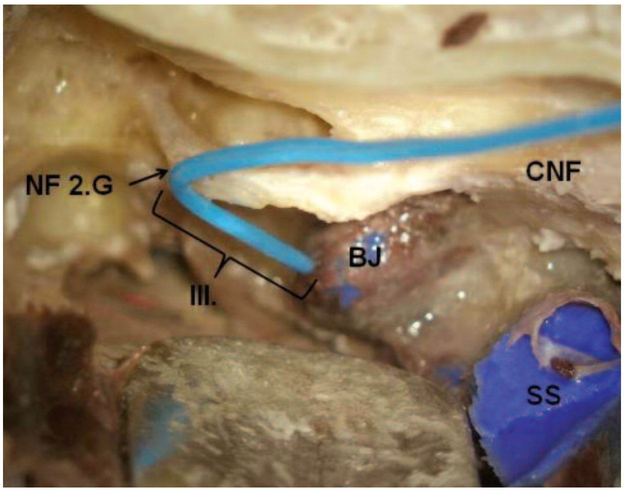

Figure 4. Postero-lateral view of the temporal bone dissection. SS: sinus sigmoideus, BJ: superior bulb of jugular vein, CNF: canalis nevri facialis, NF 2.G: second genu of the facial nerve, III.: The distance between the BJ with the second genu of the facial nerve.

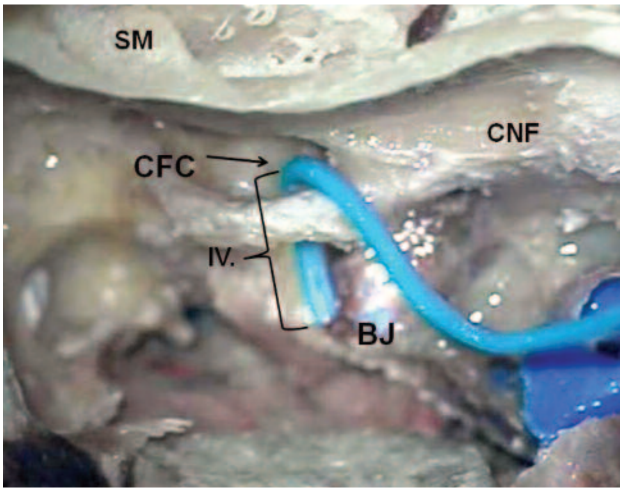

Figure 5. Postero-lateral view of the temporal bone dissection. SM: spina suprameatica, BJ superior bulb of jugular vein, CNF: canalis nervi facialis, CFC: crista fenestra cochlea, IV.: The distance between the BJ with the crista fenestrae cochlea.

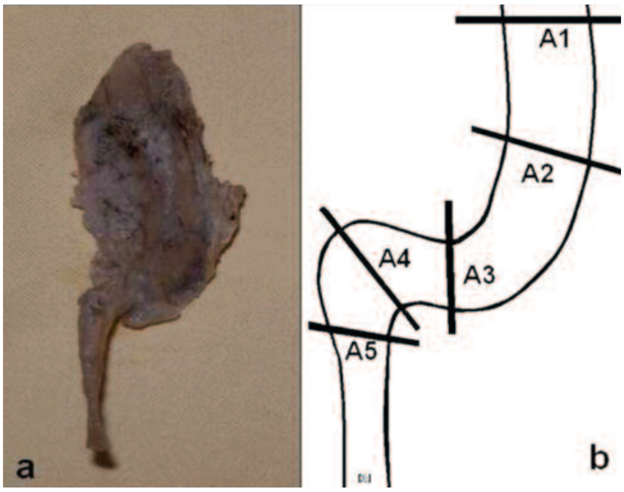

Figure 6. (a) SS, BJ and VJI vein complex, (b) Schematic view of the cross-sectional levels of SS; A1: The level of the beginning of SS, A2: The level of the mid point of the distance between A1 and A3, A3: The level at the internal opening of the jugular foramen, A4: The level of the largest diameter of the BJ, A5: The level at the external opening of jugular foramen.

A5 level: The level of the external opening of jugular foramen.

Cross-sections were aligned side by side, photographed with a scale. Pictures transferred to a computer. The cross-sectional areas were calculated using the measuring-point scale (d =) on the computer screen (Figure 7).

The data obtained were analyzed statistically: The difference between the sides and the differences between the levels were evaluated with the Wilcoxon signed-rank test. The relationship between the different levels of the cross-sectional areas of venous structures with reference measurements on the temporal bone were evaluated with Spearman's

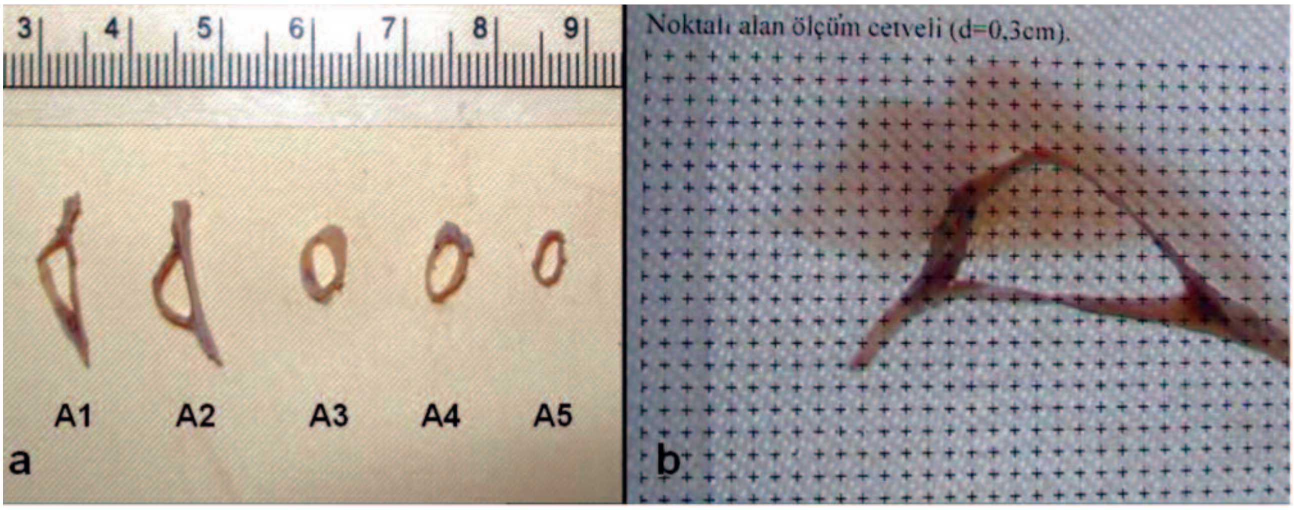

Figure 7. (a) Photograph of the cross-sections of A1-A5 with a scale. **(b)** The measuring-point scale (d = 0.3 cm).

correlation test. Statistical significance level was set at 0.05.

Results

Bilateral cross sectional area measurement of 6 cadavers revealed left sided dominance in two; right sided dominance in three cadavers for all levels. Interestingly, while values of all other levels of the right side were larger, vein cross-sectional area of the level of the external opening of jugular foramen was larger on the left side in one cadaver. Although statistical significance was not found between the right and left sides, the difference between the cross sectional areas was considerable.

Descriptive statistics for the reference measurements within the temporal bone was given in Table 1. Descriptive statistics for area measurements for 5 levels of the venous structures was given in Table 2.

The results of statistical analysis of data were evaluated under four titles:

1 - The difference between the sides was not statistically significant ($p > 0.05$), for any of the levels of the venous structures. The comparison of cross sectional areas was performed together for both sides due to the statistical insignificance between the sides.

2 - The statistical analysis results for comparison of the sectional areas of the levels were given in Table 3.

Table 1. Descriptive statistics for the temporal bone measurements.

		N	Minimum (mm)	Maximum (mm)	Mean (mm)	SD
R	I	6	6.30	16.60	11.80	4.65
	II	6	3.20	7.65	5.71	2.08
	III	5	8.07	13.40	11.02	2.23
	IV	6	3.40	11.40	6.67	2.85
L	I	5	7.85	17.30	11.77	4.23
	II	6	4.00	8.20	6.03	1.74
	III	6	7.50	13.90	11.73	2.62
	IV	6	4.80	11.90	8.10	2.71

(R: right, L: left, SD: Standard Deviation, I: The nearest distance between the middle fossa dura with Henle spine (spina suprameatica), II: The nearest distance between SS with the facial nerve, III: The nearest distance between the BJ with the second genu of facial nerve, IV: The nearest distance between the BJ with the crista fenestrae cochlea (round window niche)

Table 2. Descriptive statistics for the levels of venous structures.

	N	Minimum (mm^2)	Maximum (mm^2)	Mean (mm^2)	SD
RA1	6	38.00	105.00	67.67	23.85
RA2	6	24.00	66.00	45.67	17.51
RA3	6	13.00	55.00	37.33	15.63
RA4	6	43.00	90.00	69.67	20.72
RA5	6	22.00	48.00	34.00	10.41
LA1	8	23.00	100.00	47.63	24.21
LA2	8	24.00	62.00	38.88	14.57
LA3	8	18.00	38.00	26.63	8.18
LA4	8	22.00	105.00	49.75	33.20
LA5	8	12.00	62.00	32.25	18.25

(R: right, L: left, SD: Standard Deviation, A1: The level of the beginning of SS, A2: The level of the midpoint of the distance between A1 and A3, A3: The level of the internal opening of the jugular foramen of SS, A4: The level of the largest diameter of the BJ, A5: The level of the external opening of jugular foramen.)

Table 3. Results of statistical analysis for comparison of the cross-sectional areas of the levels (n = 14)

	A2 - A1	A3 - A1	A4 - A1	A5 - A1	A3 - A2	A4 - A2	A5 - A2	A4 - A3	A5 - A3	A5 - A4
Z	-2.859	-3.297	-.220	-3.300	-2.890	-1.853	-2.417	-2.920	-.489	-3.140
p	0.004	0.001	0.826	0.001	0.004	0.064	0.016	0.004	0.624	0.002

(p: statistical significance level, Z: test statistics, A1: The level of the beginning of SS, A2: The level of the mid point of the distance between A1 and A3, A3: The level of the internal opening of the jugular foramen of SS, A4: The level of the largest diameter of the BJ, A5: The level of the external opening of jugular foramen.)

3 - Results of analysis for the correlation between the levels were given in Table 4.

4 - The results of analysis showing correlation for the parameters measured during dissection of the temporal bone with the area measurements of the venous structures were given in Table 5.

Discussion

One of the sides is known to be often larger than the other in terms of size and flow rate of the SS [11-15]. Superficial and deep veins of the brain are drained to transverse sinus (TS), which will continue as the SS. Confluence sinuum may be regarded as a major part that might affect the left-right dominance of the transverse-sigmoid sinus complex. On the other hand, some authors suggest that the superior sagittal sinus

drains equally as possible into the left and right TS or may be predominantly or completely drains to one side. The blood from the superficial parts of the brain by the superior sagittal sinus drains into the right TS which is usually larger. The blood from in the deeper parts of the brain by the straight sinus opens the left TS which is usually smaller [16]. According to Rhoton, the differences in symptoms caused by blockage of the venous drainage on one side or the other can be explained by differences in drainage on both sides [16]. The present study revealed that the narrowest parts are the A5 levels. This is the external opening of the jugular foramen which, in fact, is the beginning part of the internal jugular vein. This information may lead to the necessity to further discuss the drainage of the transverse-sigmoid complex with the internal jugular vein. Therefore, it is not important to only consider the sigmoid sinus transverse diameter but to keep in mind the role of the jugular vein capacity. In order to decrease the morbidity and mortality of the posterior fossa and jugular foramen approaches related to the venous drainage of the brain, the surgeon is better to emphasize on the jugular vein system in addition to examining the cross sectional area of the sigmoid sinus for the dominance. Also, besides the radiological

Table 4. The results of analysis of the relationship between the levels of the venous structures.

		RA1	RA2	RA3	RA4	RA5	LA1	LA2	LA3	LA4
RA2	r	0.600								
	p	0.208								
	n	6								
RA3	r	0.371	0.771							
	p	0.468	0.072							
	n	6	6							
RA4	r	0.029	-0.486	-0.029						
	p	0.957	0.329	0.957						
	n	6	6	6						
RA5	r	0.580	0.754	0.638	-0.029					
	p	0.228	0.084	0.173	0.957					
	n	6	6	6	6					
LA1	r	-0.257	-0.429	-0.771	-0.257	-0.174				
	p	0.623	0.397	0.072	0.623	0.742				
	n	6	6	6	6	6				
LA2	r	-0.486	-0.657	-0.886(*)	-0.086	-0.377	0.886(**)			
	p	0.329	0.156	0.019	0.872	0.461	0.003			
	n	6	6	6	6	6	8			
LA3	r	-0.754	-0.928(**)	-0.638	0.522	-0.647	0.434	0.667		
	p	0.084	0.008	0.173	0.288	0.165	0.283	0.071		
	n	6	6	6	6	6	8	8		
LA4	r	-0.493	-0.899(*)	-0.899(*)	0.203	-0.882(*)	0.623	0.711(*)	0.758(*)	
	p	0.321	0.015	0.015	0.700	0.020	0.099	0.048	0.029	
	n	6	6	6	6	6	8	8	8	
	p									
	n									
LA5	r	-0.429	-0.829(*)	-0.943(**)	0.200	-0.493	0.857(**)	0.826(*)	0.699	0.898(**)
	p	0.397	0.042	0.005	0.704	0.321	0.007	0.011	0.054	0.002
	n	6	6	6	6	6	8	8	8	8

(r: correlation coefficient, p: statistical significance level, n: number of samples, R: right, L: left, A1: The level of the beginning of SS, A2: The level of the midpoint of the distance between A1 and A3, A3: The level of the internal opening of the jugular foramen of SS, A4: The level of the largest diameter of the BJ, A5: The level of the external opening of jugular foramen.)

Table 5. Results of analysis of the relationship between the surgical reference measurements with the cross-sectional areas.

Distance		A1	A2	A3	A4	A5
Between the MF dura with H. spine	r	0.371	-0.006	-0.073	0.665(*)	0.189
	p	0.291	0.987	0.841	0.036	0.601
	n	10	10	10	10	10
Between SS with the facial nerve	r	-0.127	-0.073	-0.109	0.087	-0.141
	p	0.709	0.830	0.749	0.800	0.679
	n	11	11	11	11	11
Between the BJ with the second genu of facial nerve	r	-0.600	-0.514	-0.205	-0.378	-0.465
	p	0.051	0.106	0.545	0.252	0.150
	n	11	11	11	11	11
Between the BJ with the round window niche	r	-0.555	-0.220	-0.073	-0.715(*)	-0.428
	p	0.077	0.515	0.831	0.013	0.189
	n	11	11	11	11	11

(r: correlation coefficient, p: statistical significance level, n: number of samples, H:Henle, MF: middle fossa)

investigation is to be completed by the flow rate of the right-left sinuses.

Mechanical injury caused by air drill and retractors or air drill heat injury at the presigmoidal-transpetrosal approaches, may lead to the development of thrombus by creating damage to the wall of the SS. In addition, trauma and long time application of retractors on the sinus may lead to venous drainage difficulties in these approaches. Ohata et al. evaluated 7 cases with SS occlusion as surgical complication from 143 operations performed presigmoid-transpetrosal approach. In these cases, differences in clinical course were found to be associated with hypoplastic TS and dominant SS as anatomic variations in venous system. Accordingly, the lesion was the dominant side of the TS-SS in presigmoidal-transpetrosal approach, increasing the risk of the operation [1].

There are many studies available in the literature, for sizes of the TS, SS, BJ and VJI that were obtained with MR venogram, ultrasound from life form and by indirect methods [11,17-21]. Ayanzen et al. evaluated the TS on 100 MR venogram. The right, left and codominant rates of this sinus were reported as 59%, 25% and 16%, respectively [18]. Manara et al. determined an average diameter of the right TS (6.5 mm±1.84) is significantly more than left TS (5.1 mm±1.72) in 102 patients with two-dimensional time-of-flight MR venography. In the same study, the sides of each of the cases were evaluated, determined to be dominant on the right side in 61% of cases and the left side in 17% of cases [19].

Tenenbein et al. evaluated the diameter of the VJI and the dominance of the BJ with ultrasound and cerebral angiography in 25 patients. This study revealed that the right VJI was much larger than the left in 19 cases (76%), the sides are of equal size in 2 cases (8%), the left side was much larger in 4 cases (16%). In the same study, BJ was found to be dominant on the right side in 11 cases (44%), equally in 10 cases (40%), dominant in left side in 4 cases (16%) [17]. VJI was evaluated by using a special ultrasonographic method by Lichtenstein et al. In this study, VJI was asymmetric in 50 (62.5%) of the 80 patients, in 34 (68%) of the asymmetrical cases the right side, in 16 (32%) the left side were reported to be dominant [11]. In our study, which evaluated to SS, BJ and VJI, the measurement of the difference between the sides for all levels were not found to be statistically significant despite a considerable difference among the sides. This was attributed to the small number of cadavers.

In our study, among the bilaterally measured cadavers, dominance at all levels were found in right side in three cadavers, in left side in two cadavers. In one cadaver, while values of all the other levels of the right side were larger, vein cross-sectional area of the level of the external opening of jugular foramen was larger on the left side. In this case, dominance properties of the venous structures suggest that sections may vary according to the levels. Tenenbein et al. revealed similar findings for their series [17].

Dimensions, level and position of the SS and BJ are important for the surgical corridor in presigmoidal-transpetrosal approaches to the posterior fossa. SS, which forms the posterior border of Trautmann’s triangle may limit the access to the internal auditory canal in translabrynthine approaches [22,23]. Similarly, extremely anterior location of the SS can prevent deeper dissection of the retrofacial region. A high BJ makes surgical dissection difficult for translabrynthine and retrosigmoid approaches [1,3-5]. In addition, anterior or medial location of the SS limits access to endolymphatic sac near the posterior semicircular canal [24].

Dai et al. states the diameter of the BJ in high located BJ cases is larger than those low located and the distance between the BJ with the mastoid process in the high BJ is less [25]. In the same study, left high BJ according to left low BJ settle more laterally. In addition, the diameter and the distance to midline were greater on the right temporal bones compared to the left; contrarily the distance of the sinus to the mastoid apex is greater on the left temporal bones. In cases of high BJ, protrusive depth of the SS and the diameter of the BJ also reported to be more on the right than left [25]. In our study, the cross-sectional area of the BJ level (A4) showed a positive correlation ($p = 0.036$) with the distance between the Henle spine and the middle fossa dura which is important for mastoidectomy, so when the vein cross-sectional area increases, this distance was also increased. In addition, the distance between the BJ and the round window niche showed negative correlation ($p = 0.013$) with sectional area of the BJ (A4) as the area increases, this distance is found to be reduced.

Facial nerve and its branches should be the preserved structures in the temporal bone surgery [6]. SS is a good determinant to distinguish facial nerve at the beginning of the mastoid surgery [26]. The distance between the SS with the facial nerve can create barrier to surgery [1,3,4]. Boemo et al. are reported that the facial nerve was found to be located 5.65 and anteromedially to the SS [24]. In our study, the nearest distance between the SS with the facial nerve was found to be 5.71 ± on the right, 6.03 ± on the left side.

Some of the research results suggest intracranial pressure changes, could also have associated with diameter changes in dural venous sinus [27]. Lateral sinus flow gap is reported more frequent in the patients with idiopathic intracranial hypertension than in controls [28]. Contrary, significantly venous dilatation more frequent in the patients with spontaneous intracranial hypotension is stated [29]. Similarly, in the literature, sinus anomalies reports may be related to idiopathic intracranial hypertension [28], glaucoma [30] or intracranial hypotension [31]. In addition, healthy sinus occlusions, especially in the dominant side or between the two SS do not have any patent connection through TS; can trigger venous hypertension [14]. These data increases interest to morphological characteristics and variations of the intracranial sinuses.

In this study, the cross-section measurements of the SS, BJ and VJI, which is the flow path of the intracranial venous blood, have been introduced. Statistical evaluations were presented in terms of sides and levels. Even the data obtained from limited number of cases, statistical significance was found between some levels (Table 3). According to these data, the venous flow path has a form, which is narrowing from the top to down, widening in the level of BJ and re-narrowing at the level of VJI (Table 2). Of course, the narrowing rates of this path vary from individual to individual. These narrowing rates at the certain levels of the flow path, to determine whether it is associated with idiopathic intracranial pressure changes, are needed to be clinically studied using radiological imaging methods in large series consisting of live cases.

Conclusion

To the best of our knowledge, the present study is the first investigating the cross sectional area of the sinus complex after the cautious removal of this structure. The authors believe that this method might overcome some of the weaknesses regarding the superposition, sharpness of the edges, etc. This study also indicates the importance of the sigmoid sinus with its relationship to other temporal bone structures to decide the best surgical approach for particular lesions. Also, the finding revealing the significant resistance levels indicates the necessity to evaluate the whole system from transverse sinus to internal jugular vein for the precise decision of the dominant side.

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