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ORIGINAL ARTICLE **ARAŞTIRMA YAZISI**

TRANSTEMPORAL ACOUSTIC BONE WINDOW ADEQUACY CAN BE DETERMINED BY B-MODE SONOGRAPHY: PROSPECTIVE TRANSCRANIAL B-MODE AND COLOR DOPPLER ULTRASOUND IN 375 NEUROLOGICALLY ASYMPTOMATIC VOLUNTEERS

Mehmet Akif TOPÇUOGLU, Ezgi YETİM ARSAVA, Ezgi YILMAZ, Ethem Murat ARSAVA

Hacettepe University, Medical Faculty Hospitals, Neurology Department, Ankara, TURKEY

ABSTRACT

INTRODUCTION: The success and quality of transcranial color Doppler insonation of the middle cerebral artery (MCA) can be determined by visualization of craniocerebral sonoanatomical markers defined by transcranial B-mode sonography. This strategy can bring practical gains to the neurosonology examination.
METHODS: Transcranial B-mode sonography and transcranial color Doppler ultrasonography were performed in 375 healthy control patients (Female: 217, age: 64 ± 9 years) over 50 years of age with no apparent neurological disease. The quality of sonic imaging of the contralateral temporal bone (CTB), mesencephalon (MB) and ipsilateral sphenoid bone small wing (LSW) was determined by the Suzuki classification, and their diagnostic properties were determined in terms of recordability of the MCA Doppler signal.
RESULTS: Failure to record the MCA Doppler signal on at least one side is 4.6% (95% CI: 3.2 -6.4%) and is significantly higher in women (11.1% vs. 0.6%). For failure to receive MCA doppler signal, lower limit of 95% confidence interval of the sensitivity of MB total nonvisualisation in B-mode was 87%, along with specificity of 99%; the sensitivity of LSW sonic absence was 80% and specificity was 93%; sensitivity and specificity of non-sufficient insonation of CTB were 29% and 99.5%; sensitivity and specificity of suboptimal (visualization of less than half of the border of CTB) insonation of CTB were 89.5% and 99.5%, respectively.
DISCUSSION and CONCLUSION: B mode sonography can easily identify the inadequacy of the transtemporal acoustic window for MCA Doppler examination. Failure of imaging of the contralateral temporal bone may be more guiding than mesencephalon and ipsilateral sphenoid bone.
Keywords: Transcranial Doppler, gray scale, temporal bone, diploe, flow velocity, pulsatility.

TRANSTEMPORAL AKUSTİK KEMİK PENCERE YETERLİLİĞİ B-MOD SONOGRAFİ İLE SAPTANABİLİR: 375 NÖROLOJİK OLARAK ASEMPTOMATİK GÖNÜLLÜDE PROSPEKTİF TRANSKRANİAL B-MOD VE RENKLİ DOPPLER ULTRASONOGRAFİ ÇALIŞMASI

ÖZET

GİRİŞ ve AMAÇ: Transkranial B-mod sonografi ile kranium ve içindeki anatomik belirteçlerin tespit edilmesi ile transkranial orta serebral arter (MCA) renkli Doppler insonasyon başarısı ve kalitesi belirlenebilir. Bu muayenede pratik kazanımlar getirebilir.
YÖNTEM ve GEREÇLER: 375 (Kadın: 217, yaş: 64±9 yıl) 50 yaş üzerinde ve görünürde nörolojik hastalığı olmayan sağlıklı kontrol olguda transkranial B-mod sonografi ve transkranial renkli Doppler ultrasonografi yapılmıştır. Kontralateral temporal kemik ("CTB"), mezensefalon ("MB") ve ipsilateral sphenoid kemik küçük kanadın ("LSW") sonic görüntülenebilme kalitesi Suzuki sınıflaması ile belirlenmiş ve bunun MCA Doppler sinyali kaydedilebilmesi için diagnostic özellikleri saptanmıştır.
BULGULAR: Bir tarafta MCA Doppler sinyali kaydedilememesi %4,6 (%95 GA: 3,2%-6.4%) olup kadınlarda anlamlı olarak fazladır (kadın: %11,1 ve erkek: %0,6). MCA Doppler sinyali elde edilememesi için B-modda MB'nin hiç görülememesinin

Corresponding author: Prof. Mehmet Akif Topçuoğlu MD. Hacettepe University Faculty of Medicine, Department of Neurology, 06100 Ankara, Turkey.
Phone: 03123051990 **E-mail:** matopcuoglu@yahoo.com
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duyarlığı (%95 güven aralığının alt limiti) %87, özgüllüğü %99; LSW hiç seçilemesinin duyarlığı %80 ve özgüllüğü %93; CTB hiç görüntülenememesinin duyarlılığı %29 ve özgüllüğü %99,5; CTB'nin yarısından azı görülmüş ise duyarlılık %89,5 ve özgüllük %99,5'dir.
TARTIŞMA ve SONUÇ: B mod sonografi ile transtemporal akustik pencerenin MCA Doppler incelemesi için yetersizliği kolayca belirlenebilir. Kontralateral temporal kemiğin görüntülenemesi mezensefalon ve ipsilateral sphenoid kemik küçük kanadın görüntülenememesinden daha yol gösterici olabilir.
Anahtar Sözcükler: Transkranial Doppler, gri skala, temporal kemik, diploe, akım hızı, pulsatilite.

INTRODUCTION

Rapid insonation of the middle cerebral artery (MCA) in Transcranial Colored Doppler Ultrasonography (TCCD) is of importance for the practicality of the examination. The determination of whether the transtemporal bone window is suitable for insonation is critical at this point. Otherwise, searching for the Doppler signal can cause a significant loss of time. Unfortunately, the temporal bone acoustic window in 10% of cases, especially in women and in the elderly, makes sonographic examination impossible. Moreover, sonography becomes inefficient, time consuming and low-reproducible in almost same percentage due to increased internal tabular irregularity, because of the advanced age or postmenopausal period (1-3). B-mode transcranial sonography provides the advantage of documenting some anatomical cue points, making it easier to detect the examination plane, as well as allowing the sample volume to be placed at the color filling point directly (4,5). Its one advantage over the conventional non-imaging Transcranial Doppler (TCD) examination is the easier detection of the location of the bone window, despite somewhat eliminated disadvantages by the use of M-mode technology (6). However, this advantage, namely the relationship between B-mode and the appearance of basic anatomical markers and the quality of MCA color fillings has not been studied in depth in the literature. There was no data on healthy people, the white race, and the Turkish population in this context, and the only available study was conducted in stroke patients in Japan (7). In this study, transtemporal sonic window quality was evaluated with transcranial B-mode sonography in healthy people in Turkey, and this was correlated with the quality of MCA insonation with TCCD. In addition, the first normal values were obtained for TCCD in our community.

MATERIAL AND METHODS

The study was conducted with the short-term atrial fibrillation cohort of the Hacettepe University Faculty of Medicine (Ethics Committee approval GO13/243) (8). These articles can be reviewed within the scope of the methodology, however, to put it briefly, apparently healthy individuals over the age of 50, who had no stroke history, no chronic neurological disease and no atrial fibrillation were included in the study by invitation, prospectively. This analysis was performed using TCCD studies that were routinely recorded in these patients. It does not cover the entire cohort.

In the study, GE LogiQ P6 multi-purpose ultrasonography system, 1-3 MHz sector transducer was used (3,4). Transtemporal B-mode and color Doppler examination were performed using traditional methods. All examinations were completed by the same sonographer. Although it is optimized for the most convenient imaging during the inspection, the initial configuration is as follows: B-mode frequency 2 MHz, Gain 68, depth 14 cm, DR 63, FR 53Hz: color Doppler Frequency 1.7 MHz, Gain 23.5, PRF 2 kHz, WF 185 Hz and S/P 3/16; Pulse Doppler Frequency and 1.7 MHz, Gain 18, PRF 5.3 KHz, WF 150 Hz, the "sample volume" 4-mm, DR 36, the sweep speed 3, and SV depth was 5.6 cm.

In the transtemporal B-mode examination, contralateral temporal bone (CTB), mesencephalon (MB), and ipsilateral lesser sphenoid wing (LSW) were rated according to the Suzuki classification (Figure I) (7). These structures are categorized as "Invisible" if they cannot be seen at all, "Poor" if less than half of the shape and its contours can be identified, "Fair" if more than half can be seen, and classified as "Good" if all can be viewed. The color filling of the M1 segment is classified as follows: "Invisible" if

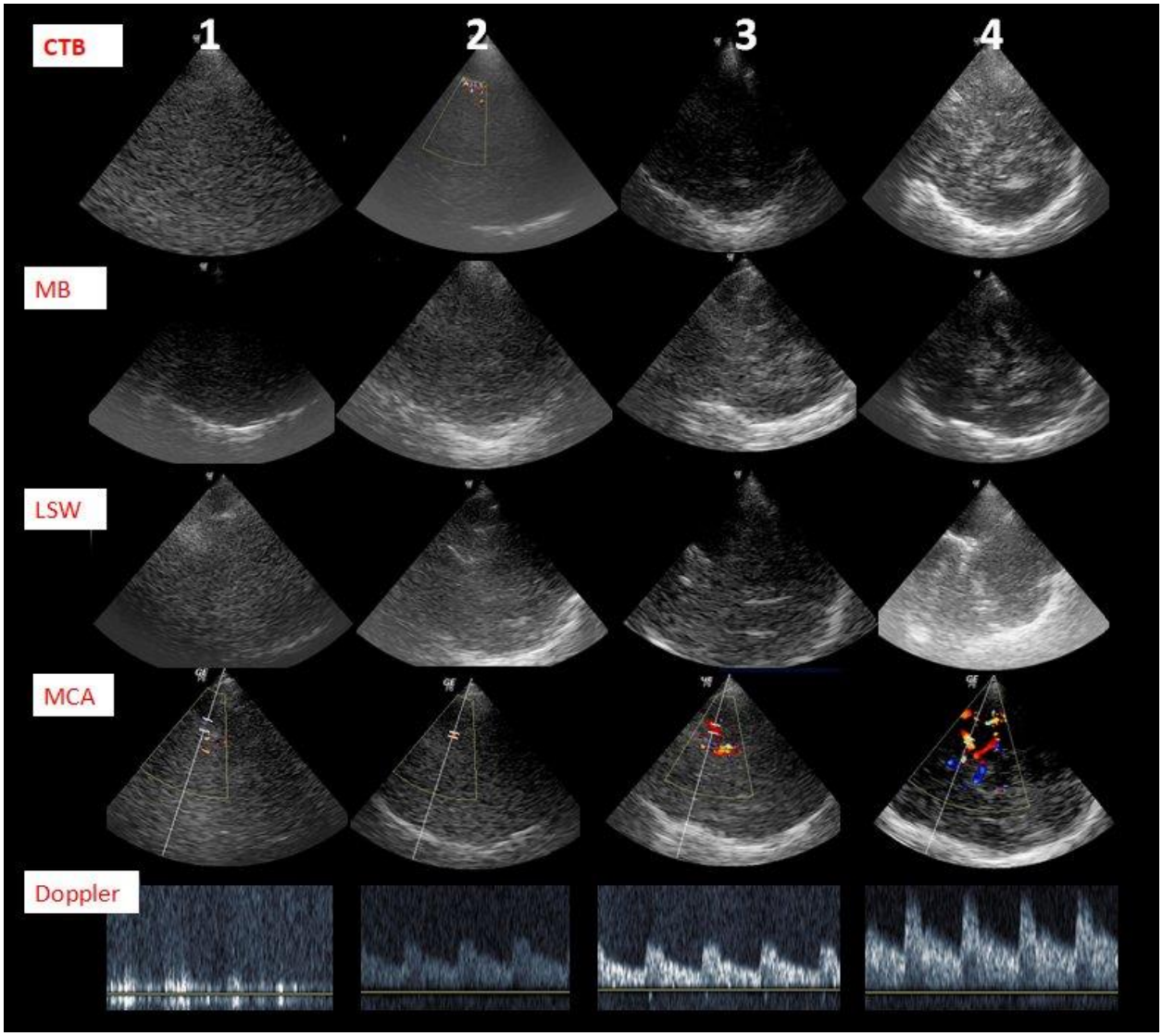

Figure I. Suzuki classification (See the text [method section] for abbreviations and explanations).

there is no signal, "Poor" only if there are color spots, "Fair" if there is a linear, but interrupted color filling, and "Good" if it is linear and continuously visible.

The mean MCA current rate ("Vmean") and pulsatility index ("PI"), which are the sonographic characteristics of MCA, were also determined by performing Pulse TCD in these patients.

Statistics: All values were given as "mean±standard deviation" and "percentage (95% confidence interval)", and Student's t test, ANOVA, Chi-square and Spearman correlation tests were used in the comparison of the groups. About the detection of studied B-mode parameters in MCA insonation, "sensitivity", "specificity", "positive likelihood ratio (L+)", "negative likelihood ratio (L-)", "positive predictive value", and "negative predictive value" were calculated and expressed as averages (with 95% confidence interval). $P<0.05$ was the accepted level for statistical significance, and all analyses were performed with the SPSS version 22 software.

RESULTS

A total of 375 people were included in the study, including 217 females and 158 males. The mean age was 64±9 years (50-90 years), body weight was 77.5±2.27 kg, height was 160±10 cm, waist circumference was 99.8±11.4 cm. During transcranialsonography examination, systolic

blood pressure was 134±18 mmHg and diastolic blood pressure was 79±11 mmHg. Of the study group, 51% had hypertension, 19.7% had diabetes mellitus, 49.5% had dyslipidemia, 19.7% had coronary artery disease, and 31.6% was active smokers.

A total of 4.63% (95% GA:3.23%-6.41%) of MCA could not be insonated. In other words, color filling was not achieved and no signal was recorded with pulse Doppler. CTB was invisible in 29% of them, whereas CTB was poorly visible in 71%. While mesencephalon was invisible in all of them, LSW was invisible in 94% cases, and was weak in 6%. Unilateral measurement was performed in 14% of the MCAs that could not be insonated. There was no difference between right and left in this respect. The mean MCA insonation depth was 51±7 mm, and Vmean was 48±11 cm/s and mean PI was 0.92±0.18. The inversely proportional relationship between age and Vmean (r=-0.369), and the proportional relationship with PI (r=0.545) was also confirmed in this series. There was no difference between insonation quality and PSV, EDV, Vmean and PI values (no data provided).

While MCA was insonatable when there was no CTB signal detected (1.4%), it was possible to have MCA Doppler recording in 14.3% of the patients, in cases with poor CTB signal (3.8%). It was possible to insonate MCA in case of a fair (11.7%) and good (83.1%) CTB. Mesencephalon was not visible in 5.6% of the cases. However, MCA current was detected in the Doppler in 17% of the cases. A visible mesencephalon at any quality in B-mode means that the MCA Doppler signal can be recorded from that side. The lesser sphenoid wing (or planum temporale) was not visible from the ipsilateral side in 4.6% of the cases.

However, MCA Doppler signal was obtained in 3% of these cases. MCA velocities can be determined in the vast majority of cases where the sphenoid wing is poorly visible (Table I). Correlation between image quality of B-mode sonoanatomic structures is high: Correlation constants were determined as r=0.744 for CTB and MB, r=0.733 for CTB and LSW, and r=0.917 for MB and LSW.

At an advanced age, transtemporal sonic window permeability decreases. The mean age of patients whose MCA could not be insonated was significantly higher (71±11 vs. 63±9, p<0.001). Those with invisibility in term of CTB, MB and LSW were 10 years older than the "good" sonic window group (Figure II).

At least one failure to insonate MCA in women was significantly more common (11.1% vs. 0.6%, p<0.001). There was no difference between MCA determination and sonic window quality on the right and left (Table II). The relationship between bone window and MCA detection with B-mode examination is more beneficial in women. If CTB was not visible in women (2.4%), then it will not be possible to insonate MCA. However, if CTB is suboptimal, then the possibility to read MCA signal is 14%. If mesencephalon was invisible (9.8%), then the probability of MCA insonation was 17% (Table II, Figure III).

In the inability to obtain an MCA Doppler signal, MB invisibility has an 87% sensitivity (lower limit of 95% confidence interval) and 99 specificity, LSW invisibility has an 80.3% sensitivity and 92.8% specificity, CTB invisibility has a 29% sensitivity and 99.5% specificity, and a half visible CTB (this is usually in the posterior part) has a sensitivity of 89.5% and specificity of 99.5% (Table III).

Table I. Transtemporal sonic window indices according to detectable MCA Doppler signals.

		Total			Female		
			MCA Doppler signal can be insonated			MCA Doppler signal can be insonated	
		Frequency	No	Yes	Frequency	No	Yes
CTB	Invisible	1.4%	100%	0%	2.4%	100%	0%
	Poor	3.8%	86%	14%	6.7%	86%	14%
	Fair	11.7%	0%	100%	17.1%	0%	100%
	Good	83.1%	0%	100%	80.3%	0%	100%
MB	Invisible	5.6%	83%	17%	9.8%	83%	17%
	Poor	10.8%	0%	100%	15.7%	0%	100%
	Fair	15.7%	0%	100%	21.7%	0%	100%
	Good	68%	0%	100%	52.9%	0%	100%
LSW	Invisible	4.5%	97%	3%	7.9%	97%	3%
	Poor	11.6%	2%	98%	17.6%	3%	97%
	Fair	17%	0%	100%	23.6%	0%	100%
	Good	66.9%	0%	100%	51%	0%	100%

Note: See the text for abbreviations.

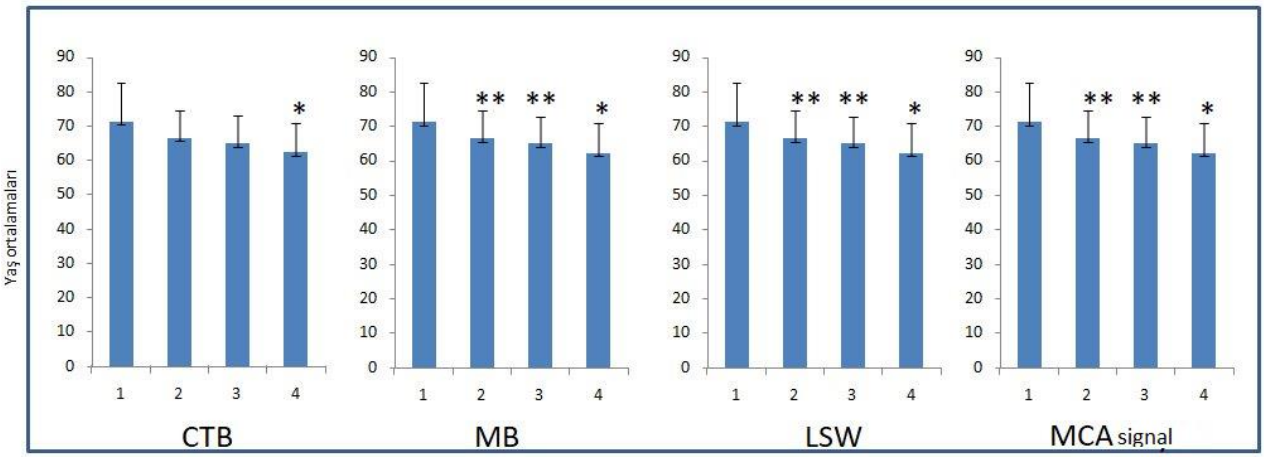

Figure II. Average age distributions of B-mode sonography indices according to Suzuki categories.

Table II. Temporal acoustic window quality by gender and lateralization.

	Left contralateral temporal bone				Right contralateral temporal bone			
	Invisible	Poor	Fair	Good	Invisible	Poor	Fair	Good
Female	2.4%	7.1%	17.1%	73.3%	2.4%	6.2%	17.1%	74.3%
Male	0%	0%	4.5%	95.5%	0%	0%	4.5%	95.5%
	Left mesencephalon				Right mesencephalon			
	Invisible	Poor	Fair	Good	Invisible	Poor	Fair	Good
Female	9.5%	16.7%	21.9%	51.9%	10%	14.8%	21.4%	53.8%
Male	0%	3.8%	7.6%	88.5%	0%	4.5%	7.6%	87.9%
	Left lesser sphenoid wing				Right lesser sphenoid wing			
	Invisible	Poor	Fair	Good	Invisible	Poor	Fair	Good
Female	8.1%	17.6%	23.8%	50.5%	7.6%	17.6%	23.3%	51.4%
Male	0%	3.2%	7.6%	89.2%	0%	3.8%	8.9%	87.3%
	Left MCA				Right MCA			
	Invisible	Poor	Fair	Good	Invisible	Poor	Fair	Good
Female	8.1%	21.4%	23.8%	46.7%	8.1%	18.6%	21.4%	51.9%
Male	0%	3.2%	8.9%	87%	0%	3.8%	10.2%	86%

Table III. Diagnostic criteria for the B mode indices.

	No MB visibility	No LSW visibility	No CTB visibility	CTB is less than half visible
Sensitivity	100.0% [89.6- 100.0%]	94.1% [80.3-99.1%]	29.41% [15.1 -47.5%]	89.5% [75.2 -97.0%]
Specificity	99.0% [98.0 - 99.6%]	99.9% [99.2 -100.0%]	100.0% [99.5-100.0%]	100.0% [99.5 - 100.0%]
Positive likelihood ratio (L+)	100.00 [47.85 -208.99]	658.82 [92.76%-4679.08]	-	-
Negative likelihood ratio (L-)	0.00	0.06 [0.02 -0.23]	0.71 [0.57 -0.88]	0.11 [0.04 -0.27]
Positive predictive value	82.9% [67.9-92.8%]	97.0% [84.2-99.5%]	100.0% [69.0-100.0%]	100.0% [89.6-100.0%]
Negative predictive value	100.0% [99.5-100.0%]	99.7% [99.0-100.0%]	96.7% [95.1 -97.9%]	99.4% [98.5-99.8%]

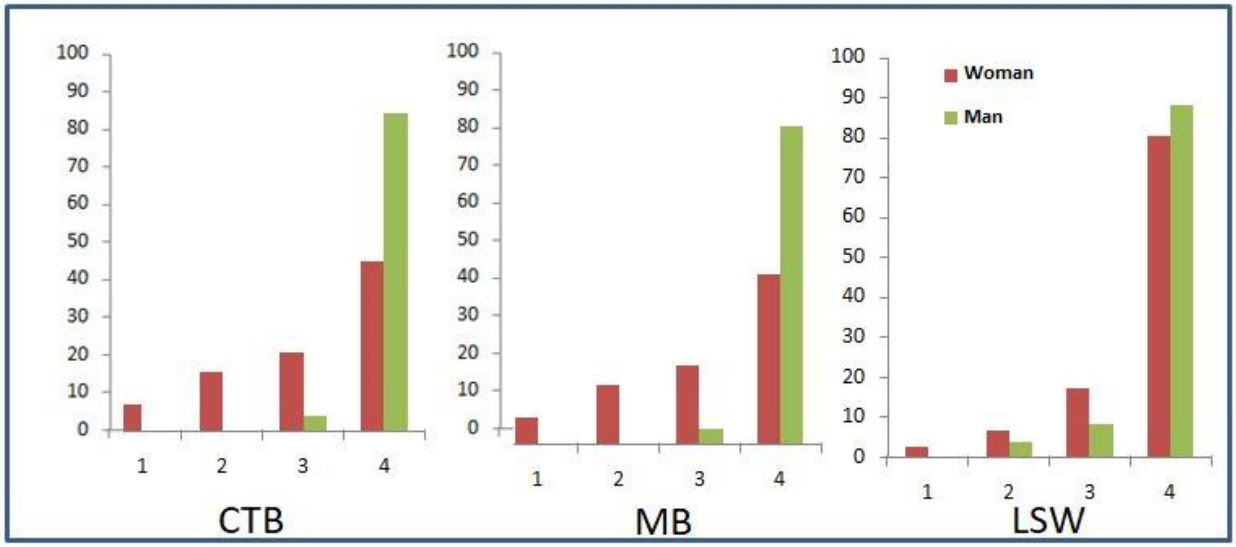

Figure III: Gender distribution of B-mode Sonography indices according to Suzuki categories.

DISCUSSION

In B-mode sonography, the success status of the MCA color Doppler examination is predictable immediately after placing the transducer in the temporal region. This appears to be particularly efficient in females. If the temporal bone on the opposite side is not visible at all, it will definitely be not visible in the MCA, according to our study. In addition, visibility of less than half of the opposing temporal bone, especially only the posterior part, i.e. the preauricular part, also likely (the success rate in this series was only 14%) indicate that MCA cannot be insonated of sufficient quality. If more than half of the opposing temporal bone is visible, MCA can almost always be adequately insonated. In this respect, the most indicative B-mode sonography parameter is the opposite temporal bone. Possible causes of the difference between us and the Suzuki group (7), which presents the most important B-mode parameter as the insonation state of the ipsilateral lesser sphenoid wing, may be differences such as race, gender, sonographer experience, and device.

Mesencephalon cannot be seen in 10% of women in B-mode on the ipsilateral side, and even in this case, the MCA Doppler signal can be obtained in 17% cases. Therefore, although the inability to display mesencephalon is important, it does not mean that MCA cannot be insonated. However, if mesencephalon is visible even a little, the MCA color Doppler signal can surely be insonated. In this case, the Doppler signal should be searched in the color-filling areas by moving the sample volume in the conventional localization and positions by appropriate "gain", "angle", and "alignment".

According to our study, the invisibility of ipsilateral sphenoid bone most likely (97%) means that MCA cannot be insonated either. However, in cases where LSW is partially seen, MCA color reads may not be possible to a certain degree, which is about 3%.

The strengths of the study include a fairly adequate number of participants, the fact that neurosonological examinations were performed by an experienced and the same neurosonologist, and its prospective design. In this study, the adequacy of the transtemporal bone window was not compared with another method. The thickness of the squamose part of the temporal bone in CT in stroke patients, the superficial irregularity and heterogeneity of the tabulas can provide information about the success of transcranial Doppler signal recording (10). In one study, the thickness above 5-mm was found to have 90% sensitivity in indicating inability to obtain an MCA TCD recording (11). In addition to being impractical, these values appear to be lower than the B-mode sonography diagnostics we have. Not having conventional TCD in this study is not a disadvantage, because the TCD set-up, acoustic

window passage, insonation success are the same as triplex TCCD systems (12).

In conclusion, this study showed that the adequacy of temporal acoustic bone window can be determined to a large extent during the B-mode phase, the first phase of the transcranial colored Doppler examination, in a relatively large number of seemingly healthy volunteers without a neurological and neurovascular disease. This will, of course, shorten the examination time and help in developing strategies for the quick color Doppler.

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