



CT angiography and Color Doppler ultrasonography features and sensitivity in detection of carotid arteries diseases

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ABSTRACT

Introduction: The aim of this research was to compare specificity and sensitivity of Color Doppler ultrasonography with CT angiography.

Methods: A total of one hundred patients suffering from carotid artery disease (n=200) were tested in this research in the period from June till October, 2011. Average age of the patients was 61.5 years, and most of the patients were in the age group ranging from 55 to 65 years. The level of carotid artery stenosis is measured according to Standards of the North America Symptomatic Carotid Endarterectomy Trail study, by method of Color Doppler ultrasonography and CT angiography.

Results: Stenosis $\leq 50\%$ registered by Doppler ultrasonography was found in 62% and by CT angiography in 64% patients. Stenosis from 70 to 79% registered by Doppler ultrasonography was found in 88% and by CT angiography in 82% patients. In patients with level of stenosis 70-79% there was a tendency of registering the stenosis to be higher by Color Doppler ultrasonography, than by CT angiography. In the case of the occlusion, there was also the similar observation, with variation of 8% carotid arteries.

Conclusion: Extracranial Doppler and color duplex ultrasound enable reliable detection of both stenosis and occlusion of carotid arteries and accordingly they occupy an important place in radiological algorithm. When it comes to CT angiography it can be concluded that it can provide accurate and exact information regarding the condition of blood vessels as good as Digital Subtractive Angiography can.

Keywords: Carotid stenosis, Color Doppler ultrasonography, CT angiography.

INTRODUCTION

Ultrasonography of neck blood vessels is a non-invasive diagnostic method for evaluating disease

in extracranial area of carotid artery. The method is not expensive and it can be easily applied (1). The reliability of carotid artery ultrasonography has been proved by the use of Doppler ultrasonography. Color Doppler ultrasonography is a technique which is used by the autocorrelation method (2). In the area where the stenosis of blood flow speed is increased, Doppler Effect registers this change ideally. Estimation of the level of stenosis based only on visual char-

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acteristics is not reliable (3). This is why it is necessary to performe acoustic evaluation as well and this evaluation includes: measuring peak systolic velocity (PSV), end dyastolic velocity, measuring the relation of peak systolic velocity (PSV) in the internal and mutual carotid artery. Staikov and associates (4) specify the optimal duplex ultrasonographic criteria in diagnosing carodid artery stenosis.

The introduction of “multi - detector CT angiography” (MDCT) method and especially”Post Processing Software” analysis has made an enormous shift in the improvement of vascular test structures as well as carotid arteries. CT angiography is a fast, non-invasive method. Either solely or in combination with other methods it is very good and useful for diagnosing carotid arteries diseases (5).

Computed Tomography Angiography (CTA) is a fast developing technology with great potential. This is especially true and important for neurovascular diseases. Other diseases including dissection, trauma, intracranial stenosis, trombosis and aneurysms can be easily diagnosed using this method. Although Duplex Ultrasonography can be considered the first method in medical examination of many patients, both Magnetic Resonance Angiogram (MRA) and CTA offer certain advantages with regard to Doppler ultrasonography. CTA and MRA are both highly precise, but CTA has several key advantages which are reflected by precision, specificity, accuracy, and data analysis speed related to carotid arteries abnormalities.

The aim of this research is to compare specificity and sensitivity of Color Doppler ultrasonography with CT angiography in detection of carotid arteries diseases.

METHODS

Patients

Prospective consecutive analysis was done; measurements on 200 carotid arteries in 100 patients were analyzed. Patients were referred to an examination due to mild neurological symptoms, dizziness, balance lost and murmurs (registered or subjective). Prior to the scan the following data was noted: age, sex, aortic tension, glucose in blood, smoking, and the state of lipids. After the patients were scanned by Color Doppler ultrasonography, they were also scanned by CT angiography within 15 days from

ultrasound examination. All ultrasound tests were published by a radiologist.

Eligibility criteria: patients older than 18 with neurological symptoms such as: instability, dizziness, neurological signs of ischemic attacks, patients with murmurs over carotid arteries (registered or subjective).

Exclusion criteria: malignant diseases, congenital malformations, trauma, severe neurological diseases, pregnancy, case history of allergies to contrast agents.

Procedure

All patients were examined while they were laying on their back. Bilateral ultrasonography of carotid arteries was performed by the use of standard ultrasound machine (Sonoline G60 Ultrasound Imaging System, Siemens AG Medical Solutions, Erlangen, Germany) and by linear probes (5-11 MHz). CT angiography of carotid arteries was performed by a standard method and by a procedure on a CT scan (Siemens 64 AG Medical Solutions, Erlangen, Germany) which was connected to a computer system and softwer for 3D blood vessels reconstruction and with abnormalities interpetor on blood vessels which were subject to analysis. The level of stenosis of carotid artery is estimated based on basic laws of Physics which include interaction, volume, pressure, and their effect on blood flow in a closed system. The relation between flow speed and carotid artery level of stenosis is defined as a result of more multi-centric studies NASCET, ACAS and ESCET (Table 1).

TABLE 1. Carotid artery stenosis criteria according to NASCET, ACAS and ESCET studies

Stenosis %	Peak systolic speed(cm/s)	Peak diastolic speed (cm/s)	Peak systolic speed relation
<50	<150	<50	<2.0
50-59	150-200	50-70	2.0-2.5
60-69	200-250	50-70	2.5-3.0
70-79	250-325	70-90	3.0-3.5
80-89	325-400	70-100	3.5-4.0
90-99	>400	>100	>4.0
Occlusion	/	/	/

Statistical analysis

The statistical test of variation analyses was used in the estimation of statistical significance of differ-

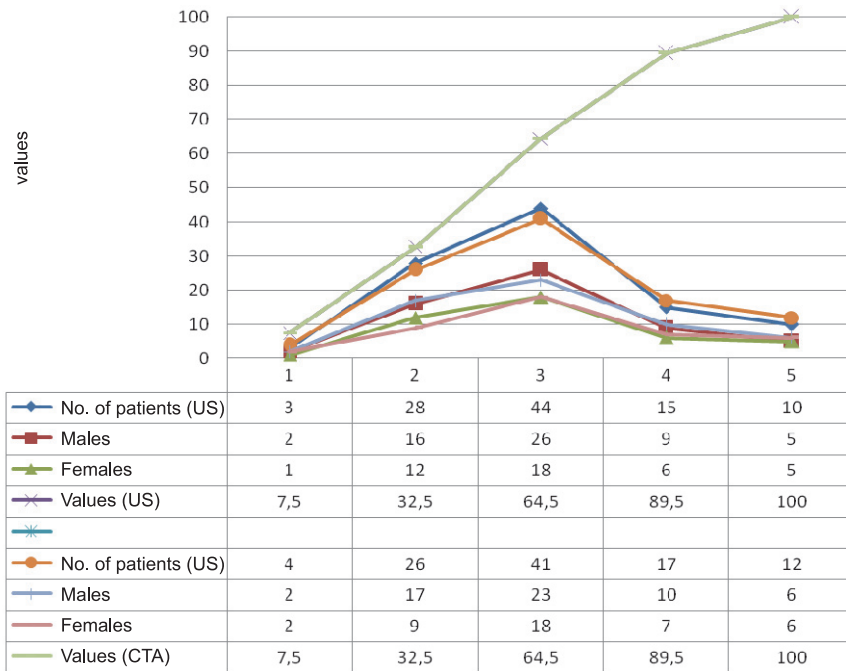


FIGURE 1. Sexual structure of patients subjected to CTA and Color Doppler ultrasonography. US – Ultrasonography; CTA - Computed Tomography Angiography.

ences in measurement of parameters in this research. Pearson correlation test as well as student test were used for examining the existence of correlation between analysed parameters. It was considered that statistically significant difference of the mean of analysed parameters did exist if there was $p < 0.05$.

RESULTS

A number of 44 female examinees participated in the study. The average age was 61.5 years (age range: from 23 to 85). High blood pressure was registered in 59% of the patients, 33% were diabetic, and 45% had increased lipids (Table 2).

In Figure 1 the structure of participants shows the tendency of mean decreasing in women, with lower

mean at ultrasound than at CTA and the tendency of increasing in men who have high arithmetic mean (9 men at ultrasound with mean of 89.5, while there were 6 women with arithmetic mean of 64.5 at ultrasound). It can be seen that there are 26 men and 18 women and that there are 23 men compared to 18 women at CTA which leads to the conclusion that men are dominant as persons with higher arithmetic mean. Arithmetic mean shows that men are more subject to stenosis, while arithmetic mean 100 (occlusion) shows that both men and women are equally represented (Figure 1).

From a total of one 100 examinees, 33 of them were suffering from diabetes. 3 of them had ultrasound arithmetic mean 7.5, and 4 of them had CTA arithmetic mean. Thereof one patient was positive, and two were negative (at ultrasound), and one patient was positive and three negative (at CTA). The figure shows the tendency of mean decreasing in patients with diabetes with lower mean at ultrasound in relation to CTA, and the tendency of mean increasing in diabetics with high mean (five positive at ultrasound with mean of 89.5 and seven with mean 100 – in contrast to six with arithmetic mean 89.5 at

TABLE 2. Characteristics of patients referred to neck blood vessels examination

Risk factors	Male	Female	Total	Variation
Age (average)	62 g.	61 g.	61.5 g.	1 g.
Diabetes mellitus	17 %	16 %	33 %	1 %
Aortic hypertension	35 %	24 %	59 %	11 %
High serum lipids	25 %	20 %	45 %	5 %

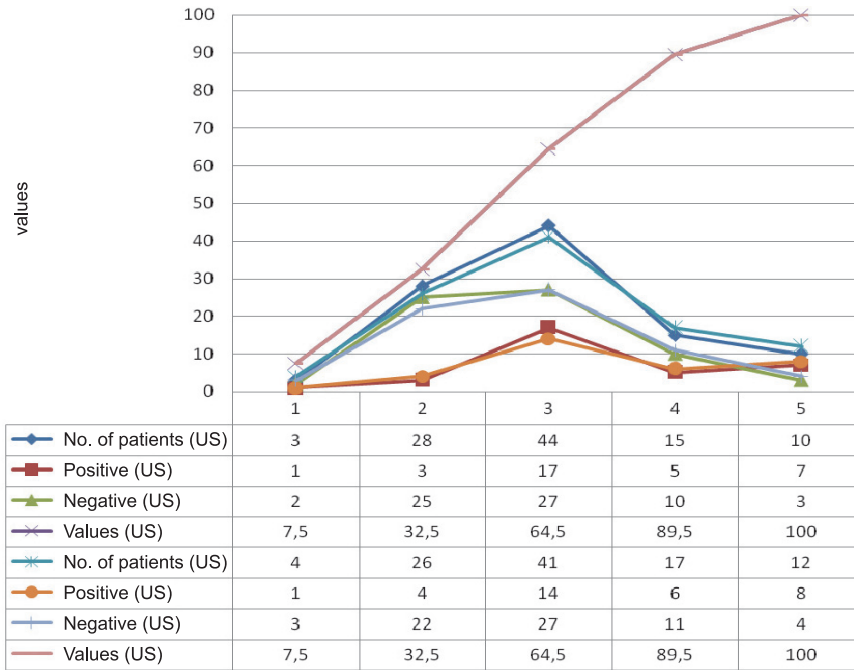


FIGURE 2. Diabetes presence in patients who were subjected to CTA and Color Doppler ultrasonography. US – Ultrasonography; CTA - Computed Tomography Angiography.

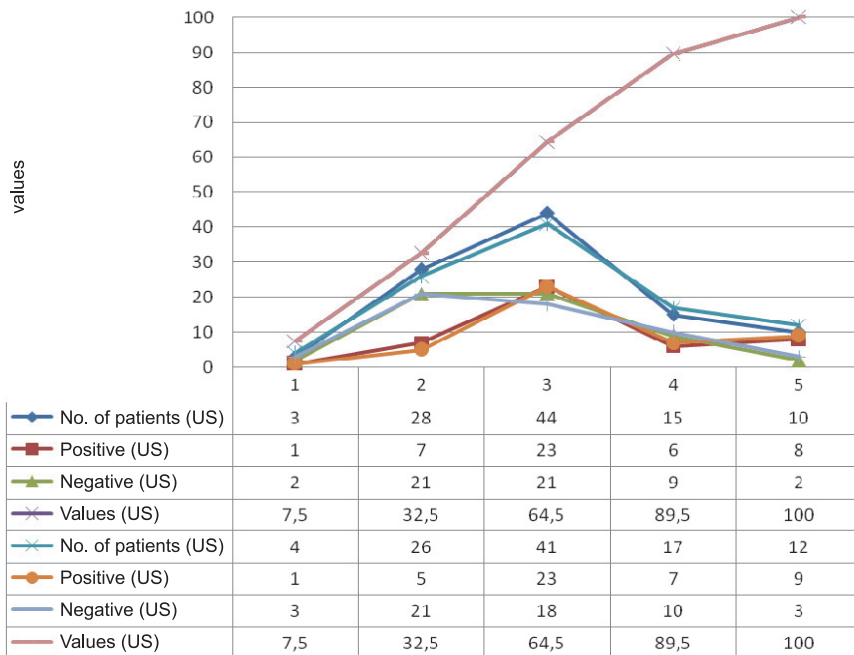


FIGURE 3. Hypertension occurrence in patients subjected to CTA and Color Doppler ultrasonography. . US – Ultrasonography; CTA - Computed Tomography Angiography.

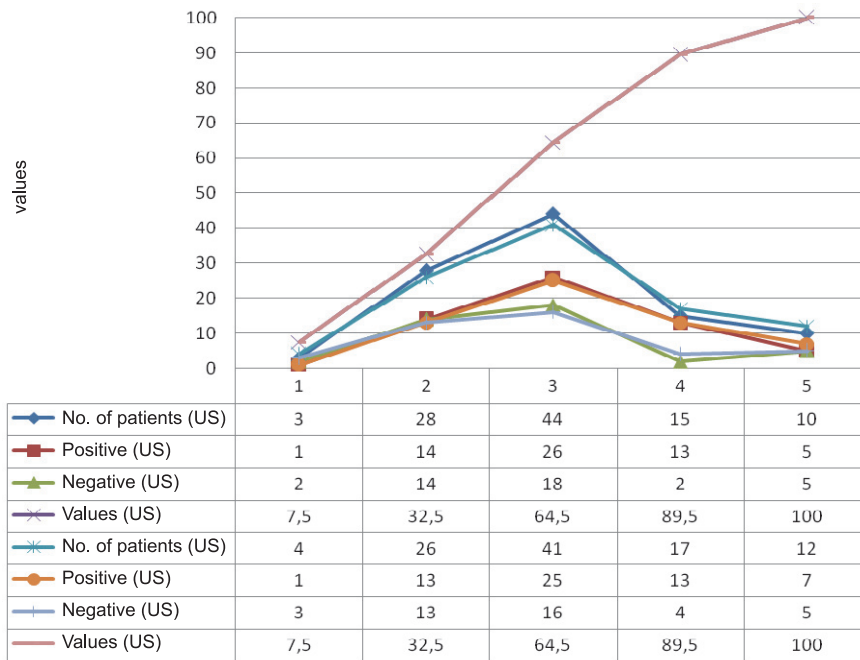


FIGURE 4. Disrupted lipid profile in patients subjected to CTA and Color Doppler ultrasonography. . US – Ultrasonography; CTA - Computed Tomography Angiography

CTA, or eight with arithmetic mean 100). It can be concluded that diabetes has a major effect on people with high arithmetic mean. Arithmetic mean shows approximately the same number of examinees with and without diabetes (Figure 2).

In our study 59 hypertensive patients were registered. Thereof three of them had ultrasound arithmetic mean 7.5, and four of them had CTA arithmetic mean 7.5. From these seven patients, one was hypertensive, and two were not (at ultrasound), and one was hypertensive and three were not (at CTA). The number of patients who had arithmetic mean 32.5 at ultrasound is 28, and this number at CTA is 26. From that, at ultrasound scan 14 of them were hypertensive, and 14 were not. On the other hand, at CTA scan 13 were hypertensive and 13 were not. A number of 44 patients had arithmetic mean at ultrasound 64.5 and at CTA that number is 41. From that, 26 were hypertensive and 18 were not hypertensive at ultrasound, and 25 were hypertensive and 16 were not at CTA. A number of 15 patients had arithmetic mean 89.5 at ultrasound, and 17 had the same mean at CTA. 13 of them were hypertensive and 2 were not, while at CTA 13 were hyperten-

sive and 4 were not. A number of 10 patients had arithmetic mean one 100 at ultrasound while that number at CTA was 12. From that, five of them were hypertensive and five were not at ultrasound, while seven of them were hypertensive and five were not at CTA. The figure shows a tendency of the mean decreasing by hypertension with lower mean at ultrasound in comparison to CTA, and a tendency of the mean increasing by hypertension with higher mean (26 positive at ultrasound with mean 64.5 in comparison to 25 positive at CTA with mean 64.5, 7 with mean one 100, while there are 5 at ultrasound). It can be concluded that hypertension has greater impact on people with higher arithmetic mean (Figure 3).

In our study there were 45 patients registered with higher serum lipids. From that, 3 patients had arithmetic mean 7.5 at ultrasound, and 4 of them had arithmetic mean 7.5 at CTA. From that, 1 patient had increased lipids, and 2 did not (at ultrasound), and 1 patient had increased lipids, and 3 did not (at CTA). The number of patients who had arithmetic mean 32.5 at ultrasound is 28, at CTA that number is 26, from that 7 of them had increased lipids, and

21 patients did not have high serum lipids at ultrasound. At CTA 5 patients had hyperlipidemia, and 21 patients did not. The number of patients who had arithmetic mean 64.5 at ultrasound is 44, and at CTA that number is 41. From that 23 of them has hyperlipidemia and 21 does not at ultrasound, and at CTA 23 patients have increased serum lipids, and 18 do not. The number of patients who had arithmetic mean 89.5 at ultrasound is 15, and at CTA 17. From that, 6 of them have increased lipids and 9 do not at ultrasound, while at CTA 7 patients have hyperlipidemia and 10 do not. The number of patients with arithmetic mean 100 at ultrasound is 10, and at CTA is 12. From that, 8 have increased serum lipids and 2 patients do not have increased serum lipids at ultrasound, while at CTA 9 patients have increased lipids and 3 do not have hyperlipidemia. The figure shows a tendency of mean decreasing by hyperlipidemia with lower mean at ultrasound in comparison to CTA, and a tendency of mean increasing by hyperlipidemia with higher arithmetic mean (23 positive at ultrasound with mean 64.5 in comparison to 23 with arithmetic mean 64.5 at CTA, 9 with arithmetic mean one 100, while 8 at ultrasound). It can be concluded that hyperlipidemia has greater impact on people who have higher arithmetic mean. (Figure 4)

The level of stenosis in carotid arteries measured by Doppler ultrasonography and by the use of Computed Tomography Angiography (CTA) is represented in Table 2.

DISCUSSION

Carotid angiography is a Gold standard (test) in determining the degree of carotid arteries stenosis. The studies which address differences between Doppler ultrasonography and carotid angiography reflect principal non-precision of both methods (6). The study by Nederkoorn and associates (7) shows that Doppler Ultrasonography has a sensitivity from 96% (CI 95%, 94-98), and specificity from one 100% (CI 95%, 99-100%). For categories in which the degree of carotid arteries stenosis was 50-59%, 60-69%, 70-79%, 80-89%, the mean of sensitivity and specificity of positive predicted mean and negative predicted mean was over 80%. A great number of factors influence the precision of Doppler ultrasonography criteria. More recent studies show the increased sensitivity and specificity of Color Dop-

pler ultrasonography in determining the degree of carotid arteries stenosis. These results imply technical improvements of newer machines and the need for every center to have its own established criteria for Color Doppler ultrasonography and which are calibrated by assistance of carotid angiography. Correctness of the test is maximized by calibration of devices which are used in testing and by implementation of the programme for quality control (8).

The aim of a non-invasive examination of arteriosclerotic lesions is detection of early lesions which are connected to a significant risk of cardiovascular disease such as coronary aortic disease, stroke, obstructive arteriosclerosis, aneurysm and aortic dissection. Another aim is development of treatment strategy for reducing risk of arteriosclerotic lesion. The expansion of non-invasive diagnostic techniques such as vascular ultrasound, MDCT and MRI has contributed significantly to improvement of morphological estimation of arteriosclerotic lesion in a routine clinical praxis. Specifically, the development of the equipment for MDCT and MRI is outstanding; both techniques have the potential to become the gold standard in evaluation of arteriosclerotic lesion in the future (9).

Carotid ultrasonography is useful for the patients with early stadium of arteriosclerosis or with manifestation of vascular disease. We can estimate Intima Media Thickness (IMT) of the stenosis as well as the elasticity of carotid artery non-invasively. IMT is known as a powerful provider of future vascular events and as a surrogate marker for arteriosclerosis (10).

With the aim to estimate the effect of non-invasive or minimally invasive methods (duplex ultrasound, MR and CT angiography) by measuring the stenosis of proximal internal neck artery before endarterectomy without preoperative intra arterial Digital Subtractive Angiography (DSA), Long and associates (11) have performed a systematic overview of bibliography (five data bases, 1990 to February, 2001). The results obtained in our study are similar to those obtained by above mentioned authors. The authors tested the value of every scanning technique through its reliability, sensitivity/specificity in comparison to DSA. Sensitivity exceeds 80%, and specificity 90% in over two thirds of methodologically reliable studies, regardless of the technique applied, although direct comparison of results had

to be avoided considering the fact that test results originate from different population.

Anzidei and associates (12) compared in 170 patients Color Doppler Ultrasound (CDU), MRA, CTA of carotid arteries and they established that CTA is a more precise technique for evaluation of carotid stenosis, that it has better performance than MRA (97%:92% for “steady-state“ MRA and 92% for “first-pass“ MRA) and that it has better precision than CDU (97%:76%).

Lovrenčić-Huzjan and associates (13) have examined patients with symptomatic carotid arteries stenoses and correlated Color Doppler ultrasound test with angiography and they proved high correlation between angiography and ultrasound in detection of different levels of carotid stenosis. Berman and associates (14), Lee and associates (15), and Curley and associates (16), have proven that ultrasound is more sensitive in detection of severe stenosis (by occlusions, pseudo- occlusions).

CONCLUSION

Color Doppler ultrasonography and CT angiography are specific and sensitive methods in detection of carotid arteries diseases. Specificity and sensitivity of CT angiography in detection of carotid arteries diseases is extremely high and it is higher than Color Doppler ultrasonography.

COMPETING INTERESTS

Authors declare no conflict of interest.

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