

Research Article

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## Investigation of structural properties of transverse sinuses in neurosurgical cases by three dimensional volume rendering technique using magnetic resonance images

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### Abstract

The detailed description of the neuroanatomical structure of the human brain's venous system, along with the examination of its neurophysiological, neurogenetic, neuropathological, and neurogeometric foundations, has not yet been sufficiently accomplished. The aim of this project is to provide accurate, useful, and up-to-date information on the structural characteristics and variations of the transverse sinuses key components of the brain's venous structures—based on neuroradiological studies. For this study, 44 patients (20 men and 24 women) aged between 20 and 79, who had undergone thin-slice magnetic resonance imaging (MRI) for various reasons at our neurosurgery clinic between 2016 and 2020, were randomly selected. The MRI images, obtained in DICOM format, were rendered into 3D using the volume rendering technique in the OsiriX program, enabling clear visualization of the transverse sinuses. Various angular, length, distance, width, and calibration measurements were then performed on these images. The resulting data were analyzed statistically using the SPSS v25 program. In the majority of patients, the right transverse sinus was dominant. No statistically significant correlation was found between dominance and gender or age ( $p = 0.681$  and  $p = 0.521$ , respectively). The exit angle of the right transverse sinus from the torcular Herophili was found to be significantly greater than that of the left transverse sinus ( $p = 0.013$ ). The diameters of both transverse sinuses were measured just before and just after the junction with the vein of Labbé, and the difference between the pre- and post-junction diameters was found to be statistically significant ( $p < 0.05$ ). Average distances between the transverse sinuses and the corresponding mastoid processes were determined, but no statistically significant difference was found between the dominant and non-dominant sides ( $p = 0.447$  and  $p = 0.912$ , respectively). The use of contrast-enhanced T1-weighted MRI combined with volume rendering to visualize the transverse sinuses in 3D by digitally removing the scalp and bone structures represents a significant advancement for the field of neurosurgery. This method highlights the importance of preoperative visualization of these veins in connection with surgical interventions. Measuring the distance of the transverse sinuses from defined anatomical landmarks and comparing these by age, gender, and dominance represents an innovative approach. Overall, this study will serve as a foundation for future research in brain venous anatomy. The numerical data and statistical findings presented here will be valuable for surgical planning and improving surgical success in centers lacking neuronavigation systems. The use of volume rendering technique with contrast-enhanced T1-weighted magnetic resonance imaging may contribute to the three-dimensional evaluation of the transverse sinuses for surgical planning. This method emphasizes the importance of preoperative visualization of venous structures. The findings of this study may provide a basis for future research on the venous anatomy of the brain and improve surgical success.

**Keywords:** transverse sinus, torcular herophilia, labbe vein, venous variations, magnetic resonance imaging, three dimensional volume rendering technique

### 1. Introduction

The venous vessels of the brain have been a less researched topic in the neurosurgical literature compared to the arterial system. Many anatomico-physiologic and cadaveric studies have focused primarily on the lateral surfaces of the brain, and detailed examination of the venous system has been relatively neglected. However, in recent years, with the development and more widespread use of surgical techniques in the midline and basal regions of the brain, interest in the venous system has increased markedly. The cerebral venous system is difficult to define as a standardized anatomical structure due to its large individual variations in size and connectivity (1, 2). The cerebral venous system plays a critical role in regulating cerebral blood flow and balancing intracranial pressure. This system, which lacks valve structures, exhibits a dynamic

network of complex anastomotic connections (3). The interruption of the main structures of the venous system during surgical intervention or occlusion by mass effect may lead to venous infarction and cause severe neurologic deficits. However, the severity of the clinical picture varies depending on the extent of anastomotic connections in the venous system. In the presence of widespread anastomoses, obstruction may present with milder clinical symptoms, whereas in areas with limited anastomotic connections, obstruction may cause severe neurologic deficits. Especially in areas with insufficient anastomoses, damage to the venous system can lead to serious life-threatening clinical pictures such as hemiplegia, coma and death. (4, 5). In order to better understand the complex structure of the venous system of the brain, neuroradiological

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studies can provide accurate, up-to-date and localizing information, as in the arterial system. Such studies provide an important guide for surgical and interventional approaches by defining the anatomical variations of the venous system in more detail. The transverse sinuses are one of the main components of the cerebral venous system. It extends bilaterally in the groove located in the occipital bone, along the posterior margin of the tentorium cerebellum and drains into the internal jugular vein via the sigmoid sinus (6, 7). Like other cranial venous sinuses, it lies between the two leaves of the dura mater (8). The Labbe vein, also known as the inferior anastomotic vein, usually drains into the transverse sinus (9, 10). The Labbe vein is of great clinical importance because of its capacity to maintain venous drainage in the event of obstruction or damage to the transverse sinus. Therefore, preservation of the Labbe vein during surgical interventions is critical to maintain venous return and prevent serious neurologic complications. (11).

One of the main objectives of this study is to process contrast-enhanced T1 sequence magnetic resonance imaging (MRI) data of the transverse sinuses using the volume rendering technique and to make them visible in three dimensions by removing the scalp and bony structures. It is aimed that the data obtained as a result of this examination will provide guidance for the surgeon during surgical planning and operation and contribute to increasing surgical success, especially in centers where neuronavigation systems are not available.

Within the scope of the study, the diameters of the right and left transverse sinuses and the exit angles from the torcular

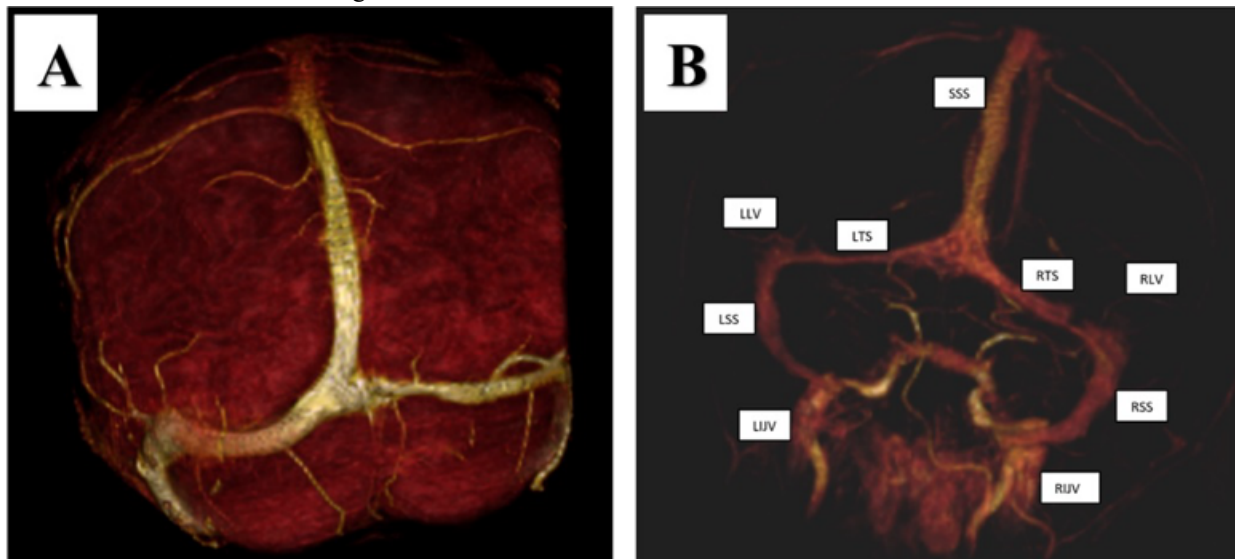
Herophili will be evaluated and the effects of the involvement of the Labbe vein on sinus calibration will be examined. In addition, it is aimed to compare these anatomical parameters in terms of both sides and to determine whether they differ according to gender and age variables. In addition, the distances of the transverse sinuses to the anatomical reference points will be measured and analyzed according to various parameters.

## 2. Material and Methods

Between 2016 and 2020, 44 patients (20 males and 24 females) aged between 20 and 79 who underwent thin-slice MRI for various reasons at the Department of Neurosurgery were randomly selected. Patients under the age of 18, as well as those with a history of cranial hemorrhage, mass lesions, cranial surgery, or cranial radiotherapy, were excluded from the study.

Within the scope of the study, 20 male and 24 female patients aged between 20 and 79 years who applied to Ondokuz Mayıs University Department of Neurosurgery with various clinical indications between 2016 and 2020 and underwent thin section magnetic resonance imaging (MRI) were randomly selected.

After obtaining the patients' contrast-enhanced T1-sequence MRIs in DICOM format, the images were rendered into 3D using the volume rendering technique in the OsiriX software, making the transverse sinuses (TS) visible (Fig. 1). Subsequently, various measurements were performed on these images, including angles, lengths, distances, widths, and calibrations.



**Fig. 1.** Contrast enhanced T1 sequence MR images processed with 3D Volume Rendering Technique in OsiriX program. (SSS: superior sagittal sinus; LTS: left transverse sinus; LLV: left vein of labbe; LSS: left sigmoid sinus; LIJV: left internal jugular vein; RIJV: right internal jugular vein; RSS: right sigmoid sinus; RLV: right vein of labbe; RTS: right transverse sinus).

A: Skin, subcutaneous and bony structures removed.

B: Dose adjustment was made and venous system was visualized.

The data obtained were analyzed in IBM SPSS 25 (IBM Statistical Package for Social Sciences) program. Descriptive statistics were given as number, percentage, mean±standard deviation and median (minimum and maximum values). Since

numerical variables were normally distributed, they were presented as mean±standard deviation. "Independent Samples T Test" was used for statistical significance between groups for variables that were found to comply with normal distribution

and homogeneity of variances of normal variables between groups was evaluated by 'Levene's test'. In the comparison of categorical variables, "Fisher Exact Test" was used by utilizing cross tabulations. In addition, the correlation between numerical variables was analyzed using the "Pearson Correlation Coefficient" since the variables were normally distributed.  $p < 0.05$  was considered statistically significant.

### 3. Results

Of the 44 patients who participated in the study, 24 (54.5%) were female and 20 (45.5%) were male. The ages of the patients ranged between 20-79 years with a mean age of  $47.3 \pm 17.3$  years. Female patients were aged between 20-79 years with a mean age of  $46.5 \pm 19$  years, while male patients were aged between 25-78 years with a mean age of  $48.3 \pm 15.5$  years, and no statistically significant difference was found between the mean ages according to gender ( $p = 0.744$ ) (Table 1).

**Table 2.** The relationship between age-gender and dominant sinus lateralization

		Right Dominant TS	Left Dominant TS	Codominant TS	p
Gender	Female	15 (51,7)	6 (54,5)	3 (75)	0.681 <sup>a</sup>
	Male	14 (48,3)	5 (45,5)	1 (25)	
Age		$47,8 \pm 18,8$	$43,8 \pm 12,7$	$53,7 \pm 18,8$	0.521 <sup>b</sup>

TS: Transverse Sinus

a: Fisher Exact Test, b: Independent Samples T Test

The exit angle of the left TS from the torcular herophilia was in the range of  $70^\circ$ - $112^\circ$  with a mean of  $95.9 \pm 7.8$ ; that of the right TS was in the range of  $79^\circ$ - $116^\circ$  with a mean of  $100.1 \pm 7.7$ . The mean right TS angle was greater than the mean left TS angle and the difference between these means was statistically significant ( $p = 0.013$ ) (Table 3).

**Table 3.** Analysis of the exit angle of the transverse sinus from the torcular herophilia between the parties

	Left TS	Right TS	p
Exit Angle	$95,9 \pm 7,8$	$100,1 \pm 7,7$	0,013*

\* Independent Samples T Test

Both dominant and other TS diameter means were found to be higher after the addition of the labbe vein than before and

**Table 5.** TS diameters of patients according to gender

	Female	Male	p
Pre-Labbe Dominant TS Diameter (mm)	$7,2 \pm 1,8$	$6,7 \pm 1,6$	0,323*
Post-Labbe Dominant TS diameter (mm)	$9,2 \pm 1,3$	$9,0 \pm 1,4$	0,572*
Pre-Labbe Non-dominant TS Diameter (mm)	$4,6 \pm 1,4$	$4,7 \pm 1,3$	0,826*
Post-Labbe Non-dominant TS Diameter (mm)	$7 \pm 1,5$	$6,8 \pm 1,3$	0,656*

\* Independent Samples T Test

The distance between the TS and the same side mastoid process was measured and compared according to gender. The measurement points were the point where the labbe vein joins the TS and the same side mastoid process, and the distance was calculated in centimeters. The mean distance between the dominant TS and the same side mastoid process was  $2.1 \pm 0.1$

**Table 6.** Distance between the TS and the same side mastoid processes of the patients

	Female	Male	p
Distance of the dominant TS to MP	$2,1 \pm 0,1$	$2 \pm 0,1$	0,447*
Distance of the non-dominant TS to MP	$2,2 \pm 0,2$	$2,1 \pm 0,1$	0,912*

MP: Mastoid Process

\* Independent Samples T Test

**Table 1.** Demographic properties of the patients

	Female	Male	Total	p
	24 (54,5)	20 (45,5)	44	0.128**
Mean Age	$46,5 \pm 19$	$48,3 \pm 15,5$	$47,3 \pm 17,3$	0.744*

\* Independent Samples T Test; \*\* Chi-square

The dominant transverse sinus was right in 29 patients (65.9%), left in 11 patients (25%) and codominant in 4 patients (9.1%). In patients with dominant left transverse sinus, the proportion of women (54.5%) was higher than that of men (45.5%), whereas in patients with dominant right transverse sinus, the proportions of women (51.7%) and men (48.3%) were close to each other. In patients with codominance, the proportion of women (75%) was higher than that of men (25%). However, no statistically significant relationship was found between the gender of the patients and the dominant transverse sinus lateralization ( $p = 0.681$ ). Again, no statistically significant relationship was found between age and dominant sinus lateralization ( $p = 0.521$ ) (Table 2).

this difference was statistically significant ( $p < 0.05$ ) (Table 4).

**Table 4.** Analysis of the change in TS diameter before and after the addition of labbe vein

	Pre-Labbe	Post-Labbe	p
Dominant TS diameter(mm)	$6,9 \pm 1,7$	$9,1 \pm 1,3$	$< 0.05^*$
Non-dominant TS diameter (mm)	$4,7 \pm 1,4$	$6,9 \pm 1,4$	$< 0.05^*$

\* Independent Samples T Test

When the relationship between the mean TS diameters measured and gender was analyzed, no statistically significant result was found ( $p > 0.05$ ) (Table 5).

in women and  $2 \pm 0.1$  in men. The mean distance between the nondominant TS and the same side mastoid process was  $2.2 \pm 0.2$  in women and  $2.1 \pm 0.1$  in men. There was no statistically significant difference between these measurements between male and female patients ( $p > 0.05$ ) (Table 6).

The relationship between age and TS diameters was analyzed and no statistically significant correlation was found ( $p>0.05$ ) (Table 7).

**Table 7.** The relationship between age and TS diameters

		Pre-Labbe Dominant TS Diameter	Post-Labbe Dominant TS Diameter	Pre-Labbe Non-dominant TS Diameter	Post-Labbe Non-dominant TS Diameter
Age	Pearson Correlation(r)	-0,156	-0,080	-0,059	0,069
	p	0,510	0,738	0,805	0,774

#### 4. Discussion

No correlation was found between the gender and age of the patients included in the study and the lateralization of the dominant TS, and it was found that the right TS was dominant in the majority of the patients. Our results are similar to the literature (12, 13).

The exit angles of the transverse sinuses (TSs) from the torcular Herophili were analyzed, and it was observed that the exit angle of the right TS was statistically significantly greater than that of the left TS. This finding may be associated with the dominance of the right TS. No previous studies examining these angles were found in the literature.

As a result of the measurements, it was found that both dominant and nondominant TS diameter increased statistically significantly after the addition of the labbe vein. The reason for this may be thought to balance the pressure against the increased volume load with the loss of the labbe vein. If it were possible to measure blood flow velocities right here, it would be possible to determine whether the blood flow velocity, which should be low on the dominant side due to the laws of physics, is really low or high. There are some studies in which the diameter of the TS has been examined; however, it has been stated that no clear inference can be made due to morphologic variations (14).

It was observed that TS diameters on both sides were not gender-dependent, both left and right TS diameters increased in both sexes with the shedding of the labbe vein, but the amount of this increase did not change with gender. Recent studies have reported that TS thrombosis is more common in women (15). Although no anatomical dimensional or angular difference was found, it is likely that one of the reasons for this statistic in the clinic is the different functioning physiology between the two sexes.

The distance between the point where the labbe vein drains into the TS and the mastoid process was calculated in the patients and it was found that these measurements did not vary depending on gender. With these calculations, anatomical information was obtained to make the surgery safer and easier, including the skin incision and dissection phase. Although not similar to our measurements, there are studies showing the estimated localization of the sinuses and torcular herophilia by measuring the distances to the determined anatomical points (16).

It was found that TS diameters did not change with age. Many anatomical and physiological changes occur in the human body with aging. However, it is remarkable that the transverse sinus diameter remains constant. In studies, it has been reported that venous anatomy changes with age in pediatric patients and the sinuses reach maximum diameter at a certain age (17).

This study has revealed many important results, but it also has some deficiencies. Considering the diagnosis of the patients at the time of presentation to the clinic while making comparisons will show whether the results obtained change in patients presenting with different diagnoses and in which patient group they are more applicable. This is only possible by increasing the number of patients included in the study.

The venous system in the midline and basal regions of the brain, which has received more attention with the development of surgical techniques over time, often has variations in size and connections. This study has provided very important numerical and statistical data on the venous anatomy of the brain. We believe that these data will pioneer future studies on the cerebral venous system. It is a fact that as the number of studies and data increase, surgical planning can be made more accurately and surgical success will increase, especially in centers without neuronavigation systems.

In this study, the anatomical structure and variations of the transverse sinuses were analysed in detail and significant findings were obtained especially in terms of dominance orientation, exit angles and diameter variations associated with the Labbe vein. It was observed that the transverse sinuses were more dominant on the right side, but this dominance was not related to gender or age. Furthermore, there were significant differences between the exit angles of the sinuses from the torcular Herophilia and the involvement of the Labbe vein caused significant changes in sinus diameter. Distance measurements to the mastoid process were similar regardless of gender. The findings obtained may provide a better understanding of the anatomical position of the transverse sinuses in neurosurgical practice and may guide surgical planning. This study constitutes an important resource in terms of raising awareness of anatomical variations, especially in centres where neuronavigation is not available, and may form the basis for more comprehensive morphometric studies in the future.



**Conflict of interest**

The authors declared no conflict of interest.

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None to declare.

**Authors' contributions**

Concept: M.A., R.E., Design: M.A.E, Data Collection or Processing: M.A.E, Analysis or Interpretation: M.A.E, R.E., C.C., Literature Search: M.A.E, R.E., C.C., Writing: M.A.E., R.E., C.C.

**Ethical Statement**

This study was conducted with the approval of the Ondokuz Mayıs University Clinical Research Ethics Committee, based on our application numbered 2021000136-3 and approval decision number 2021/136.

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