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Usg And Cta Correlatıon In Carotıd Artery Stenosıs

Meltem Duraklı Ulukök[1*], Ümit Derundere[2]

[1]0000-0002-09850103, sevimeltem@gmail.com, Cankaya Medical Center, Izmir, Turkey
[2]0000-0002-0865-1073, umitderundere@yahoo.com, Cankaya Medical Center, Izmir, Turkey

***Corresponding author:** Meltem Duraklı Ulukök
sevimeltem@gmail.com, Cankaya Medical Center, Izmir, Turkey

Cerebrovascular pathologies due to atherosclerosis are the most common cause of morbidity and cardiovascular diseases and the 3rd widely known cause of mortality after cancer (Silvennoinen HM ,2007). Cerebrovascular pathologies are responsible for 95% of stroke, and ischemic stroke is the cause of approximately 80% of stroke cases due to cerebrovascular pathologies. Cardiac thromboembolism is responsible for only 1/5 of transient or permanent cerebral ischemia, and 4/5 is due to atherosclerosis (Landewehr P ,1995). It is stated in the literature that extracranial carotid artery atherosclerosis ranks third among the causes of ischemic stroke. (Ooi Y.C, 2015).

Present knowledge base indications for the solving of carotid artery stenosis on the presence of detectable symptoms and the degree of percentage (%CS) of carotid artery stenosis (Hobson RW 2nd, 2008). Therefore, in order to plan the treatment that will provide the most benefit to the patient, it is of great importance to determine the pathology correctly and to measure the degree of stenosis correctly. In the previous European Carotid Surgery Study (ECST) and North American Symptomatic Carotid Endarterectomy Studies (NASCET), carotid endarterectomy (CEA) has been reported to be beneficial in patients who are symptomatic and have stenosis between 70% and 99%. (European Carotid Surgery Trial,1991, North American Symptomatic Carotid Endarterectomy Trial Collaborators.1991).

However, DSA is far from being a screening method due to its invasiveness, relatively high mortality-morbidity (1-4%) and high cost. It has been reported that the risk of stroke and TIA is 0.4-2% after DSA (Heiserman JE, 1994). It has even been shown that minor asymptomatic infarcts due to microemboli develop in patients who do not have any obvious neurological complications after DSA (Bendszus M, 1999). The morbidity of angiography is increased in patients with "pseudoocclusion" (very narrow stenosis with a "string sign" on angiography) and emphasize the need of a safer method in order to diagnose possible cases.

This is the reason why non-invasive or minimally invasive diagnostic methods such as US, MRA and CTA are more preferred as screening methods.

Color Doppler US (CDUS) is used as an inexpensive, noninvasive and important screening test that provides morphological and hemodynamic information. Even with a high degree of stenosis, the accuracy of conventional ultrasound in detecting ICA stenosis is uncertain. It is stated that this rate is between 95-99% (Ascher E, 2002, Mansour MA, 1995). Considering the diagnosis of occlusion, the positive predictive value (PPV) of RDUS scan is in the range of 86-98% when compared with standard angiography (Mattos MA, 1992, Kirsch JD, 1994, Bridgers SL. 1989, Bornstein NM, 1987). Some centers have used CDUS as the only standard method for carotid artery exploration before endarterectomy (Patel SG, 2002). On the other hand, it is known that some symptomatic patients with near-obstructive stenosis are mistakenly classified as having occlusion in their evaluation with CDUS (Hammond CJ, 2007, Verlato F, 2000). There are disadvantages such as the technical equipment of the device used in this imaging method, the anatomical features of the patient and the experience of the practitioner being decisive, and the inability to visualize the vessel lumen in the presence of dense plaque calcification. The main disadvantage of CDUS is interobserver variability, which raises concerns about its safety and highlights the need for another noninvasive, but less operator-dependent and more reliable imaging modality (Corti R, 1998, Wessels T, 2004, Nonent M, 2004, Patel SG). , 2002, Leclerc X, 1995, Leclerc X, 1999). Although

MRA is a reliable method especially in advanced stenosis, it tends to overestimate the degree of stenosis (Masaryk TJ, 1993).

CTA is a rapid, noninvasive and relatively inexpensive test. The development of multi-detector computed tomography (MDCT) systems has revolutionized the field of CTA, and the entire carotid-vertebral system, from the aortic arch to the intracranial segments, can be visualized in the arterial phase within a few seconds. Today, CTA is used in addition to or as an alternative to DSA in the investigation of carotid and vertebral artery stenosis and intracranial aneurysmsMoreover, some studies in the literature suggest that it is possible to consider CTA as a gold standard. (Chen CJ, ,2004, Lubezky N, 1998, Droste DW, 1999). However, catheter angiography continues to be a reference examination method today due to its known advantages.

In addition to the degree of carotid stenosis, the morphological features of the plaque causing stenosis are also important determinants of stroke risk (Rothwell PM, 2000). Recent studies on carotid artery disease suggest that plaque morphology should be evaluated for better treatment planning. With the introduction and widespread use of carotid USG, which is a non-invasive method, carotid artery stenosis is more easily detected and its importance as a stroke risk factor becomes clearer. Determining the degree of stenosis in the carotid system, the contents of the plaques and the surface properties of the plaques by Doppler ultrasonography and evaluating the risk of rupture of the plaques are important in the choice of treatment in stroke patients.

Medical treatment is applied in patients with stenosis below 50% who are symptomatic. In stenosis between 50-69%, in addition to medical treatment, Doppler USG is used every 6 months to investigate whether there is a progression. Carotid endarterectomy is performed in patients with stenosis greater than 70% and symptomatic in the 'near occlusion' group. Surgery is not possible in case of complete occlusion.

The annual risk of developing stroke in asymptomatic carotid stenosis is 1.3-3.3%. Thus, it is important to determine which types of plaques cause stroke to prevent stroke (Mathiesen EB,2001). Of the morphological features of the plaques, rupture of the fibrous cap, intra-plaque hemorrhage, lipid-rich large necrotic body, erosion on the mural thrombus, and neovascularization of the plaque were associated with ischemic cerebrovascular disease (Shyam Prabhakaran, 2006, Peng Gao, 2007). It was found that plaques with irregular surfaces increase the risk of ischemic stroke 3 times (Mathiesen EB,2001). Plaque structure and content are equally important in the preference of surgical treatment in patients with symptomatic and moderate stenosis and in patients with asymptomatic stenosis (Hatsukami TS, 2010). Atheromatous carotid plaques should be carefully examined to determine plaque extension, localization, surface contour, and luminal stenosis.

The USG B mode image shows the physiological characteristics of blood flow along with plaque morphology in the artery wall, including flow velocity and flow direction. Ulceration plaque morphology (ulcer, ulcerless), plaque type (fatty, calcified, mixed) are important parameters to determine the risk of plaque rupture and subsequent thromboembolism (Sun R,2018). The plaque structure is characterized as low, medium or high echogenicity and homogeneous or heterogeneous. The homogeneous plaque has a single echo and its surface is smooth (Langsfield M, 1988). The heterogeneous plaque has more complex echoes and contains at least one or more sonolucent areas. Heterogeneous plaque contains intraplaque hemorrhage and/or lipid, cholesterol and protein materials. Low-echogenic plaques are common in symptomatic cases, and hemorrhage and ulceration often accompany such plaques (Polak JF, 1998).

In line with the results of the consensus meeting, which was formed by a large number of US users, published in 2003, the parameters that should be used in carotid artery stenosis today are determined as in the table (Table 1). It is the method recommended by NASCET, which was defined for angiography and is now accepted for US, for the proportional determination of the amount of narrowing in the stenosis area (Figure 1). In this method, the diameter at the narrowest point in the longitudinal plane is proportional to the diameter of the normal distal artery.

Stenosis Degree (%)	ICA PSV (cm/s)	ICA / CCA PSV ratio	ICA EDV (cm/s)
Standard	<125	<2,0	<40
<50	>125	<2,0	<40
50–69	125–230	2,0–4,0	40–100
70 – pre-occlusion	>230	>4,0	>100
Pre-occlusion	Variable	Variable	Variable
Occlusion	No flow	-	No flow

Table 1. ICA stenosis criteria of 'Society of Radiologists in Ultrasound'. (ICA: Internal Carotid Artery, PSV: Peak Systolic Velocity, CCA: Common Carotid Artery, EDV: End-Diastolic Velocity)

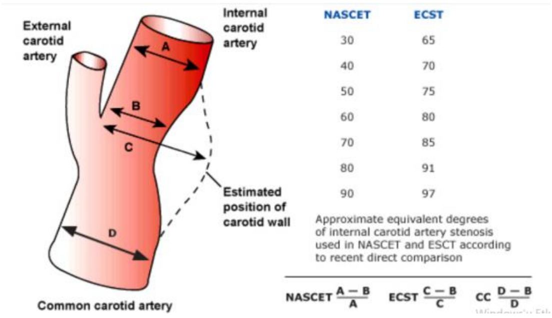

Figure 1. Schematic representation of stenosis measurement methods.

MATERIALS AND METHODS

In this study, we tried to determine the correlation between the efficacy of CTA compared to CDUS in the detection, characterization and quantification of carotid artery disease and the percentage of detected carotid stenosis. For this purpose, 47 (20 female, 27 male) patients who presented to the neurology outpatient clinic with the clinical suspicion of carotid artery stenosis and had complaints of imbalance, dizziness, history of TIA, hemiparesis, hemihypoesthesia, temporary vision loss in our center for 14 months from September 2021 to December 2022 were included in the study. A total of 94 carotid arteries were evaluated with CDUS and CTA. Those who had previous endarterectomy or stenting, and those with contraindications for contrast material were not included in the analysis.

CDUS: Sonographic examination was performed using the Samsung R7 device. Doppler examination includes gray scale, color Doppler, power Doppler and spectral Doppler examination of bilateral common carotid artery (CCA), internal carotid artery (ICA), external carotid artery (ECA) and vertebral arteries for each case. Determination of stenosis grades in color mode was determined by the lumen-filling pattern of the flow, the presence of jet or turbulent flow in plaque-detected areas, and the ratio of the residual lumen diameter in the stenosis region to the total vessel diameter in that region. Appropriate doppler angle was adjusted to measure peak systolic velocity (PSV), end-diastolic velocity (DSH) values in the stenotic area and to calculate ICA/CCA PSV and DSH ratios.The cut-off values used to define the stenosis were as follows; No significant stenosis was diagnosed when PSV was <80cm/s (<30%); Mild stenosis (30% to 40%) was found when PSV was <125cm/s; Moderate (50% to 69%) stenosis was diagnosed when the PSV ranged from 125 to 230 cm/s; and severe (70% to 99%) stenosis was mentioned when PSV was detected >230cm/s (Fig. 2). Failure to detect flow in CDUS was determined as a criterion for suspecting occlusion. The degree of stenosis expressed as a percentage was determined by combining both the morphological and hemodynamic approaches. "Society of Radiologists in Ultrasound" criteria were used for the percentage (%) stenosis grading of plaques (Table 1).If the height difference on the examined plaque surface was more than 2 mm and was irregular, the plaque was considered to be ulcerated. If the deformation of the plate surface was equal to or less than 2 mm, the plate was considered as having a smooth ground (Manolio Ta, 1999).

Figure 2: 80-90% stenosis in the right ICA proximal in CDUS

CTA: CTA examinations were carried out with a Canon brand device with 80 rows of detectors. The patient was placed in the supine position and the head was extended as far as possible. It was stated to the patients that they should not swallow during the scanning, but that they could breathe very superficially. Anterior-posterior and lateral cervical topograms were then taken. 60 ml of nonionic contrast agent was administered through a 20 G cannula placed in the antecubital vein and with an automatic pump injector at a rate of 4-5 ml/s for the application of direct contrast scanning without non-contrast examination. 12 seconds after the start of contrast agent administration, the examination area was scanned from caudal to cranial, with collimation 2 mm, table speed 4 mm/sec, tube settings 120 kVp, automatic modulation in the range of 80-180 mA depending on the patient. Scanning was completed in 30 seconds on average. While the matrix was 512x512, the FOV (field of view) ranged between 110-190 mm. After the scanning was completed, reconstruction was performed with a section thickness of 0.3 mm. The number of sections varied between 200-250 depending on the length of the imaged area. In order to distinguish mural calcifications from contrast material in axial sections, the window width was adjusted to 500 and the window level to 225. 3D images were created from the axial sections obtained by using the MIP program in the work station of the multi-detector CT device. Percentage of diameter stenosis was calculated according to NASCET criteria (Figure 3)

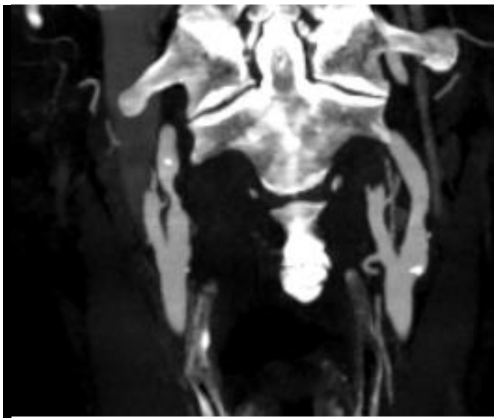

Figure 3: 70-80% stenosis in right proximal ICA in CTA

FINDINGS

First of all, the data obtained in the research were summarized with descriptive statistics. Then, the relationships between the variables were examined by chi-square analysis. 54 male and 40 female patients were included in the study. DM was detected in 37.2% of the participants, and HT in 59.6%. 59.6% of the participants smoke. 60.6% of them applied with the complaint of dizziness. Stenosis was found in the right ICA in 50% of the patients and in the left ICA in 47.9%. While USG detected ICA stenosis less than 50% in 43.6% of the participants, this rate was 46.8% in CTA. When the plaque morphology was examined, ulcerated plaque was detected at a rate of 92.6% by US and 89.4% by CTA. The mean age of the participants was 66.78±9.03 (Table 2).

		N	**%**
Gender	Male	54	57,4
	Female	40	42,6
DM	Yes	35	37,2
	No	59	62,8
HT	Yes	56	59,6
	No	38	40,4
Smoking	Yes	38	40,4
	No	56	59,6
Complaint	Dizziness	57	60,6
	TIA	32	34,0
	Hemiparesis	5	5,3
US Blocked Vein	Right ICA	47	50,0
	Left ICA	45	47,9
	Right CCA	1	1,1
	Left CCA	1	1,1
CTA Blocked Vein	Right ICA	47	50,0
	Left ICA	45	47,9
	Right CCA	1	1,1
	Left CCA	1	1,1
US stenosis %	<50	41	43,6
	50-69	23	24,5
	70-99	21	22,3
	100	9	9,6

CTA stenosis %	<50	44		46,8	
	50-69	21		22,3	
	70-99	24		25,5	
	100	5		5,3	
US Plaque	Ulcerated	7		7,4	
	Non-ulcerated	87		92,6	
CTA Plaque	Ulcerated	10		10,6	
	Non-ulcerated	84		89,4	
	N	**Min**	**Max**	**Mean**	**S.d.**
Age	94	38	84	66,78	9,03

Table 2: Descriptive Statistics

A statistically significant relationship was found between CTA and US in determining the percentage of stenosis according to the Fisher's Exact Test (p<0.01), (Table 3).

			CTA %				Total	Test value	p
			<50	50-69	70-99	100			
US %	<50	Count	38	3	0	0	41	99,030*	0,000
		% within US %	92,7%	7,3%	0,0%	0,0%	100,0%		
		% within CTA %	86,4%	14,3%	0,0%	0,0%	43,6%		
	50-69	Count	6	11	6	0	23		
		% within US %	26,1%	47,8%	26,1%	0,0%	100,0%		
		% within CTA %	13,6%	52,4%	25,0%	0,0%	24,5%		
	70-99	Count	0	7	14	0	21		
		% within US %	0,0%	33,3%	66,7%	0,0%	100,0%		
		% within CTA %	0,0%	33,3%	58,3%	0,0%	22,3%		
	100	Count	0	0	4	5	9		
		% within USG %	0,0%	0,0%	44,4%	55,6%	100,0%		

		% within CTA %	0,0%	0,0%	16,7%	100,0%	9,6%		
Total		Count	44	21	24	5	94		
		% within USG %	46,8%	22,3%	25,5%	5,3%	100,0%		
		% within CTA %	100,0%	100,0%	100,0%	100,0%	100,0%		

Table 3: Percentage of stenosis detected in CTA and US, *Fisher's Exact Test

A statistically significant, positive and strong correlation was found between CTA and US in detecting ICA stenosis (p<0.01, r=0.866) (Table 4).

		US %	CTA %
US %	r	1,000	,866*

Table 4: Correlation between CTA and USG in determining the percentage of stenosis,*p<0,01

While evaluating the plaque morphology, it was determined that there was a statistically significant, positive and strong correlation between CTA and US in determining whether the plaque is ulcerated or not (p<0.01, r=0.822), (Table 5).

		US Plaque	CTA Plaque
US Plaque	r	1,000	,822*

Table 5: CTA US correlation for plaque morphology, *p<0,01

DISCUSSION

In symptomatic patients with suspected ICA occlusion, knowledge of the residual lumen supports decisions regarding the choice of the ideal treatment method, whether medical or surgical. Thus, it improves prognosis and prevents neurological symptoms with cessation of embolic events. Differentiating advanced stenosis of the carotid artery from total occlusion is very important in terms of treatment and prognosis. The presence of symptomatic stenosis (>70%) is an indication for CEA. On the other hand, it is stated that ICA complete occlusion cases are treated conservatively. DSA was accepted as the gold standard in the diagnosis of carotid and vertebral artery origin stenosis in NASCET and ECST (European Carotid Surgery Trial) methods (Barnet HJ, 1998). Today, DSA remains the "gold standard" imaging method for the preoperative evaluation of carotid artery stenosis and cerebrovascular circulation before carotid endarterectomy. It is known that the complication rate is high because it is an invasive procedure. In the previous NASCET study, the rate of death or major stroke after angiography was expressed as 1% (North American Symptomatic Carotid Endarterectomy Trial Collaborators.1991). In one study, it has been suggested that there are both prospective and retrospective studies in the literature, in which 1% of major strokes, 3% of minor neurologic problems, and 2.1% of hypersensitivity are found after performing angiography (Hankey GJ, 1990).

These complications have led to the need for new imaging methods that can be used as noninvasive and screening tests. Today, DSA is used to guide the treatment planning and/or interventional treatment procedures of the cases examined with noninvasive imaging methods rather than being a screening method. Among the methods, the most used ones today are CDUS, MRA and CTA. In many studies in the literature, it has been determined that the accuracy of non-invasive methods is measured by taking DSA as a reference. Nowadays, a common practice in carotid-vertebral artery stenosis in many centers around the world is to use CDUS and CTA together and to refer to DSA if there is inconsistency between these test results. Recent developments in MRA techniques show that it can contribute significantly to the definition of carotid artery pathologies. However, MRA has limitations such as overestimation of stenosis, less sensitivity in detecting ulceration, less coverage of the anatomical area, and flow dependence, especially when performed without contrast (Patel MR, 1994, Debernardi S, 2004).

CDUS is a noninvasive imaging method used as the first diagnostic test in symptomatic patients and as a screening test in asymptomatic patients in the evaluation of extracranial carotid artery disease (Worthy SA, 1997, Polak JF 1993, Khaw KT. 1997, Urwin RW, 1996, Horrow MM, 2000, Grant. EG, 2000, Perkins JMT, 2000). In many studies, it has been reported that the accuracy rate of CDUS is over 90% (Horrow MM, 2000, Grant EG, 2000). CDUS reveals all stages of atherosclerosis very successfully and accurately, from preclinical intimal-medial thickening to total occlusion (Khaw KT. 1997, Grant EG, 2000, Byrnes KR, 2012). It can be used safely in patients who cannot be given contrast due to allergies or kidney failure. It is a relatively inexpensive, reliable examination when performed by experienced personnel, with high sensitivity and specificity, and is superior to angiography for plaque characterization and examination of flow changes (Anzidei M, 2012, Khaw KT, 1997, Byrnes KR, 2012). While performing CDUS in patients with carotid artery disease, the percentage of stenosis may differ from center to center. The main diagnostic parameters of the percentage of carotid stenosis in CDUS are based on rate criteria. Accordingly, measurement errors due to improper selection of the Doppler spacing or incorrect determination of the Doppler angle may result in measurement error in the percentage of stenosis during duplex US of the carotid artery. Also, the "overestimation phenomenon", which is defined as the overestimation of the lesion contralateral to the occlusion or high-grade stenosis in CDUS, is another limitation that can lead to false positive results if not known (Horrow MM ,2000, Byrnes KR, 2012). This phenomenon is explained as the compensatory flow increase causing velocity increase without changing vessel diameter on the opposite side of high stenosis or occlusion (Horrow MM ,2000). Another disadvantage of the method is that CDUS is technically limited to extracranial vessels (Worthy SA, 1997, Polak JF, 1993, Khaw KT, 1997, Polak JF, 1992). Since atherosclerosis is a common disease, it can involve multiple vessels or multiple regions in one vessel. On the other hand, tandem lesions can be missed due to the inability of US to directly evaluate the cerebral circulation, the aortic arch and the proximal part of the brachiocephalic trunk, which is a factor that may change the choice of treatment (Worthy SA, 1997,). In a study by Worthy et al., they found an accompanying severe intracranial tandem lesion in 7% of their cases with extracranial carotid stenosis (Worthy SA, 1997,). Another important disadvantage of CDUS is that it is not always sufficient to distinguish total occlusion from subtotal occlusion. As the stenosis approaches occlusion, the flow velocity falls below 2 cm/s, which is not possible to detect with most Doppler systems.

CTA correlates perfectly with angiography in identifying and grading carotid stenosis (Schwartz RB, 1992, Dillon EH, 1993, Gumming MJ, 1994, Link J, 1996). Because of these determinations, CTA has been accepted as the new "gold standard" (Chen CJ, 2004, Lubezky N, 1998). In two meta-analysis studies, sensitivities between 85% and 95% and specificities between 93% and 98% were reported to detect severe stenosis (>70%) via CTA (Koelemay MJ,2004, Hollingworth W,2003). With the development of multi-detector computed tomography (MDCT) devices, the entire carotid system, including the intracranial section from the aortic arch, can be scanned in the arterial phase in as little as 10 seconds. Therefore, more than one level of stenosis can be demonstrated in a single study in patients with extensive atherosclerotic disease. MDCT is an operator-independent, rapidly applicable imaging method and has high sensitivity and specificity in the diagnosis of carotid artery stenosis (Rubin GD, 1999). With axial sections, mural calcification and contrast material discrimination can be easily made if the appropriate window width and level are provided. It has been shown that CTA can show many lesions that cannot be detected by Doppler US (Oliver TB, 1999). Vascular anatomy and the percentage of stenosis can be evaluated very well with multiplanar reconstruction. It can distinguish lipid, fibrous component and calcium in atheromatous plaques. In the same session, intracranial anatomy can also be demonstrated, and thus, concomitant pathologies (stenosis, aneurysm, etc.) at this level can be detected noninvasively. However, it is not suitable for monitoring the response to treatment because it contains ionizing radiation and nephrotoxic contrast material is required (Anzidei M, 2012, Byrnes KR, 2012).

In the study of Balcı et al. investigating the compatibility of CTA with DSA, the results showing the highest compatibility with DSA were obtained from axial images. The compatibility ratio of DSA and axial-CTA was found to be 0.84. A 0.82 agreement was found between maximum intensity projection (MIP)-CTA and DSA results (Balcı Y, 2014). Many studies with similar results to these findings have shown that axial-CTA is more reliable than MIP-CTA in the evaluation of carotid artery stenosis (Silvennoinen HM, 2007).

In the current literature, it is reported that a series of attempts have been made to determine whether RDUS is sufficient to diagnose occlusion (Mattos MA,1992, Kirsch JD,1994, Bridgers SL,1989, Bornstein NM,1987). Bridgers et al showed that the PPV of the CDUS scan for occlusion diagnosis was 86%. PPV was 97% in asymptomatic patients, but PPV decreased to 72% in symptomatic patients (Bridgers SL, 1989). A 1994 study concluded that angiography is only necessary when patients are symptomatic and in case of possible suspicion of CEA. Moreover, the PPV of duplex scanning was found to be 92% in the same study (Kirsch JD, 1994). In another study, 87% of PPV was reported for duplex scanning for the diagnosis of occlusion, while in another study this rate was stated as 98%. In these two studies, it was concluded that angiography is valid if CDUS screening is suspicious (Mattos MA, 1992; Mansour MA, 1995). There are also studies that found a color flow Doppler PPV of 97%, which is stated to be sufficient for the diagnosis of carotid artery occlusion (Berman SS, 1995).

In many studies in the literature, it has been reported that Doppler US can lead to many wrong occlusion diagnoses (Chen CJ, 2004, Lubezky N,1998, Mansour MA,1995, Hammond CJ, 2008, El-Saden SM, 2001, Sardanelli F,1999). From the reviewed literature, it is clear that CDUS is not sufficient for the diagnosis of carotid artery occlusion in all cases. CTA offers an excellent alternative to angiography, with a PPV of 95%, with high accuracy in distinguishing advanced stenosis from occlusion, and a negative predictive value of 100% in cases where CDUS-based occlusion is suspected. In our study, the results were found to be compatible with each other, except for 12 of 94 arteries evaluated with CDUS and CTA. Accordingly, the correlation between both analyzes was found to be 0.86 (strong positive correlation).

In some studies in the literature, it has been reported that the accuracy of B-mode US for carotid stenosis increases when interpreted together with flow rate criteria (Rotstein AH, 2002, Beebe HG, 1999). According to MacKenzie et al., B-mode US image was 85.3% (CS > 65% in B-mode US), 82.2% (CS > 70% in B-mode US), and 87% in carotid stenosis subgroups. Calculated overall accuracy of 0 (CS > 78% in B-mode US) (MacKenzie KS,2002). In another study, it was stated that any method that does not show the feature of being invasive is not reliable enough to be used instead of DSA. In the same study, it was stated that patients primarily preferred CDUS. It was stated that this was followed by CTA, followed by DSA and MRA, respectively (Patel 2002). According to another study, it is stated in terms of the presence of moderate symptomatic carotid disease that concordant results should be sought in conventional angiography or two non-invasive imaging studies. Here, it has been suggested that a noninvasive menstrual imaging technique is appropriate only in the presence of severe symptomatic stenosis (Kennedy J, 2004).

In our study, when CDUS showed a mild-to-moderate stenosis (n:64), it was confirmed by CTA with a compliance rate of 86.5% (49/64). The compliance rate was 66.6% (14/21) in cases where CDUS showed severe stenosis. In the study of Titi et al., the overall compliance calculated between

CDUS and CTA was 79.1% (Titi M, 2007). Nonent et al. (2003) showed CDUS-CTA compliance rate of 79.1% in asymptomatic surgical patients (>60% stenosis) and between 75% and 83% in symptomatic patients (Nonent M, 2004). These limitations highlight the need to combine other non-invasive imaging techniques to assist in decision making prior to endarterectomy. In many centers, two non-invasive methods are used before proceeding to endarterectomy, and CDUS and CTA are the most preferred. We also use CDUS and CTA together in our center before CEA.

Although the degree of stenosis is considered a distinguishing factor in determining the patients to be selected for carotid endarterectomy in studies, it is now suggested that plaque morphology is an important factor in this regard (Anzidei M, 2012, Khaw KT, 1997). Especially in complicated structures, ulcerated plaques have been shown to increase the incidence of embolism and ischemic stroke. For this reason, it has been shown that plaque characterization is also important in atherosclerotic involvement of the carotid artery, besides the rate of stenosis, and which examination is successful in this area has been investigated.

Since 1986, there has been a debate about which imaging modality US is the most appropriate imaging modality for diagnosing carotid ulcerations and is superior to angiography for ulceration detection (Bornmyr S, 1986). In some studies, it is suggested that the sensitivity and specificity of the methods are high (Fürst H, 1992, O'Donnell TF Jr, 1985), while some studies suggest that US is insufficient in the diagnosis of ulcers due to its low sensitivity (23-47%). 1987, Anderson DC, 1983, Comerota AJ, 1990). On the other hand, this rate is higher in plaques with <50% stenosis (Comerota AJ, 1990). The diagnostic accuracy of the US technique for ulceration needs to be investigated extensively. Because US is the first-line modality in the evaluation of the carotid arteries (Fürst H, 1992, Johnson JM, 1982, Connolly JE, 1985, O'Donnell TF Jr, 1985, Friedrich JM, 1987, Hansen F). , 1989). Compatibility between observers is low for US, in addition to its low accuracy (Sitzer M, 1996). However, considering the technological developments in the field of US, current US devices are expected to provide wide accuracy in the diagnosis of carotid ulceration. These technological developments include modern transducers and image optimization techniques (Hu CH, 2006). The different acceptance of diagnostic criteria and definitions for ulceration in different studies may be the reason for the difference in results regarding US accuracy. In the current study, a statistically significant, positive and strong correlation was found between CTA and US in terms of detecting whether the plaque is ulcerated or not ($p<0.01$, $r=0.822$).

Advances in US equipment and examination techniques have made it possible to determine arterial wall layers and to measure layer thickness on US images. Therefore, in today's practice, duplex US seems to be an important initial diagnosis method in carotid artery disease. Although it does not cause hemodynamically significant stenosis, heterogeneous plaques can lead to embolism and acute thrombosis. It is predicted that patients with plaque ulceration may benefit from carotid endarterectomy, increasing the importance of CDUS, which shows plaque characterization well (Anzidei M, 2012, Khaw KT, 1997). There are also US studies in which the volume of atherosclerotic plaque is shown in three dimensions (Landry A, 2007, Ludwig M, 2008). The limitations of the method are the issue of giving proper angle in tortuous veins, underestimating the degree of stenosis because small ulcerations are overlooked or large ulcerations are evaluated as normal lumen, high-grade stenosis is evaluated as occlusion, acoustic shadowing caused by calcific plaque, differences in parameter selections, operator dependence and technical differences depending on the device (Anzidei M, et al. 2012, Worthy SA, 1997, Polak JF 1993, Khaw KT, 1997, Urwin RW, 1996, Horrow MM, 2000, Grant EG, 2000, Perkins JMT, 2000- Byrnes KR, 2012, Serfaty JM ,2000, Polak JF, 1992, Dix J, 2000). There are many factors that affect the velocity measurement of duplex US. These factors include anatomical factors (such as kinking of the carotid artery), hemodynamic factors (such as occlusion of the contralateral carotid artery), presence of a tandem lesion or an existing carotid intervention (AbuRahma AF, 1998, Hood DB, 1996, Moneta GL ,1995, Moneta GL 1993) systemic factors (such as change in blood pressure or cardiac output) (Sprouse LR 2nd ,2005, MacKenzie KS,2002). It has been found that CTA is very successful in showing calcific, fatty or complicated plaques and can reveal even small ulcerations. On the other hand, DSA is quite insufficient to detect plaque ulcerations (Streifler JY, 1994). MDCT for the evaluation of carotid disease is a valuable modality for accurate stenosis grading of disease and fewer complications compared to DSA. (Saba L, 2007, Berg M, 2005). Plaque morphology is of great importance in terms of the treatment method to be preferred in the patient. According to some researchers, ulcerating plaques constitute a contraindication for percutaneous transluminal angioplasty (PTA) and stenting (Moore WS, 2000).

Studies comparing US and MDCT have shown little agreement between these methods, both for diagnosing ulcerations and categorizing plaques as flat or irregular (Saba L, 2011). MDCT with histology is known as the reference method. Moreover, this method is superior to US, with a sensitivity of 37% versus 93% and a specificity of 91% versus 98% in the diagnosis of ulceration. (Saba L, 2007, Vucaj-Cirilovic V, 2011). CT is superior to other modalities in demonstrating calcification and can show even very fine calcifications. MDCT's ability to easily detect ulcers is partially due to remodeling software such as specialized three-dimensional multiplanar reconstruction (MPR), maximum intensity projection (MIP), and volume rendering (VR). Especially with axial sections, it is possible to distinguish mural calcification from contrast material and to examine both the vessel wall and its lumen in detail. However, it should be kept in mind that dense mural calcifications surrounding the lumen may cause beam hardening artifacts and reduce luminal opacity. The disadvantages of CTA are that it contains ionizing radiation and requires the use of nephrotoxic contrast material.

In conclusion, recent advances in the sensitivity of Doppler US equipment make it possible to accurately diagnose the vast majority of patients with ICA stenosis, regardless of their level. However, in cases where patients are symptomatic or with suspicious CDUS scans, it is necessary to combine other non-invasive imaging techniques so that more accurate results can be obtained at the decision point for endarterectomy.

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