



















Original Article

# The Comparison of the Right and Left Sigmoid Sinus Cross-Sectional Areas in Fetal Period and the Factors Affecting the Venous Dominance

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**OBJECTIVES:** Skull base is an important and a challenging area for surgeons. Success in skull base surgery depends on various factors such as pre-operative evaluation, appropriate surgical technique, anesthesia duration, intraoperative neuromonitorization and wound care.

**MATERIALS and METHODS:** This study was performed in the Anatomy dissection laboratory of M.U. Medical Faculty (Ethical committee approval number 2010-103). Twelve fetuses between 17-33 gestational weeks fixed with formaldehyde were enrolled to the study.

**RESULTS:** This study was planned to investigate the cross sectional areas of the sigmoid sinus in three levels to compare the right-left sides and the probable relationship among the levels in fetuses to further delineate the developmental factors on jugular foramen asymmetry. The cross-sectional measurements of sigmoid sinus lumen were done on 3 levels which are described as A1 level; sinodural angle, A2 level; the midpoint between the sinodural angle and endocranial orifice and A3 level as the entrance (endo-cranial orifice) of the jugular foramen. There is a strong positive correlation between left (L) A1 and L A2 and also the same for L A1 and right (R) A2. These strong and positive correlations are all valid between L A2-L A3, L A2-R A2, L A2-R A3, L A3-R A3, R A1-R A2.

**CONCLUSION:** Multicenter studies would be beneficial to investigate the topic with greater number of fetuses also on the different regions for genetic differences.

**KEYWORDS:** Fetus, jugular foramen, sigmoid sinus

## INTRODUCTION

Skull base is an important and challenging area to work on for surgeons. Besides its complex anatomy, asymmetry of some structures may complicate the surgical procedure and enforces surgeons to be cautious about complication risks. The positions of sigmoid sinus and jugular bulb are highly variable <sup>[1]</sup>. These variabilities may cause difficulties during neurootological and neurosurgical procedures using translabyrinthine, retrolabyrinthine, and retrosigmoid approaches. Asymmetries and variabilities in sigmoid

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sinus' venous flow and size should be considered preoperatively to minimize complications related to skull base surgery and to prevent undesirable results like venous occlusion, cerebral hemorrhage, infarction, and dural arteriovenous malformations.

Despite the sigmoid sinus importance for skull base surgery, there is an ongoing debate regarding the underlying mechanisms for asymmetric sigmoid sinus and jugular foramen development. The asymmetry is attributable to either postnatal factors [2] like mastoid pneumatization or prenatal factors including genetic development, architecture of the confluens sinuum, brain development, location of ossification centers, neural crest cell effect, and molecular insult [3].

Among these theories, mastoid pneumatization takes a step forward. Various studies have shown the relationship between mastoid pneumatization and sigmoid sinus position and dominance [4]. The pneumatization process is influenced by factors like chronic otitis media or ventilation tube application [5]. Moreover, some researchers have suggested that genetic factors influence both mastoid pneumatization and sigmoid sinus developmental process [6]. All these data suggest that consideration of developmental factors is essential for understanding the cause of sigmoid sinus asymmetry.

The purpose of this study was to investigate the cross-sectional area of the sigmoid sinus at three levels to compare the right and left sides and to determine the probable relationship among the levels in fetuses to further delineate the developmental factors for jugular foramen asymmetry. To the best of our knowledge, this is the first investigation in the English literature on the cross-sectional area calculation in fetal sigmoid sinus.

## MATERIALS AND METHODS

Between 2000 and 2005, fetuses were donated to the anatomy department of the Mersin University, School of Medicine, after evaluation by the pathology department. Fetuses with structural deformities and congenital anomalies were not included in the study. Twelve fetuses (eight female and four male) aged between 17 and 33 gestational weeks fixed in formaldehyde were enrolled into the study. Six fetuses were obtained from the mothers in the second trimester and six from those in the third trimester. The mean head circumference of the fetuses was 213.13 mm, crown–rump length was 231.45 mm, and foot height was 52.52 mm. This study was performed in the Anatomy Dissection Laboratory of the Mersin University Medical Faculty (Ethical committee approval number 2010-103).

First, craniotomy was performed to expose the brain hemispheres; following this, careful resection of the brain was performed through slice-by-slice removal to observe the neurovascular structures of the anterior, middle, and posterior fossae. Then, right and left sigmoid sinuses were dissected from the sinodural angle to the endocranial orifice of the jugular foramen. This dissection was performed under a surgical microscope (C.Z.; OPMI pico, Germany) using microsurgical instruments. Then, cross-sectional measurements of the sigmoid sinus lumen were obtained at three levels, which are described below.

A1 level: Sinodural angle

A2 level: The midpoint between the sinodural angle and endocranial orifice

A3 level: The entrance (endocranial orifice) of the jugular foramen

The specimens prepared at the above mentioned levels were put on a scale and photographed. The photographs were transferred to a computer, and the lumen areas were calculated using the measuring-point scale ( $d=0.1$  mm) on the computer screen with the formulation ( $d^2 \times \text{number of points in the lumen}$ ) [7, 8].

## Statistical Analysis

In the statistical analyses, paired t-test was used for the comparison of the means of right and left sides and Student's t-test was used for the comparison of the means of sex-stratified groups using web-based biostatistics software E-PICOS (www.e-picos.com; MedicReS, World Headquarters, One World Trade Center, 85<sup>th</sup> Floor, Suite 8500, New York, NY 10007).

## RESULTS

The calculated areas of the right and left sigmoid sinuses are presented in Table 1 with their minimum, maximum, and mean values. We could not find right or left dominance at any level (Table 2). Statistical

**Table 1.** The calculated minimum, maximum and mean values of right and left A1, A2, A3 areas

	n	Min	Max	Mean±S.D
Age	12	17	38	26.33±6.68
L A1 <sup>†</sup>	12	0.37	3.75	1.81±1.102
L A2 <sup>††</sup>	12	0.23	3.53	1.73±0.98
L A3 <sup>†††</sup>	12	0.29	7.89	2.02±1.97
R A1 <sup>‡</sup>	12	0.72	5.70	2.40±1.58
R A2 <sup>‡‡</sup>	12	0.59	5.57	2.09±1.43
R A3 <sup>‡‡‡</sup>	12	0.56	4.89	1.72±1.20

Min: minimum; Max: maximum; N: Number of fetuses; S.D.: Standard deviation

<sup>†</sup>: Left sinodural angle

<sup>††</sup>: The midpoint between the sinodural angle and endocranial orifice (left side)

<sup>†††</sup>: The entrance (endo-cranial orifice) of the jugular foramen (left side)

<sup>‡</sup>: Right sinodural angle

<sup>‡‡</sup>: The midpoint between the sinodural angle and endocranial orifice (right side)

<sup>‡‡‡</sup>: The entrance (endo-cranial orifice) of the jugular foramen (right side)

**Table 2.** The comparison of right and left values of the three measured areas

		Mean±S.D.	S.E.	Difference between means	p
(n=12)	L A1 <sup>†</sup>	1.81±1.10	0.32	-0.58	0.124
	R A1 <sup>‡</sup>	2.40±1.58	0.45		
(n=12)	L A2 <sup>††</sup>	1.73±0.98	0.28	-0.35	0.222
	R A2 <sup>‡‡</sup>	2.09±1.43	0.41		
(n=12)	L A3 <sup>†††</sup>	2.02±1.97	0.56	0.29	0.300
	R A3 <sup>‡‡‡</sup>	1.72±1.20	0.34		

S.E.: Standard error (S.D./√n)

<sup>†</sup>: Left sinodural angle

<sup>††</sup>: The midpoint between the sinodural angle and endocranial orifice (left side)

<sup>†††</sup>: The entrance (endo-cranial orifice) of the jugular foramen (left side)

<sup>‡</sup>: Right sinodural angle

<sup>‡‡</sup>: The midpoint between the sinodural angle and endocranial orifice (right side)

<sup>‡‡‡</sup>: The entrance (endo-cranial orifice) of the jugular foramen (right side)

significance was not found between male and female fetuses according to crude values. However, the age-adjusted values indicated statistical significance had each sex-stratified group (male and female) comprised seven fetuses (Table 3). Table 4 shows the calculated area values according to the gestational age. Statistical significance was not found between the right (R) and left (L) values at A1, A2, and A3 levels in either male or female group (Table 5). There was a strong positive correlation of L A1 with L A2 and R A2. Furthermore, there was a strong and positive correlation between L A2 and L A3, L A2 and R A2, L A2 and R A3, L A3 and R A3, and R A1 and R A2. Besides, moderate correlations existed between L A1 and L A3, LA1 and R A1, L A1 and R A3, and L A2 and R A1. All these data are presented in Table 6. There was a strong positive and statistically significant correlation (85.6%) between L A1 and L A2 ( $r=0.856$ ,  $p<0.0001$ ).

**Table 3.** The calculated minimum, maximum and mean values of right and left A1, A2, A3 areas and the comparison of sides in terms of gender

	Male (N=4)		Female (N=8)		p	p (Age adjusted)
	Min-Max	Mean±S.D.	Min-Max	Mean±S.D.		
Age	17-27	22.50±4.43	18-38	28.25±7.00	0.060	0.217
L A1 <sup>†</sup>	0.37-1.68	0.98±0.57	0.89-3.75	2.23±1.08	0.403	0.989
L A2 <sup>††</sup>	0.23-2.19	1.38±0.88	0.62-3.53	1.91±1.03	0.298	0.601
L A3 <sup>†††</sup>	0.29-1.72	1.14±0.66	0.95-7.89	2.45±2.29	0.600	0.370
R A1 <sup>‡</sup>	0.72-3.15	2.04±1.09	0.86-5.70	2.58±1.81	0.299	0.961
R A2 <sup>‡‡</sup>	1.05-1.96	1.45±0.40	0.59-5.57	2.41±1.68	0.422	0.831
R A3 <sup>‡‡‡</sup>	0.97-1.66	1.30±0.28	0.56-4.89	1.93±1.45	0.060	0.217

S.E.: Standard error (S.D./√n)

<sup>†</sup>: Left sinodural angle

<sup>††</sup>: The midpoint between the sinodural angle and endocranial orifice (left side)

<sup>†††</sup>: The entrance (endo-cranial orifice) of the jugular foramen (left side)

<sup>‡</sup>: Right sinodural angle

<sup>‡‡</sup>: The midpoint between the sinodural angle and endocranial orifice (right side)

<sup>‡‡‡</sup>: The entrance (endo-cranial orifice) of the jugular foramen (right side)

P.S. The minimum necessity sample size would be indicated as 7 in each sex group for statistical significance if maximum type 1 error is 5% and minimum power level is 80%.  
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**Table 4.** The comparison of right and left values of the three measured areas according to gestational age (in weeks)

	2. Trimester (N=7)						3. Trimester (N=5)					
	Min-Max	Mean±S.D.	S.E.	Difference between means	p		Min-Max	Mean±S.D.	S.E.	Difference between means	p	
L A1 <sup>†</sup>	0.37-1.76	1.13±0.52	0.19	-0.37	0.405		1.18-3.75	2.76±0.99	0.44	-0.88	0.241	
R A1 <sup>‡</sup>	0.72-3.15	1.51±0.80	0.30				2.11-5.70	3.64±1.61	0.72			
L A2 <sup>††</sup>	0.23-2.19	1.15±0.61	0.23	-0.21	0.369		1.54-3.53	2.55±0.80	0.35	-0.54	0.422	
R A2 <sup>‡‡</sup>	0.59-1.96	1.36±0.49	0.18				1.25-5.57	3.10±1.77	0.79			
L A3 <sup>†††</sup>	0.29-2.11	1.29±0.60	0.22	0.05	0.787		0.97-7.89	3.03±2.81	1.26	0.63	0.352	
R A3 <sup>‡‡‡</sup>	0.56-2.20	1.24±0.56	0.21				0.98-4.89	2.40±1.59	0.71			

<sup>†</sup>: Left sinodural angle

<sup>††</sup>: The midpoint between the sinodural angle and endocranial orifice (left side)

<sup>†††</sup>: The entrance (endo-cranial orifice) of the jugular foramen (left side)

<sup>‡</sup>: Right sinodural angle

<sup>‡‡</sup>: The midpoint between the sinodural angle and endocranial orifice (right side)

<sup>‡‡‡</sup>: The entrance (endo-cranial orifice) of the jugular foramen (right side)

## DISCUSSION

Studies aiming to investigate the time of sigmoid sinus asymmetry initiation may not just indicate whether the dominance formation is prenatal or postnatal but also canalize to further investigate the mechanism of asymmetry formation.

According to the literature, asymmetry is mainly attributable to post-natal factors like mastoid pneumatization [4]. Diamant [5] reported lack of mastoid pneumatization in animals after experimental otitis media induction and have reported increased mastoid pneumatization after ventilation tube application in patients with serous otitis media. These findings are reliable indicators of a strong influence of post-natal environmental factors on mastoid pneumatization. However, Diamant et al. [4, 6] have shown that genetics might influence even the postnatal factors. In their study, they found a correlation between pneumatization levels of children and their parents. Strong evidences have been shown regarding the relationship between the mastoid pneumatization and sigmoid sinus position.

The majority of studies on sigmoid sinus asymmetry have been performed as morphometric investigations on adult cadavers and MR venograms [9, 10]. Reportedly, the incidence of right dominance is 68% and that of left dominance is 20%; both sides have been reported to be equal to each other in 12% of cases [11]. Accordingly, it can be concluded that right dominance is seen in the majority of series in terms of mediolateral diameter. In contrast, lower surface area has been attributed mainly to the anteroposterior dimension in cranio-synostosis cases [12]. However, the underlying probable mechanisms have seldomly been discussed.

Several explanations have been provided for the dominance of sigmoid sinus through different mechanisms. One of these mechanisms is the flow pattern of brain venous circulation. Therefore, flow direction of the sinuses gains great importance for the formation of the sigmoid-jugular complex dominance. In general, the right transverse sinus (TS), which receives blood from superficial veins, has been found to be larger than the left TS, which receives blood from the deeper veins of the brain. Ayanzen et al. [9] have reported a 59% right TS dominance rate in their study based on MR venograms. Likewise, Manara

**Table 5.** The comparison of the difference of right and left values of the three measured areas in each sex group

	Male (N=4)					Female (N=8)				
	Min-Max	Mean± S.D.	S.E.	Difference between means	p	Min-Max	Mean±S.D.	S.E.	Difference between means	p
L A1 <sup>†</sup>	0.37-1.68	0.98±0.57	0.28	-1.05	0.218	0.89-3.75	2.23±1.08	0.38	-0.35	0.422
R A1 <sup>‡</sup>	0.72-3.15	2.04±1.09	0.54			0.86-5.70	2.58±1.81	0.64		
L A2 <sup>††</sup>	0.23-2.19	1.38±0.88	0.44	-0.07	0.882	0.62-3.53	1.91±1.03	0.37	-0.49	0.207
R A2 <sup>‡‡</sup>	1.05-1.96	1.45±0.40	0.20			0.59-5.57	2.41±1.68	0.60		
L A3 <sup>†††</sup>	0.29-1.72	1.14±0.66	0.33	-0.162	0.508	0.95-7.89	2.45±2.29	0.81	0.52	0.205
R A3 <sup>‡‡‡</sup>	0.97-1.66	1.30±0.28	0.14			0.56-4.89	1.93±1.45	0.51		

†: Left sinodural angle

††: The midpoint between the sinodural angle and endocranial orifice (left side)

†††: The entrance (endo-cranial orifice) of the jugular foramen (left side)

‡: Right sinodural angle

‡‡: The midpoint between the sinodural angle and endocranial orifice (right side)

‡‡‡: The entrance (endo-cranial orifice) of the jugular foramen (right side)

**Table 6.** The correlation analysis among groups

Correlations		Age	L A1	L A2	L A3	R A1	R A2	R A3
Age	r	1	0.820	0.636	0.430	0.791	0.749	0.465
	p		0.001	0.026	0.163	0.002	0.005	0.127
L A1 <sup>†</sup>	r		1	0.856	0.648	0.639	0.801	0.597
	p			0.000	0.023	0.025	0.002	0.040
L A2 <sup>††</sup>	r			1	0.760	0.581	0.755	0.761
	p				0.004	0.047	0.004	0.004
L A3 <sup>†††</sup>	r				1	0.209	0.436	0.938
	p					0.515	0.157	0.000
R A1 <sup>‡</sup>	r					1	0.890	0.360
	p						0.000	0.251
R A2 <sup>‡‡</sup>	r						1	0.532
	p							0.075
R A3 <sup>‡‡‡</sup>	r							1
	p							

†: Left sinodural angle

††: The midpoint between the sinodural angle and endocranial orifice (left side)

†††: The entrance (endo-cranial orifice) of the jugular foramen (left side)

‡: Right sinodural angle

‡‡: The midpoint between the sinodural angle and endocranial orifice (right side)

‡‡‡: The entrance (endo-cranial orifice) of the jugular foramen (right side)

r: The relationship between age and area at various levels. (-1 ≤ r ≤ +1)

The relationship between the variables is explained by correlation coefficient. (rxy) This value is indicated between -1 and +1 (0 included)

0.90-1.00: Highly strong correlation

0.70-0.89: Strong correlation

0.40-0.69: Moderate correlation

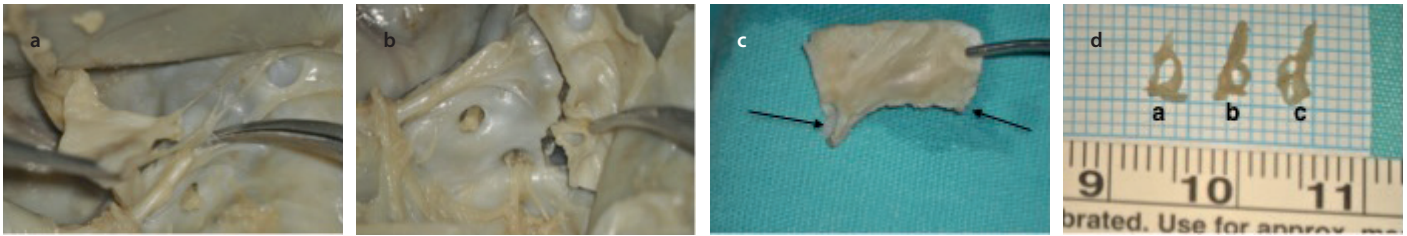
0.20-0.39: Poor correlation

0.00-0.19: No relationship

et al. [13] have found the average values of the right TS diameter to be significantly higher than those of the left TS diameter. From this viewpoint, greater volumetric preload of the right TS may be considered a probable scenario for the right dominance. Therefore, fetal mea-

surements and longitudinal radiological venous flow investigations need to be performed to contribute to the related literature to better highlight the initiation phase of this scenario and the dynamics of TS-confluens sinuum-sigmoid sinus complex. It is believed that the





**Figure 1. a-d.** Shows the preparation stages of sigmoid sinus lumen. a) Interior view of the skull base showing the lumen of the sigmoid sinus at the transverse sinus intersection. b) The dissection of the sigmoid sinus. c) The resected sigmoid sinus. d) Method of area measurement by mm papers and in for the three different level of sigmoid sinus.

architecture of the confluens sinuum is the most effective prenatal factor for the right/left sigmoid sinus domination. Conversely, some researchers have proposed the right/left side partition of the superior sagittal sinus drainage as the reason for this obscure process<sup>[10, 14]</sup>. The anatomy of the confluens sinuum may explain the direction of the flow in the present study. We noticed that the shape and structure of the confluens sinuum show great diversity and seem to direct the flow unequally (Figure 1 a-d). However, other theses on genetic developmental effects are still at reasoning levels due to lack of powerful evidences. Besides the architecture of the confluens sinuum, brain development, location of ossification centers, neural crest cell effect, and molecular insult are also condemned<sup>[15-18]</sup>. From the molecular aspect, there are two main cascades including skeletogenesis and apoptosis during the final process of skull development. It has also been evidenced that genes from the Dickkopf family and matrix metalloproteinase 9 regulate these processes<sup>[11, 15, 19]</sup>.

The asymmetry of the cranial base deserves great attention not just for the investigational purposes but also for a better understanding of the developmental anatomy. Thorough anatomical knowledge is of utmost importance to achieve surgical success in this complex area<sup>[20]</sup> and to better understand the developmental process of skull base structures<sup>[21]</sup>. Cranial base asymmetry should be taken into consideration preoperatively, and every individual landmark for the chosen surgical approach to skull base should be suspected regarding whether it is in its normal location and has dimensions within normal range. Furthermore, hypoplasias and aplasias of all the skull base structures pose unavoidable surgical risks for the surgeons. Likewise, sigmoid sinus aplasia in the posterior fossa might even prove to be fatal if the surgery of the jugular foramen is to be performed on the only draining side.

## CONCLUSION

Fetal cadaver investigations may not only serve to better understand the mechanisms of asymmetry and/or hypoplasia-aplasia formation but also be fundamental to enlighten the preventive means probably affecting the sigmoid sinus dominance through multiple factors. Multicenter studies with greater number of fetuses would be better able to investigate this topic; furthermore, studies across different regions will provide an insight into the role played by genetic differences.

**Ethics Committee Approval:** This study was carried out on twelve fetuses of a gestational age ranging from 17 to 38 weeks with ethic committee approval (Date: 21.01.2011, Number: B.30.2.MEÜ.0.20.05.04/11) and studied in the Anatomy laboratory of Mersin University School of Medicine.

**Informed Consent:** N/A.

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