

Ultrasound assessment of atherosclerotic plaque morphology in patients with carotid stenosis

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Abstract: *This article presents the results of ultrasound assessment of the morphology of carotid atherosclerotic plaques using duplex scanning and offline videodensitometric analysis of 160 carotid atherosclerotic plaques. Ultrasonic densitometry analysis of images may be used to identify vulnerable and potentially unstable lipid-rich carotid plaques, which are less echogenic in density than stable or asymptomatic, fibrotic plaques. Atherosclerotic plaques with higher values of energy and greater homogeneity should be more stable and less prone to rupture.*

Keywords: *atherosclerotic plaques, duplex scanning, ultrasound densitometry analysis, carotid stenosis*

Introduction

Preoperative duplex scanning (DS) has been widely practiced to assess the risk of ischemic cerebrovascular accident and address the issue of indications for carotid endarterectomy, which determine the degree of stenosis of the carotid arteries, echo-structure of atherosclerotic plaques (AP). Moreover, the correspondence of the structure of characteristics with echoes of plaques was observed in 67-90% of cases [16]. A rather large discrepancy between the research results indicates the need for an in-depth study of the structure of atherosclerotic plaques in the carotid arteries. The echogenic characteristics of atherosclerotic plaque obtained using DS are determined by a combination of various structural components with hypoechoic properties - foci of atheromatosis, edema, necrosis, as well as heterogeneity - sites of fibrosis and calcification, as well as organized hemorrhages. The predominance of certain components in the structure of plaques determines the severity of the hypo- or hyperechoic component in the characteristic of the echo. The videodensitometric approach, like radio frequency analysis, is still limited to research applications. Baroncini L et. all believe that future studies are needed with a large number of patients with this type of analysis [4,5]. According to researchers, ultrasonic densitometry analysis (UDA) allows to objectively determine the heterogeneous and complex composition of plaques with hemorrhage, ulceration, rupture of intima and stratification in patients with carotid arteries stenosis (CAS).

Purpose. Study of possibility of using of ultrasonic densitometry analysis for study the morphology of atherosclerotic plaque

Materials and Methods

In the laboratory of ultrasound diagnostics of the diagnostic department of the Central Clinical Hospital N1 in Tashkent at 82 patients (average age 67,8±6,9 years) was held DS

with UDA of 160 atherosclerotic plaques (AP). Carotids ultrasound performed by duplex scanning on ultrasonic system Voluson 530 DMT with linear transducer 5,5-7,0 MHz. To characterize the types of plaques, an extended classification of Gray-Weal used [10]. The degree of ICA stenosis by diameter evaluated according to the recommendations of NASCET, ECST, as well as by the lumen area [8,15].

After receiving the stored ultrasound images, offline was provided data analysis. For implementation of UDA a gray scale image used a special option “Hystography” and following sequence, according to the protocol. Contours of area and contrast each AP subjectively optimized by operator. Software ultrasonic scanner enabled us to receive, store a sequence of continuous two-dimensional images in mode of cine-loop, forming the continuous cycle of digital recording (60 frames per 2 seconds). To visualize of AP in the longitudinal direction used front, side and posterior projection. The position of probe adjusted so that ultrasonic beam is perpendicular to the wall of the artery [2,4,5,7,19].

The results subjected to statistical analysis using the statistical software (Sta_win.exe.). Correlation of quantitative parameters studied with analysis of Pearson. Significant differences considered with values $p < 0,05$.

Results

According to CAS, AP are distributed to $CAS < 50\%$ ($n=107/67\%$), $CAS > 50\%$ ($n=53/33\%$). As part of the classification of AP, according to B-mode ultrasound, a qualitative assessment of the structure of AP carried out taking into, account its echogenicity and homogeneity with the allocation of two types of plaques. The ultrasound morphology of each AP was characterized as heterogeneous (mixed hyperechoic) and hypoechoic, (isoechoic or homogeneous). Entropy and homogeneity reflect the degree of roughness of the image, and their values increase with decreasing homogeneity [1,3,6,9,12]. Mathematical determination of these parameters of texture well described in the papers Mazzone A.M. et al. [14]. AP images were normalized using 2 echo anatomical reference points: gray-scale median (GSM) blood and GSM adventitia. The study showed that heterogeneous AP were noted in 34 of 107 arteries with $CAS < 50\%$ (21%), in 36 of 53 arteries with $CAS > 50\%$ (69%). Patients were distributed in 2 groups depending on of symptoms: 1- group — symptomatic patients ($n = 44$); 2-group consisted of asymptomatic patients ($n = 38$). So, heterogeneous APs were found 3,29 times more often by $CAS > 50\%$. Patients with $CAS > 50\%$ were more often symptomatic. Patients with $CAS < 50\%$ were more likely to have homogeneous AP, and patients were more often asymptomatic ($p < 0.001$). Results of UDA for 1 group were as follows: average gray scale $41,2 \pm 15,1$; for 2-group $89,8 \pm 11,3$ ($p < 0,002$), values of entropy $7,11 \pm 0,33$ and $6,34 \pm 0,42$ ($p > 0,05$), of energy $0,006 \pm 0,009$ and $0,019 \pm 0,011$ ($p < 0,01$), and of homogeneity $0,42 \pm 0,038$ and $0,45 \pm 0,067$, respectively ($p > 0,05$).

Among parameters of first choice, the average gray level was higher in 2-group. Among the parameters of second order, values of energy were higher in 2-group ($p < 0,05$). As in other studies, videodensitometric analysis of image, registered with optimal installation of ultrasonic scanner, showed that the average value of pixels for fibrose AP was > 150 . For comparison, the average values of pixels for soft tissue were less than 50 (blood 1–5, adipose tissue 2–15, and muscle tissue 4–50) [4,19].

All plaque images were evaluated for texture parameters including a set of first-order (mean gray level; and standard deviation) and of second-order (entropy, energy, and homogeneity) parameters. The mean gray level (MGL) represents the median of the frequency distribution of gray tones of the pixels included in the region of interest (gray scale median of the region) in a scale of 256 gray tones (0 = the darkest tone; 255 = the brightest tone) [4, 19].

Discussion

The process of acquiring, analyzing, and interpreting images in mode B remains operator dependent. Ultrasound examination of an atherosclerotic plaque requires not only an assessment of the degree of stenosis, but also its echogenicity (hypoechoic or hyperechoic, heterogeneous or homogeneous). These characteristics are too subjective for everyday clinical practice and depend on the preparation and experience of ultrasound [11,20]

It is important to assess the degree of embolic hazard of ASB, the identification of stable and so-called “vulnerable”, unstable AP [4,9]. Recently, it has become possible to implement thanks to ultrasonic technologies using special image processing techniques for AP. In our study, we used the method of ultrasonic densitometric analysis as a quantitative parameter for assessing the properties of AP and the risk of stroke in patients with carotid atherosclerosis [12, 13, 20].

The analysis used by us is radio frequency and it requires additional time and a special option of an ultrasonic device. In addition, an additional image analysis allows us to determine the gray scale level that we used to identify the vulnerable and potentially unstable carotid ASB. Similar ASBs are less echogenic or asymptotically more dense than fibrotic AP.

We applied the second-order parameters (energy) to assess structural changes in AP, including inflammatory processes and changes in the extracellular matrix [17,19, 20]. The results of video densitometric analysis of carotid atherosclerotic plaques confirm the results of other researchers who showed the relationship of the parameters of such an analysis to identify unstable AP and the level of matrix metalloproteinases [3,4].

Conclusion

As higher the degree of stenosis, as greater the likelihood of association with ultrasonic heterogeneous AP and cerebrovascular symptoms. A positive correlation of heterogeneous AP with symptoms was greater than with any degree of CAS.

UDA of images may be used to identify vulnerable and potentially unstable lipid-rich carotid plaques, which are less echogenic in density than stable or asymptomatic, more densely fibrotic plaques. AP with higher values of energy and greater homogeneity should be more stable and less prone to rupture.

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