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The evaluation of cerebral venous normal anatomy and variations by phase-contrast cranial magnetic resonance venography

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Abstract

Background: The aim of our study is to determine the ability of the PC-CMRV technique to detect cranial anatomy, variations, thrombosis, to reveal the deficits of the technique and to discuss the reasons for these deficits on a physics basis.

Materials and methods: PC's detection rates of anatomic variations and physiological filling defects (FDs) were evaluated in 136 patients and compared with the time-of-flight (TOF) technique MRI and cadaveric studies.

Results: The dominance correlation between the three evaluated sinuses (*transverse sinus (TS), sigmoid sinus, jugular vein*) which originated from different embryological buds were statistically significant and the right vessel chain was dominant. PC is inadequate to show some vessels like *inferior sagittal sinus* (anatomically, this vessel is approximately present in 100% of the cases, but it was only visualized in 41.2% of the patients in PC-MRI). Visualization of *major veins* was sufficient. PC-MRI creates physiological FDs in 27.2% (72,3% middle,10.3% inner,17% outer part) of the patients. The FDs were concentrated in the middle part and not observed in the dominant sinus.

Conclusions: The defects of visualization are present due to the PC's technique. It can be misdiagnosed as agenesis or thrombosis. PC creates a high incidence of physiologic FDs in *TS*. The results are not reliable, especially if FDs are in the middle part or non-dominant side.

Key words: magnetic resonance, venography, dural sinuses, phase contrast, arachnoid granulations

INTRODUCTION

Cranial magnetic resonance venography (CMRV) is the basic imaging method in the evaluation of venous sinuses, since it is a non-invasive and non-irradiating technique [1]. Time-of-flight (TOF) and phase-contrast (PC) are the techniques used in CMRV [2]. CMRV is the most common method used in scientific research to evaluate venous variations [3]. Our study is one of the first studies performed with the PC technique using a 1.5 Tesla MRI machine.

According to literature, right chain vascular structures are remarkably dominant. *Why is that? Transverse sinus* (*TS*) and *sigmoid sinus* (*SS*) originate from the *posterior plexus*, *jugular vein* (*JV*) originates from the *anterior cardinal vein (ACV)*. The correlation between these embryological structures can be determined by comparison of dominance [4]. *Can the embryological mechanisms be explained by evaluating the correlation of vascular structures originating from different embryological bud's? Is the embryological mechanism independent or interdependent?*

Venography is a technique mostly used to detect thrombosis. Filling defects (FDs) are the main diagnostic finding in cranial magnetic resonance venography (CMRV), but it can also be seen as physiological except for thrombosis [3,5]. The percentage of these defects had been evaluated in previous studies [5-7], however the points where the defect is located on the *TS* are not specified. *In which segments are FDs common? Which physical and physiological mechanisms can be associated with these FDs?*

The aim of our study is to determine the ability of the PC-CMRV technique to detect cranial anatomy, variations, thrombosis, to reveal the deficits of the technique and to discuss the reasons for these deficits on a physics basis.

MATERIAL AND METHODS

Patients

Ethics committee approval was obtained for this study with document number 0945/7. 214 patients who had CMRV were chosen for the preliminary exam. Patients with a history of operation, thrombosis, ischemic change, tumor, congenital anomalies, small vessel disease and demyelinating diseases were excluded from the study. All subjects were followed up for two years to exclude thrombosis.

Finally, 136 patients were included in the study :50 males and 86 females; mean age [±SD], 48,7 ± 16,3 years, range, 18-93 years. Males mean age [±SD] is 47,6 ± 12,9 years; range between19 and 86 years old. Females mean age [±SD] is 50,6 ± 13,7 years; range between 18 and 93 years old. All our patients were in the adult age group. CMRV and conventional MRI's (CMRI) of all the patients were evaluated by one experienced radiologist and one neuroradiologist and evaluated together again in case of a discrepancy.

Imaging examinations

A 1.5-tesla PHILIPS (The New Intera Nova, Philips medical system, Best, Netherlands) device was used for scanning. CMRV examinations were performed using the 3D PC technique without applying any saturation band. Maximum intensity projections (MIPs) were created at the MR operating console for the 3D CMRV dataset. The standard parameters that were used as follow: FOV = matrix 230/70 = 256x256, slice 160, thickness =1, Col= 1, TR / TE: 16 / 6,8. The images were obtained with axial sections in 3D / FFE sequence. The last images were created with a velocity encoding (VENC) method by applying bipolar gradients sequentially along the cardinal directions (x-, y-, and z-).

Image analysis

The images obtained with the picture archiving and communication system (PACS) were scanned in different projections for various veins in each patient. All veins were evaluated in raw images and 3D MIP images obtained by PC technique.

TS, *SS*, *JV*s dominancy were determined according to gender. Measurements were taken 1 cm from the torcular herophili for the *TS*, 1 cm from the *TS* junction for the *SS*, 1 cm

from the *SS* junction for the *JV* [8,9]. If there is a difference greater than 1/5 between the sinuses, the larger side was evaluated as dominant.

In addition, *Superior sagittal sinus (SSS), Inferior sagittal sinus (ISS), Straight sinus (StS), internal cerebral vein (ICV), Galen vein (GV), Basal vein of Rosenthal (BVOR), occipital vein (OV), Labbe vein (LV) and Trolard vein (TrlV)* were evaluated bilaterally. All vein's PC visualization rates were compared with anatomical cadaveric studies and we found the real visualization. The bilateral *TS* was divided into 3 equal parts (I: Inner part, II: Middle part III: Outer part) and physiological FDs' percentages were calculated.

Statistical analysis

The obtained data were enrolled and tabulated using the Office excel (Microsoft) data recording system. The data were analysed using statistical software (SPSS, IBM). All continuous variables were expressed as counts and averages were calculated (mean [± SD]). Percentages were calculated for qualitative values. Pearson and chi-square analysis were used for comparisons. The p value < 0,05 was accepted as statistically significant. Kendal Tau B test was performed in the non-parametric correlation analysis.

RESULTS

Dominances of *TS, SS* and *JV* were evaluated:

For *TS*: Right(R)-dominance was found in 52(38,23 %), left(L)-dominance in 37(27,95%), co-dominance in 47(32,35%) of the patients.

For *SS*: R-dominance was found in 54(39,70%), L-dominance in 38(27,95%), co-dominance in 44(32,35%) of the patients.

For *JV*: R-dominance was found in 46(33,82%), L-dominance in 30(22,06%), co-dominance in 60 (44,12%) of the patients.

According to gender:

For males; *TS*: R-dominance was found in 20(44,00%), L-dominance in 12(24,00%), co-dominance in 16(32,00%) of the patients *SS*: R-dominance was found in 23(46,00%), L-dominance in 13(26,00%), co-dominance in 14(28,00%) of the patients *JV*: R-dominance was

found in 19(%38,00) L-dominance in 10 (20,00%), co-dominance in 21 (42,00%) of the patients.

For females; *TS*: R-dominance was found in 30(34,88%), L-dominance in 25(29,06%), co-dominance in 31(36,04%) *SS*: R-dominance was found in 31(36,04%), L-dominance in 25(29,07%), co-dominance in 30(34,88%) of the patients *JV*: R-dominant was found in 27(%31,40) L-dominance in 20(23,25%), co-dominance in 39(45,34%) of patients.

The *TS*, *SS*, *JV*'s dominances' prevalence and frequency according to gender group are demonstrated in Table 1.

There was no statistically significant difference according to gender (*TS*, p=0,567; *SS*, p=0,507; *JV*, p=0,726).

Kendal Tau B correlation analysis was applied to evaluate the relationship between *TS*, *SS*, and *JV* dominance. The dominance relationship between the three evaluated sinuses on the right and left separately was statistically significant. The strongest correlation (τb: 0.945) was found between left *TS* and left *SS*. The lowest level of relationship (τb: 0,791) was found between left *TS* and left *JV*. Tau b correlation between sinuses is demonstrated in Table 2.

All patients had *SSS*. However, *SSS* was completely visualized in 132(97,06%) patients. In 4(2,94%) patients, the anterior part of the *SSS* was not seen. ISS were visualized in 56(41,17%) of the patients [32 (37,21%) females 24 (48,00%) males]. *StV*, *ICV*, *GV* were visualized in all of the patients. *BVOR* was seen in 130(95,59%) and *OC* in 11(8,09%) of the patients. The percentage of detection of venous structures in the study are demonstrated in Table 3.

The existence of *TrlV* and *LV* were coded (as '+' present, '-' absent).

For *TrlV*: R+L+ was found in 28(20,59%), R+L- in 30(22,06%), R-L+ in 23(16,91%), R-L- in 55(40,44%) of the patients.

According to gender:

For females, R+L+ was found in 17(19,77%), R+L- in 19(22,09%), R-L+ in 13(15,12%), R-L- in 37(43,02%) of the patients.

For males, R+L+ was found in 11(22,00%), R+L- in 11(22,00%), R-L+ in 10(20,00%), R-L- in 18(36,00%) of the patients.

For *LV*: R+L+ was found in 73(53,67%), R+L- in 27(19,85%), R-L+ in 21(15,44%), R-L- in 15(11,03%) of the patients.

According to gender:

For females, R+L+ was found in 49(56,98%), R+L- in 17(19,77%), R-L+ in 10(11,63%), R-L- in 10(11,63%) of the patients.

For males, R+L+ was found in 24(48,00%), R+L- in 10(20,00%), R-L+ in 11(22,00%), R-L- in 5(10,00%) of the patients.

There was no statistical difference according to gender. (p:0,153 for *TrlV* and p:0,060 for *LV*). Bilaterally, *TrlV* and *LV* visualization rates according to the gender are demonstrated in Table 4.

Finally, physiological FDs in the TS were evaluated. They were present in 37 of 136 patients (27,2%). 10 of these patients had FDs in more than one segment. In total 47 FDs were determined. 34 of them were in the middle segments.

Two patients (1,48%) had FDs in the right outer part: one partial (0,74%) and one complete (0,74%). Both of them were in the non-dominant sinuses. Fifteen FDs (11,03%) were in the middle part of the right *TS*: thirteen were partial (9,55%) and two complete (1,48%). Thirteen were in the non-dominant sinuses, whereas two in the co-dominant sinuses. Two patients (1,48%) had FDs in the right inner part: one partial (0,74%) and one complete (0,74%). Both of them were in the non-dominant sinuses. Three patients (2,21%) had FDs in the left inner part: two partial (1,48%) and one complete (0,74%). Three of them were in non-dominant sinuses. Nineteen (13,97%) were in the middle part of the left *TS*: sixteen partial (11,76%) and three complete (2,21%). Sixteen were in the non-dominant sinuses, whereas three in the co-dominant sinuses. Six (4,41%) were in the outer part of the left *TS*: one partial (0,74%) and five complete (3,67%). Five were in the non-dominant sinuses, whereas one in the co-dominant sinuses. There was no FD in the dominant sinuses. The FDs according to segments were demonstrated in figure (Fig. 1).

DISCUSSION

The dominance of the cerebral venous vessels is crucial before the radical neck dissection, excision of tumours invading the *TS, SS, JV* or glomus jugular tumours that may require ligation of the internal *JV*s [10]. In this study *TS*, *SS*, and *JV*'s dominances were found as right dominance (44%), co-dominance (32%) and left dominance (24%) (Fig. 2). Although the percentages change, the order didn't change for both anatomic and radiological studies as well as this study [5,11,12]. *Why right dominance is more visualized than left?* We can find

the answer to this question in the hypotheses belonging to the embryological development period. The *superior vena cava* originates from the *right ACV* together with the right *JV*. The caudal part of the left *ACV* largely regresses in the development process. If it does not regress, an anomaly called *double vena cava* occurs. *ACV*s merge with the *posterior plexus* which gives origin to *TS* and *SS*. Earlier joins coinciding with the regression process on the left, possibly lead to recessive left vessel chain. *ACV* regression on the left side influences not only *JV* but also *TS* and *SS* [4,13]. This study revealed that if the *TS* was dominant, the *SS* and *JV* were also dominant on the same side [2]. It showed that ipsilateral embryological buds move together. This information supports the hypothesis above.

Since the use of oral contraceptives and pregnancy is associated with cranial venous thrombosis, the use of CMRV is more common in women [3]. In our study, the majority of our patients were females (86 females, 50 males). There was no statistically significant gender-related difference between the *TS*, *SS* and *JV* dominances (p=0,567 for *TS*, p=0,507 for *SS*, p=0,726 for *JV*). The results of Goyal et al. were similar [14].

PC's venous detection rates were evaluated and compared with anatomic studies. *SSS* was found at a rate of 100%. This finding is similar to the literature [5-7]. SSS develops from the marginal sinus. Partial fusion defect at the attachment point of the marginal sinus to the foramen cecum causes a partial growth defect anteriorly. This situation is called *partial split sinus (PSS)* [2]. In Kaplan and Browder's cadaveric series, *PSS* prevalence was found as 6% [15]. In our study, *PSS* variant of the *SSS* was observed at a rate of 2.94%. The signal loss may occur in the anterior section because the flow is going in the same direction as the artery, when an inferior saturation band is used to prevent arterial flow in TOF images [9]. In comparison with cadaveric studies, the percentage values are lower in our study. Its mean is that there is no signal loss due to PC technique in this area, unlike TOF.

In radiological studies, the presence of the *ISS* was noted between 33-43% [16,17]. In our study, it was found at a rate of 41.17% (Fig. 3). In this case, it is necessary to look at the cadaveric studies. According to these ones, ISS was not detected in only 1% of the cases. To sum up, normally *ISS* is present but devices' visualization and technique aren't adequate to show this vessel [18]. We looked at a study performed with more primitive device (0.35-tesla low-resolution) conducted by Sharma for explain more clearly the effect of device quality on venous visualization. Visualization rates with the low-tesla device of *ISS*, *BVOR, ICV* are respectively 11%, 34%, 60%.

In this study, many vascular structures that we visualized could not be sufficiently imaged. We can say that the lower the quality of the device, the poorer the visualization [19]. 3T, 5T and 7T devices' visualization of minor venous vessel probably will be higher than our study. It is open to further research.

In our study, *BVOR* was detected at a rate of 95.58%. It was not observed unilaterally in five and bilaterally in one of the patients. In Ayanzen's TOF research, *BVOR* was detected in 91% of the patients. Our data are close to these findings [5]. We didn't find a cadaveric study to compare the percentage of basal vein [18]. *StS, ICV, and GV* were detected in all of the patients. Results of other studies were similar to ours [5,19]. When FDs are found in 100% visualized veins, it should be accepted primarily as pathological.

It has been reported that the *OV* is more prominent in patients with thrombosis [20]. If the *TS* and *SS* are hypoplastic, the *OV* is used as an alternative outflow pathway [9]. In our study, the *OV* detection rate with PC was found as 8,09%. *OV* prevalence is between 4% and 35.5% according to data from reviewed anatomic and radiological TOF studies by Goyal et al [14]. Our results were included in the aforementioned interval (Fig 4).

TrlV and *LV* form the main venous communicant anastomotic network. The *LV* provides the connection between the *silvian veins* and the posterior group, whereas the *TrlV* provides the connection between the *SSS* and *the silvian veins*. For this reason, it is also named as *trolard-labbe circle*. For example, when *JV* ligation is performed, if this network is not fully developed, venous infarction is probable. The *LV* should be preserved in temporal lobectomies and surgical interventions for epilepsy. Isolated thrombosis in *LV*, *TrlV* and related infarct cases have been reported in the literature [21,3]. The angiographic studies elaborating information about these veins are present too [22]. Returning to our main subject, after we indicated why the *LV* and *TrlV* should be fully visualized and their clinical importance; our technique's detecting rate of *LV* and *TrlV* is close to other anatomical and radiological studies [5-7]. In addition, during our study, we noticed that there was no study according to gender regarding *LV* and *TrlV*, and we added it as a subtopic to the paper. There was no statistically significant difference (p:0,153 for *TrlV* and p:0,060 for *LV*) according to gender (Fig 5 a,b).

CMRI evaluation can give useful findings about thrombosis but it is not adequate in the final diagnosis. In MRI; the intensity of the thrombus changes according to the period. *What is the weaknesses of CMRI and CMRV?* Thrombus due to effect of *deoxyhemoglobin* appears isointense at T1 and hypointense at T2 in the first 5 days. During this period, the hypointensity of the thrombus at T2 makes it impossible to be detected in CMRI. Thus,

venous thrombus can only be detected by angiography [3]. Since 7% of deaths due to venous thrombosis happens in this period, it is important for the patient to be diagnosed early. Unfortunately, diagnosis is usually delayed for 7 days [9]. In these early days, where CMRI does not show any benefit and there is a risk of mortality, misleading sinus FDs are more important. Patients are mostly diagnosed within 5-15 days. This phase is also called the *metheamoglobin* phase. During this period, the thrombus T1 and T2 are hyperintense [3]. T1 hyperintensity is reflected as hyperintense in TOF technique also. Deleting of the flow void leads to interpreting the CMRV as normal. This situation is not seen in the PC technique. In this period PC is superior than TOF [9]. After 15 days, *re-canalization phase (chronic phase)* starts [3]. In the chronic phase, pathways form within the thrombus. There is also dural enhancement accompanying capillary formation. Thus, it leads to a false negative result in contrast-enhanced MRI angiographic evaluation [9]. In this period, it cannot be mentioned that contrast enhanced MR angiography, which is accepted to be more advantageous than non-contrast CMRV, is superior to TOF and PC. It will be useful to evaluate CMRV FDs by comparing them with CMRI. Each technique has its pros and cons according to the period. It will be useful to evaluate CMRV images together with CMRI to prevent FDs from causing false diagnosis. In the early period, contrast enhanced MRI angiography, digital subtraction angiography in selected cases can be used for diagnosis [23].

TOF technique is used overwhelmingly in the CMRV examinations. The reason why PC research is rarely used is the long time according to TOF scanning [2]. Before mentioning the physical mechanisms of FDs, let’s briefly talk about the general points of the techniques. Phase shift is undesirable in TOF therefore, "phase compensation technique" is used to prevent this. Phase shift that we want to prevent in TOF constitutes the basic of imaging in PC. In this technique, images are taken in pairs (phase shift) while operating in (+) and (-) gradient directions. Fixed textures are removed from the image with "Image subtraction"; thus, only vascular structures are made visible. The technique is not sensitive to saturation due to flow; consequently, vascular structures with slow blood flow are better visualized in PC than in TOF. In addition, functional information such as flow direction and speed can be obtained with this technique [24]. PC's background suppression feature and anatomic detailing are superior to TOF’s ones [2,25].

PC’s has many disadvantages. The duration is long in PC and the eddy current effect is evident. It is sensitive to turbulence, spin saturation and intervoxel dephasing. It is also affected by intrinsic factors of the nucleus. Gradient imperfection secondary to inappropriate setting is creating aliasing artifacts in the flow direction as well. Gradient performance is

directly related to device quality. There are many biomedical engineering articles in the literature about PC gradient settings. It is necessary to predict the appropriate gradient phase in advance [2].

Apart from this, there are some factors that cause FDs independent from the technique. This group consists of *arachnoid granules (AG)* and *fibrotic bands* located in the sinuses [9]. *SSS* and *TSs* are the most common places where AGs are seen. The majority of them are located between the middle and lateral parts in the *TS* (92%) [26-28]. Apart from the prominent eddy current effect due to PC technique, *AG* contributes to the formation of FD with mechanical effects [27,28]. Fibrotic bands can make mechanical barrier effect too but it is rarely seen [9].

The FD were detected in the centre (*R2-L2*) at the rate of 72,3%, in the inner part (*R3-L1*) at the rate of 10.3%, in the outer part (*R1-L3*) at the rate of 17% in *TS* (Fig. 6). All the disadvantages resulting from intrinsic nuclear factors mentioned above are present in all of the segments. Gradient effects are more pronounced on sharp turns in the segments *R3-L1* and *R1-L3* (outer and inner parts of *TS*). Besides, when the eddy current effect and the over mentioned physical barrier effects (*AG*) are added, a complex set of causes creates artifacts in corners and central segments [2,25,29].

The movements of the spins in the presence of magnetic field gradients change the phase of the MR signal. These effects occur if blood flow goes a long way in the imaging volume, such as the *TS*. Phase shifts created by this movement cause artifacts in the phase coding direction and degrade image quality. This physical effect is more pronounced in PC than TOF [25]. The intrinsic nuclear factors contribute also to cause *L2-R2 (middle parts of right and left TS)* midpoint artifacts. Since the flow continues on a linear line, it will not be affected by the gradient effect's refraction. The *AGs* is considered as the primary flow defect factor in the middle part. *AGs* are concentrated between the middle and lateral segments. When blood crosses from a physiological barrier like *AG*, the eddy current effect is towards the part where the blood is going, not where it comes. Considering the anatomical point where AGs are concentrated, this area exactly corresponds to the middle part of the sinus [25]. Since that the venous sinuses are structures that don't have a muscularis mucosa, that can expand according to the flow rate and they don't contain valves; two-way flows are possible and reverse flows are more pronounced in the middle section according to the hydro physics rules [3,25]. Add to this, the venous sinuses that are connected to the right atrium by a relatively short vascular way without valves, are affected by diastolic contractions [13]. Another question is *why physiological FDs are not usually detected in the SSS in MRI*? Two theorems

can be put forward for this. The first is the flow rate. The *TS* is the main portal, collecting all venous blood. It is connected to the *superior vena cava* via the *SS* and *JV*. It is clear that *SSS* and *other minor veins* have lower flow rate. The second reason is the presence of *AGs*. Despite AGs are abundant in the *SSS*, giant *AG*s are found in the *TS* thus eddy current effects of giant AGs can be more prominent. [3,25].

The FDs were in the non-dominant or co-dominant *TSs*. No FD was found in the dominant *TS*. Since the non-dominant sinus percentage was higher on the left side, the frequency of FDs was higher on the left side too (right 40.4%, left 59.6%). To conclude, a FD in the dominant sinus should be primarily interpreted as thrombosis in PC studies. Physio pathologically, in recessive sinuses, eddy currents are sharper. When the diameter of the sinus is narrow, the number of spins per unit area decreases. The space-occupying effects of AGs become more pronounced.

The FD rates with TOF technique that were found by Ayanzen, Alper and Saad Ahmet; are respectively 31%, 24% and 10.8% [5-7]. In our study, the rate that was found is 27%. We can say that our FD rates are similar to other TOF and PC studies.

The study has some limitations. The tests have not been confirmed with anatomic specimen.

CONCLUSIONS

This study is the first to assess the performance of PC technique by using normal anatomic and variations data. It is also the first time that dominances were correlated for explaining embryologic movements during the development of this region. Our results showed that the right vessel group is mostly dominant and found statistically significant correlations between the dominances of *TS, SS* and *JV* originating from different embryological buds. Left *ACV* regression also affects the *posterior plexus* during *superior vena cava*'s embryological development at right. Our article supports this embryological theorem. The visualization degree of major veins in PC were sufficient but it was inadequate for determining some vessels like *ISS* (anatomic presence was approximately 100%, visualization was only 41,2%). In comparison with our device, low-tesla device's visualization of vessels is poorer. The higher the quality of the device, the higher the visualization rate. FDs observed in the veins normally visualized should primarily considered as thrombosis. For the first time, *TS*'s FDs was evaluated according to segments in PC and causes of FD's were discussed based on physiopathology. Indeed, PC creates a high proportion of physiological FDs in *TS*. Results should not be trusted, especially if FDs are

present in the middle part or non-dominant side. In the middle segment, defects are primarily related to slow flow and *AG* while eddy current artifacts affected the corner parts. TOF and PC are similar to create FDs. Let's remind, the research has been done in normal patients and concerns the PC's ability to demonstrate normal anatomy and its variations. PC may be superior for showing thrombosis because of the above mentioned physical rules. This topic will be opened future research.

Availability of data and material: This is a retrospective study. Approval was obtained from İzmir Atatürk Training and Research Hospital with 0945/7 before the study. The data were obtained from the pacs system and no illegal or prohibited data was included in the study.

Code availability: During the study, the programs purchased by Muğla Sıtkı Koçman University and İzmir Atatürk Education and research hospital were used legally.

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SINUS		R-dominant		L-dominant		C-dominant	
		Number	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**
TS	Female	30	34,88 %	25	29,06 %	31	36,04 %
	Male	22	44,00 %	12	24,00 %	16	32,00 %
	Total	52	38,23 %	37	27,95 %	47	32,35 %
SS	Female	31	36.04 %	25	29.07 %	30	34.88 %
	Male	23	46.00 %	13	26.00 %	14	28.00 %
	Total	54	39,70 %	38	27.95 %	44	32,35 %
JV	Female	27	31,40 %	20	23.25 %	39	45,34 %
	Male	19	38.00 %	10	20,00 %	21	42.00 %
	Total	46	33.82 %	30	22.06 %	60	44.12 %

Table 1. TS,SS,JV dominances according to gender and side

Table 2. Dominances correlation of the TS, SS,JV sinuses with keddall tau -b test

Dominancy	**Compared sinuses**	**Tau-b correlation coefficient**	**Probability value**
Right dominant	ST and SS	τ_b:0,877	p:0;000
	ST and VJ	τ_b:0,877	p:0;000
Left dominant	ST and SS	τ_b:0,945	p:0;000
	ST and VJ	τ_b:0,791	p:0;000
Co-dominant	ST and SS	τ_b:0,836	p:0;000
	ST and VJ	τ_b:0,836	p:0;000

Table 3. PC's visualization ratio in cranial venous vessels

Anatomic Localisation		**Present**		**Absent**	
		Number	Percentage	Number	Percentage
SSS		136	100 %	0	0 %
	Complete	132	97,06 %		
	Incomplete	4	2,94 %		
ISS		56	41,17 %	80	58,83 %
	Female	32	37,21 %	54	62,79 %
	Male	24	48,00 %	26	52,00 %
SV		136	100 %	0	0
ICV		136	100 %	0	0
GV		136	100 %	0	0
BVOR		130	95,59 %	6	4,41 %
OV		11	8,09 %	125	91,91 %

Table 4. PC's visualization ratio of Trolard and Labbe veins

Veins		R+ L+		R+ L-		R- L+		R- L-	
		Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Trolard	Female	17	19,77 %	19	22,09 %	13	15,12 %	37	43,02 %
	Male	11	22,00 %	11	22,00 %	10	20,00 %	18	36,00 %
	Total	28	20,59 %	30	22,06 %	23	16,91 %	55	40,44 %
Labbe	Female	49	56,98 %	17	19,77 %	10	11,63 %	10	11,63 %
	Male	24	48,00 %	10	20,00 %	11	22,00 %	5	10,00 %
	Total	73	53,67 %	27	19,85 %	21	15,44 %	15	11,03 %

Figure 1: Segmental distribution of filling defects in transverse sinuses, abbreviations; R: right, L: left.

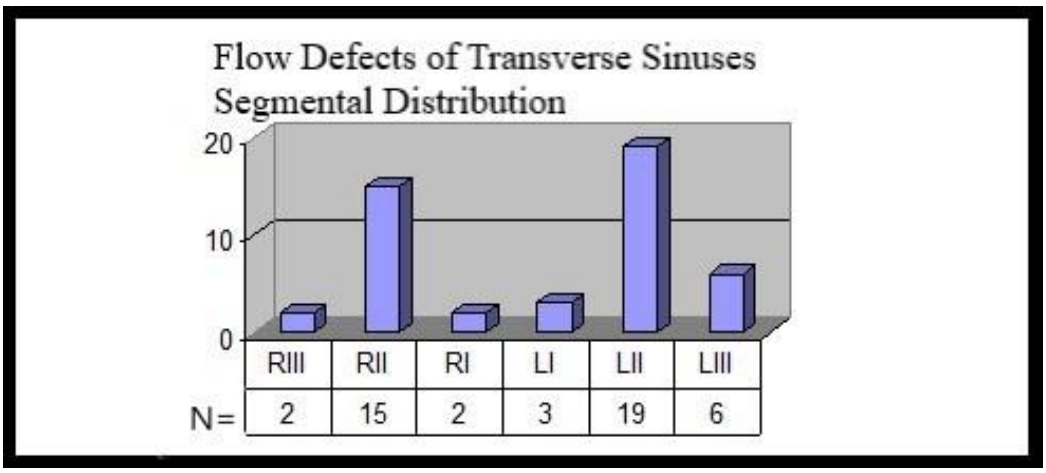

Figure 2. Venous sinuses are dominant in right (arrow: *SS* arrowhead: *TS* cutted arrowhead: JV)

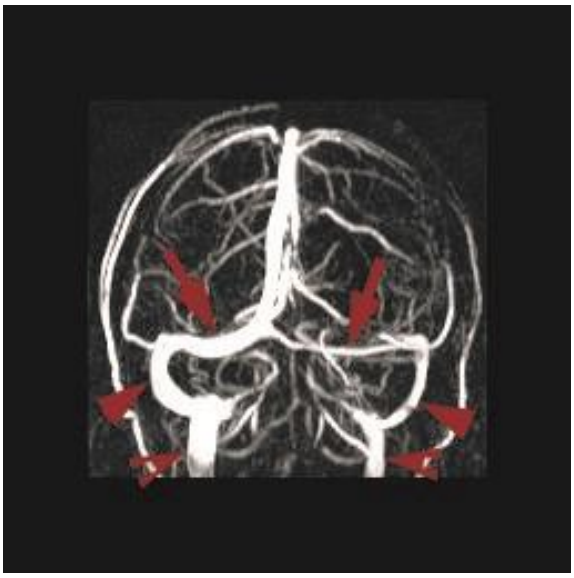

Figure 3: Internal cerebral veins (arrow) and *GV* (arrowhead) in MIB images

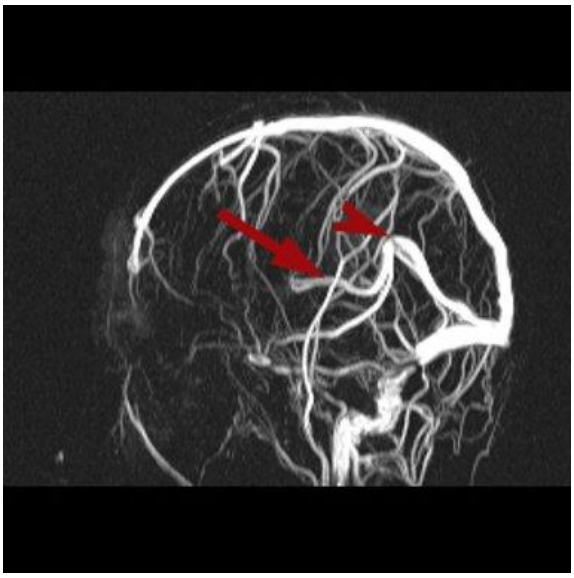

Figure 4: *OV*s in posterior view of MIB images(arrow)

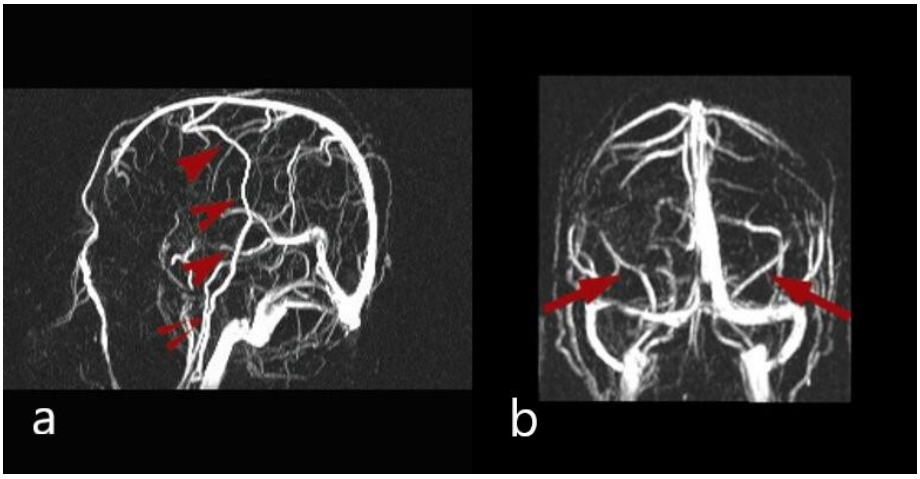

Figure 5: *TrldVs* (arrowheads) and *LVs* (arrows)

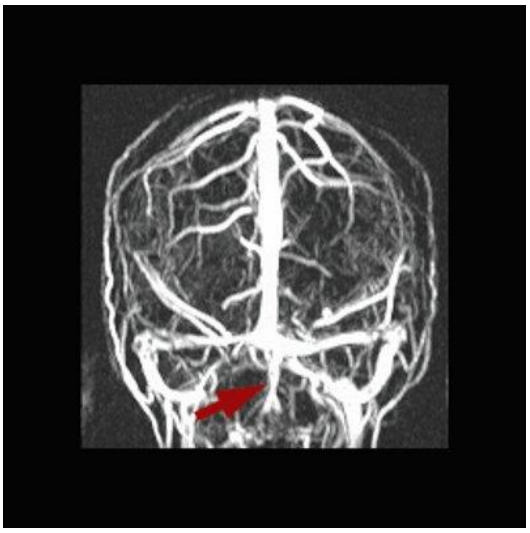

Figure 6: Physiological filling defects of *TS* **a.** Filling defect of left inner and middle segments (arrow) **b.** Filling defects of right inner segment (arrow) **c.** Filling defect of left inner and middle segments (arrow) **d.** Filling defect of right outer segment (arrowhead)