

ORIGINAL ARTICLE

The Significance of the Ultrasound Parameters of Carotid Artery Atherosclerosis in Neuroangiosurgical Practice

Ilga Kikule, Gertrude Enina, Zenija Kovaldina

Department of Neurology, Gailezers Clinic, Riga Eastern Clinical University Hospital, Latvia

Summary

Introduction. Atherosclerosis of the extracranial part of the cerebral arteries is a major pathogenetic risk factor of cerebral infarction (CI) and transitory ischemic attacks (TIA). An ischemic stroke is one of the leading causes of death and long-term disability in many developed countries and is a condition that becomes more prevalent with age.

Aim of the study. To define the diagnostic implications of the US examinations of the extracranial part of the carotid arteries in respect of neurological practice and taking into consideration the age, gender and the localisation of the ischemic damage of patients with atherothrombotic MCA infarction.

Materials and methods. 540 patients treated in the Stroke Unit of Gailezers University Clinic who were diagnosed as having a first MCA infarction of atherothrombotic genesis in the acute phase were examined. The patients were 36 to 91 and were divided into 6 age groups. The group of patients examined comprised of 267 people – 49.4% – females and 273 – 50.6% – males. US examinations of the carotid arteries were performed with a high resolution Philips iU22 ultrasonographic device with a multifrequency linear probe of 3.0 to 9.0 MHz.

Results. The ultrasonologic parameters of the carotid artery atherosclerosis in patients with first atherothrombotic infarction of MCA revealed that 70.8% were aged between 60 to 79. This indicated that the risk of atherothrombotic MCA infarction was highest in this age group and this needs to be taken into account in angiosurgical practice. The largest number of women – 50.6% – with an MCA infarction were in the 70 to 79 age group but the largest number of men – 41.0% were found in the 60 to 69 age group. In patients with a first MCA infarction stable carotid artery plaques with lumen stenosis of less than 50% in the age group below 59 were found in 47.2% of cases among other parameters, i.e. 7.4% more frequently than in the age group from 60 to 79 ($p < 0.1$) and 11.8% more than in the age group above 79 ($p < 0.05$). The frequency of carotid artery extracranial segment stenosis of less than 50% did not differ significantly in different age groups and was 12.6% on average. Occlusion as a delayed pathogenetic risk factor of atherothrombotic infarction was observed in 62 – 11.5% – of patients. In a large number of patients, 34.3% on average, unstable plaques with an uneven surface, ruptures, craters, wall thrombosis and with hemorrhages were found less frequently. This frequency increased significantly with age. There was frequent evidence of the localization of carotid artery atherosclerotic lesions in relation to the locality of CI to be bilateral as well as heterolateral.

Conclusion. To diagnose atherosclerotic lesions of the carotid artery and to confirm indications of surgical and pharmaceutical therapy more statistically significant information needs to be obtained through specialized neuroangio-US examinations.

Key words: atherosclerosis; carotid artery; cerebral infarction; neurovascular ultrasound; carotid endarterectomy; endovascular intervention.

INTRODUCTION

Atherosclerosis of the extracranial part of the cerebral arteries is one of the most common causes of cerebral infarction (CI) and transitory ischemic attacks (TIA). An ischemic stroke is one of the leading causes of death and long-term disability in many developed countries and is a condition that becomes more prevalent with age (1). Atherosclerosis causes approximately one third of all strokes, including repeated strokes and accounts for approximately 20% of all strokes (2). Carotid artery stenosis is an unpredictable disease and it can progress slowly or quickly or maybe not change over significant periods of time (2, 3).

The aim of modern pharmaceutical therapy is to reduce the development of atherothrombosis and enable the prevention of ischemic strokes. It has been proved that antiagregants can reduce the incidence of CI and

TIA and that statins have an atherothrombotic plaque stabilizing effect (4, 5, 6, 7, 8).

The surgical correction of an atherosclerotic lesion of the carotid arteries can significantly reduce the risk of an ischemic stroke. Several large random studies, for example the North American Symptomatic Carotid Endarterectomy Trial (NASCET), The European Carotid Surgery Trial (ECST) and The Asymptomatic Carotid Artery Atherosclerosis Study (ACAS) have proved the efficacy of surgical therapy and a reduction in mortality (9, 10, 11, 12).

Decisions in clinical practice concerning carotid endarterectomy or endovascular therapy are still mainly based on the degree of artery lumen stenosis and the age of the patient. The endarterectomy of the carotid artery is considered as a standard revascularization therapy. The indications for surgical therapy of the

carotid artery disease can be viewed from five different aspects: neurologic symptoms, the degree of stenosis, concomitant diseases, local changes in the blood vessel as well as plaque morphology. In clinical practice, the choice of indications for the invasive method is based on the first two points, while the choice between both methods – endarterectomy or endovascular therapy – is based mainly on points 3, 4 and 5 (12, 13).

Nowadays in clinical practice, lumen stenosis of the carotid artery extracranial part is diagnosed by noninvasive methods at first and most commonly with the duplex-dopplerographic US method, particularly for express diagnostics, with computer tomography angiography (CTA) or by the use of magnetic resonance angiography (MRA). While digital subtraction angiography (DSA) is still an historical gold standard, it is most commonly substituted by noninvasive examination methods, particularly in cases of indications of endarterectomy (14).

The use of modern high quality devices for US examination of cerebral blood vessels enables a neurosonologist specialist to verify and visualize atherosclerotic changes of the extracranial part of the carotid artery wall, the detection of which is limited by noninvasive angiography methods. Consequently, the thickness of the intima-media and the whole artery wall can be measured. The stability of atherosclerotic plaque and wall thrombotic changes that are often sources of cerebral arteries emboli can be determined in detail. The US parameters can give additional information to an angiosurgeon when considering indications and choosing a method of surgical correction. The US method enables the width of localisation, the degree, the structural characteristics of the stenosis of the extracranial part of the carotid artery to be established and monitored in dynamics with no limitations. This can be done before and after surgical and endovascular manipulations and also while monitoring the frequency of microemboli.

It should be noted that in order to consider the options for the angiosurgical correction of an atherosclerotic lesion of the carotid artery an evaluation of the general health of the patient and age and gender are very important. The specifics of the extracranial US parts of carotid artery parameter deviations in different age groups taking into account gender have not been described well in research, particularly for patients clinically to have confirmed atherothrombotic MCA infarction. The most frequent localization of different degree atherosclerosis US parameters of the carotid artery in relation to cerebral infarction localization needs to be evaluated too.

AIM OF THE STUDY

To define the diagnostic implications of the US examinations of the extracranial part of the carotid arteries in respect of neurological practice and taking into consideration the age, gender and the localisation of the ischemic damage of patients with atherothrombotic MCA infarction.

MATERIALS AND METHODS

Examinations were performed on 540 patients treated in the Stroke Unit of the Gailezers Clinic who were diagnosed as having a first MCA infarction of atherothrombotic genesis in the acute phase. Patients were aged from 36 to 91 and were divided into 6 age groups. There were 267 – 49.4% – females and 273 – 50.6% – males.

Repeated computer tomography (CT) of the head, ultrasound examinations of extra and intracranial arteries were performed and blood coagulation, lipid and glucose biochemical values were measured of all patients. Transthoracic echocardiography, magnetic resonance (MR) of the brain, CT angiography (CTA), MR angiography (MRA) or digital subtraction angiography (DSA) and other examinations necessary for the evaluation of the state of patients in the Stroke Unit were carried out.

Duplex ultrasonography was the first noninvasive diagnostic method of choice for examination of atherosclerotic lesions of the carotid artery in this study. This is because it is easily available and usable, as well as being relatively low-cost compared to other methods. As is commonly known, this method depends on the type of the ultrasound device, the experience of the operator and his/her skills. When the data of different writers is compared, the sensitivity of the duplex dopplerographic method for the establishment of hemodynamically significant carotid artery stenosis is 86 to 90%, but specificity 87 to 96%. (15–17).

CTA or DSA was used more frequently than MRA in our practice as a confirming test following duplex ultrasonography if the hemodynamic parameters of significant carotid artery stenosis were doubtful. This choice was made by the angiosurgeon.

Ultrasound examinations of the carotid arteries were performed with a high resolution Philips iU22 ultrasound device with a multifrequency linear probe of 3.0 to 9.0 MHz. The common carotid artery and the extracranial part of the internal carotid artery were measured using B-mode ultrasonography or the visualization of blood vessel in gray scale, colour-coded duplex dopplerography and dopplerography with a flow spectral analysis.

The thickness of the intima-media ($N < 1.0\text{mm}$), thickening 1.0 to 1.5mm was established (18). Atherosclerotic plaques were defined as local wall thickening by less than 1.5 mm and absolute plaque size, localization, surface evaluation, plaque structure, echogenicity and stability. These were analysed. The plaques were classified as stable – homogenous with a smooth surface with or without calcinates, or unstable – heterogeneous with uneven surface, niches, ulceration, hemorrhages and thrombosis. (19–20). The degrees of carotid artery stenosis were classified as the reduction of lumen by $< 50\%$, $> 50\%$ and lumen occlusion. The ECST method was used to establish the degree of artery stenosis.

Transcranial duplex dopplerography was also carried out for all patients to define the genesis of atherothrombotic cerebral infarction more precisely, evaluating the

segmental flow values of cerebral blood vessels, verified stenoses and occlusions of intracranial arteries, the diagnostics of embolic signals and the compensatory mechanisms of cerebral blood flow were also measured.

The statistical processing and analysis of data was performed with SPSS 16.0 using the χ^2 test.

RESULTS

When the US parameters of the carotid artery atherosclerosis of patients with first atherothrombotic infarction of MCA were evaluated, the division by age groups was taken into account (See Table 1). In the examined patient group, 70.8% of patients were 60 to 79. Only 20.3% were below 60 and 8.9% older than 80.

Table 1. The number (n) of patients with atherothrombotic stroke of MCA in female, male and combined group in different age groups

Age group	<40	40-49	50-59	60-69	70-79	≥80	Total
Female	-	9	23	59	135	41	267
Male	2	24	52	112	76	7	273
Total	2	33	75	171	211	48	540

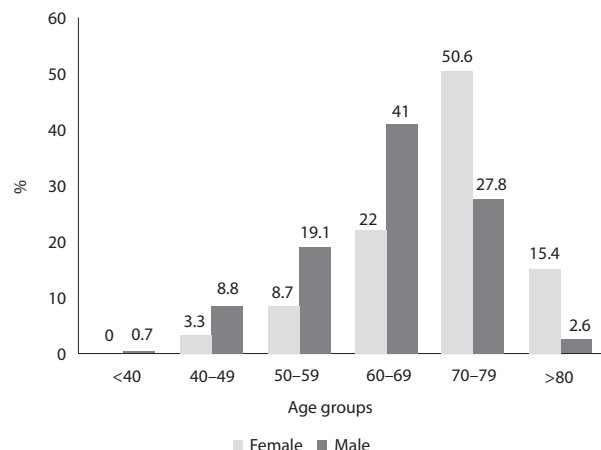


Fig. 1. The number of female and male patients by percentage in different age groups

This table shows that the risk of atherothrombotic MCA infarction was highest in the 60 to 79 age group and this needs to be taken into account in angiosurgical practice. When the number of patients in the female and male groups were analysed, the largest number - 50.6% of women with MCA infarction - were aged between 70 to 79 but 60 to 69 in males (41.0%) ($p < 0.01$). There were only 2 men in the age group below 40. There were 16.7% more men than women in the age group from 40 to 59. However there were 12.8% ($p < 0.05$) more women than men in the age group ≥ 80 .

The incidence of different carotid artery atherosclerosis US parameters was different in patients with MCA infarction, and in 222 - 41.1% - of 540 patients stable plaques with lumen stenosis $< 50\%$ were observed. The stenosis of less than 50% of the extracranial segment of the carotid artery as a major risk factor of CI was established in 71 - 13.1% - of patients. Occlusion as a risk of delayed atherothrombotic infarction pathogenesis was noted in 62 - 11.5% - of patients.

Unstable plaques of the carotid artery extracranial segment with uneven surfaces, ruptures, craters, wall thrombi and, less frequently, with hemorrhages were identified in a large number of patients - 18 % up to 34.3%.

Anamnesis data showed that none of the patients observed had undergone any examination of the cerebral blood vessels, including US, until the development of a cerebral infarction. It should be noted that none of the patients observed had undergone carotid artery endarterectomy or angioplasty until they had suffered a cerebral infarction.

When researchers analysed the frequency of the US parameters of carotid artery atherosclerosis in the six different age groups, it was noticed that stable plaques with lumen stenosis in the carotid artery of less than 50% was found only in 2 patients below 40. In other age groups all analysed atherosclerosis US parameters were present in different ratios (see Figure 2).

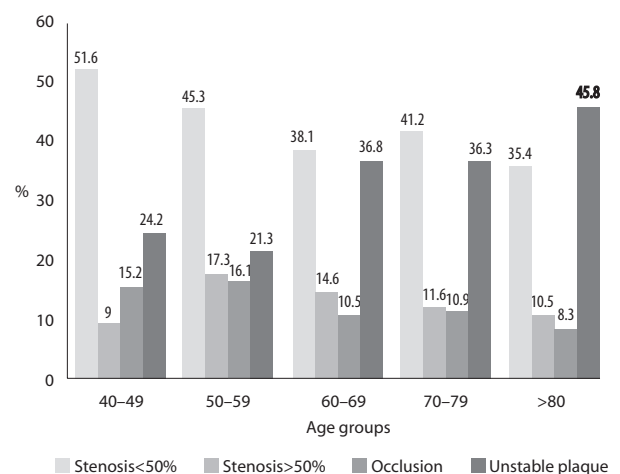


Fig. 2. The frequency (%) of carotid artery atherosclerosis US parameters in patients with an MCA infarction by different age groups

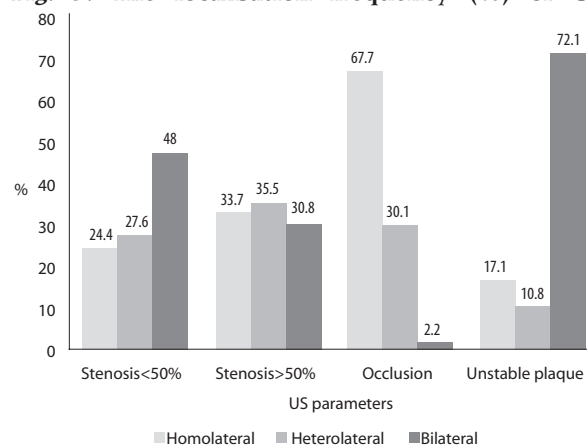
The frequency of observed carotid artery atherosclerosis US parameters differed depending on the patient age in the age groups between 40 to 59 and 60 to 79 and over 80. In patients with a first MCA infarction carotid artery stable plaques with lumen stenosis of less than 50% in the age group below 59 were 47.2% among other parameters, 7.4% more than in the age group of 60 to 79 ($p < 0.1$) and 11.8% more than in the group above

79 ($p<0.05$). It should be noted that the frequency of carotid artery extracranial segment stenosis of less than 50% did not differ significantly in different age groups and was approximately 12.6%. The frequency of carotid artery occlusion in the age group from 40 to 59 was 15.7%, from 60 to 79 – 10.7%, but above 80 it was 8.3%. The incidence of occlusion in different age groups did not differ significantly. In contrast to other carotid artery atherosclerosis US parameters the number of unstable plaques in patients with an MCA infarction in relation to other parameters increased significantly with patient age ($p<0.01$). In the 40 to 59 age group the frequency of unstable plaques was 22.3%, but it was 36.4% in the 60 to 79 age group and 45.8% in those over 80. Consequently, the frequency of unstable plaques of the carotid artery – which is a significant factor of risk of cerebral infarction and has a negative impact on the results of neurosurgical treatment - increased significantly with the age of CI patients.

When the frequency of particular carotid artery atherosclerosis US parameters in female and male groups was compared, it was established that the number of unstable plaques in female group was 7.1% bigger, but in male group stenosis of > 50% of carotid artery extracranial segment and occlusion were observed 8.5% more frequently. ($p<0.1$) The frequency of carotid artery atherosclerosis US parameters in female and male groups of different ages were compared and some differences were observed. The largest number of women with MCA atherothrombotic infarction was from 70 to 79 (135 of 267 patients), but from 60 to 69 (112 of 273 patients) in men. Carotid artery stenosis of > 50% was not observed in the female group from 40 to 49.

The localisation frequency of carotid artery extracranial part US parameters in relation to MCA infarction localization was also different (see Figure 3).

Fig. 3. The localisation frequency (%) of US



parameters of carotid artery extracranial part atherosclerosis in relation to the localization of MCA infarction

The most commonly noted stable plaques with artery lumen stenosis of < 50% were bilateral and 23.6%; they were less frequently homolateral and 20.4% heterolateral. Stenoses of > 50% with the same frequency were present in the infarction localization or the opposite side, as well as bilateral. When the bilateral localization of stenoses in relation to MCA infarction localization was compared, it was that the stenoses of < 50% occurred more frequently – 17.2% - than that of > 50% ($p<0.05$). Occlusion of the carotid artery was most commonly homolateral in 42 of 62 patients; in 18 of these patients 29.0% stenosis was of > 50% in the second carotid artery.

The frequency of the localisation of unstable plaques differed significantly; it was noted that in 72.1% of cases they were bilateral and in other cases 6.3% more frequently ipsilateral than heterolateral.

It was also observed that the localization of frequency of the US parameters for patients with MCA infarction of the extracranial part of carotid artery atherosclerosis was bilateral in 45.1% of cases, 28.5% of cases were homolateral and 26.4% heterolateral. The established frequent bilateral and heterolateral localization of the atherosclerotic process is also the significant criteria in choosing indications and methods for surgical treatment of damage to the carotid artery.

DISCUSSION

The first noninvasive diagnostic method for examination of carotid artery atherosclerotic lesion is doppler ultrasonography; this is because it is easy available and usable.(14) It should be noted that the use of this method is significantly influenced by the experience of the user and the skills using and interpreting data. In comparison to catheter angiography, the sensitivity of the Duplex Dopplerography method is 86%, specificity – 87% for the determination of hemodynamically significant carotid artery stenosis (14-16).

This examination method for screening needs to be used for all patients with a history of TIA or CI, as well as in patients with risk factors of cardiovascular disease, diabetes mellitus, arterial hypertension, established atherosclerotic damage to the coronary and peripheral blood vessels, smokers and in particular for all people with a history of cerebrovascular incidents after the age of 50. This would enable a timely start for preventive measures, both pharmaceutical and surgical. The American Society of Echocardiography (ASE) has published a report on the clinical use of carotid US to prove subclinical vascular disease and analyse cardiovascular risk. However, this report has not been sufficiently explicit in evaluation the criteria of the US parameters in the examination of the carotid artery, specifically the morphologic parameters of walls of artery. These parameters have a significant role in neurovascular and neuroangiurgical practice(21).

The degree of carotid artery stenosis is a parameter of the risk of a cerebral infarction in patients with severe stenosis, but morphological characteristics of the atherosclerotic plate are important for slight

and moderate stenosis; however plaque instability significantly increases the risk of a stroke.

According to data from a number of different researchers and also from our data, approximately 15 to 70% of cerebral infarctions result from thromboembolism as a result of unstable plaques in the carotid bifurcation region (22–24).

In experimental and clinical studies it has been shown that plaques with ulcerations have been observed with the same frequency in patients with both homolateral and heterolateral cerebral dyscirculation symptoms and that atherosclerotic plaques frequently facilitate the formation of wall thrombi and carry the risk of thromboembolism. In patients with symptomatic carotid artery disease the risk of plaque ulceration is higher, causing lesion-independent ischemia and may be associated with the occurrence of thromboemboli or hemodynamic disorders (25).

We have established conclusively in our study that in the pathogenesis of atherothrombotic MCA infarction the major role is most frequently played by unstable plaques of the extracranial part of the carotid artery with wall thrombi and possible thromboembolism can increase significantly with age.

Our study found that acute cerebral ischemia is based on a relatively frequent extracranial part of carotid artery stenosis <50% which is bilaterally located and spread equally across different age and gender groups. Carotid artery stenosis > 50% was observed less than 18 % of cases and the stenosis did not depend on the age of CI patients.

A particularly important risk factor in the development of MCA infarction proved to be unstable plaque in the carotid arteries, regardless of the degree of stenosis, and which may be a source of arterio-arterial embolism and the main pathogenic factor for CI. The most important role in the determining of these embolus is transcranial duplex dopplerography in recent years and this has also been confirmed by the data of other writers (25–27).

The study demonstrated the significance of ageing in relation to the continuing instability of plaque in the extracranial part in the carotid artery.

The neuroangio-US method gives sufficient clinical information for the diagnosis of carotid artery plaque instability, and also for the evaluation of thromboembolism. Consequently it is important to perform transcranial dopplerography, particularly monitoring.

CONCLUSION

In the examination of the extracranial part of the carotid artery in patients with atherothrombotic MCA infarction stable plaques with stenosis of < 50% was observed that this is the most common cause that underlays the ischemic process however unstable plaques are a common source of thromboembolism. These US parameters of carotid artery atherosclerosis were common in all age groups however the frequency of unstable plaques increased significantly with age.

The frequency of artery stenosis of > 50% and occlusion

in different age groups was not significant in 9.0 to 17.3% of cases.

The largest number of patients with MCA infarction in the female group was in the age group from 70 to 79 and in the male group from 60 to 69. However, the characteristics of the changes of carotid artery atherosclerosis US parameters did not differ substantially in either groups.

The relationship between the localization of the US parameter of the carotid artery and the localization of MCA infarction varied. Unstable plaques and stable plaques with a stenosis by < 50% were bilateral most commonly, stenoses by > 50% with the equal frequency were homo-, hetero- and bilateral, but occlusion was homolateral most commonly.

Significant additional information for the diagnosis of carotid artery atherosclerotic lesion and for the more precise establishment of surgical and pharmaceutical therapy indications can be obtained with specific neuroangio-US examinations.

Conflict of interest: None

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Address:

Ilga Kikule

Department of Neurology

Riga Eastern Clinical University Hospital,

Clinics „Gailezers”

Hipokrata Street2, Riga, Latvia, LV1038

Email: ilga.kikule@gmail.com