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Clinical value of ultrasound in the evaluation of vascular function after carotid plaque formation

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Abstract: *The purpose of this study is to explore the value of vascular intima-media measurement (QIMT) and vascular function assessment system (QAS) in evaluating the structure and function of carotid artery in patients with carotid plaque. 30 patients with carotid artery plaque confirmed by ultrasound were randomly selected into the plaque group, and 31 healthy volunteers were enrolled in control group. Parameters of carotid artery were collected by QIMT and QAS, respectively. The parameters included intima-media thickness (IMT), dilatation coefficient (DC), α elastic coefficient (α), β elastic coefficient (β), pulse wave velocity (PWV) and augmented index of reflected wave (AIx). The results showed that IMT, α, β and PWV in plaque group were significantly higher than those in control group, while DC was significantly lower than that in control group, and the difference was statistically significant (P < 0.05).There was no significant difference in AIx between plaque group and control group. In conclusion, the carotid IMT is thickened, the elasticity is reduced and the stiffness is significantly increased in the plaque group; QIMT and QAS technology can detect the early changes of carotid structure and function, and provide a reference for early intervention and treatment of clinical cardiovascular and cerebrovascular events.*

Keywords: *Carotid artery; Plaque; Elasticity; Ultrasound*

1. Introduction

In recent years, the incidence of common cerebrovascular diseases has been increasing year by year, which seriously threatens human health and safety[1]. Studies have found that if carotid atherosclerosis is not found in time and given appropriate intervention treatment, it is easy to form unstable plaques, then fall off or bleed, and form thrombosis leading to stroke[2].Atherosclerosis, as an early feature of carotid atherosclerotic plaque, is of great significance in clinical diagnosis. The location of carotid artery is superficial and easy to explore, which is an important channel to observe and understand the changes of systemic arterial elasticity function, and can reflect systemic arteriosclerosis to a certain extent. In this study, QIMT and QAS were used to observe the neck vascular elasticity of patients with carotid plaque, and to explore the value of these indicators in reflecting vascular elasticity by comparing with normal people, so as to provide objective imaging basis for further clinical research.

2. Data and method

2.1. Object of study

Patients with carotid plaque were screened and diagnosed by ultrasound before the examination.In this study, 30 patients with carotid plaque (12 males and 18 females) were randomly selected from our hospital from September to November 2021, aged 38 to 72 years old, with an average age of (60.03 ± 10.32) years old, and their height was 156 to 178 cm, with an average height of (165.6 ± 6.6) cm; The average body weight was (67.9 ± 8.8) kg. 31 healthy subjects (12 males and 19 females) were matched for age, height and weight to the plaque group. All enrolled patients were knowledgeable about the study and Sign the informed consent form voluntarily.

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2.2. Inclusion criteria

(1) Plaque localized intraluminal protrusion with thickness ≥1.5 mm, located in the common carotid artery, bifurcation, or internal carotid artery. (2) No traumatic vascular surgery such as carotid plaque stripping or embolectomy was performed. (3) Physical examination was normal. (4) The electrocardiogram was normal.

2.3. Exclusion criteria

(1)Acute vascular complications in the last month.(2)Familial hypercholesterolemia.(3)Patients with severe liver and kidney dysfunction.(4)Patients with malignant tumor.(5)Pregnant or lactating women.

2.4. Ultrasound instrument

2.4.1. Ultrasound instrument

Esaote Mylab 9 color Doppler ultrasound diagnostic instrument equipped with (L4 ~ 15) probe with probe frequency of 4 ~ 15 MHz was used.

2.4.2. Ultrasound image acquisition and processing

The subjects rested for 20 minutes in a quiet clinic, and the blood pressure of the right upper limb was measured and recorded into the analysis software system. Instruct the subject to be in a supine position and comfortable state, examine the longitudinal and transverse sections of the subject's bilateral carotid arteries under the two-dimensional ultrasound mode, examine the intima, observe whether there is plaque formation, record the positive results, and complete the following image acquisition by professionals: (1)Two-dimensional long axis view of blood vessels was taken to clearly display the intima-media of the anterior and posterior walls of the common carotid artery, so that the blood vessels were located in the center of the screen, and the ultrasound beam was perpendicular to the arterial wall; (2)Place the QIMT reference line at the position near the common carotid artery enlargement, with a distance of 1 cm between the sampling frame and the carotid artery enlargement, start the automatic measurement, and display the IMT measurement result of the common carotid artery on the left side of the two-dimensional ultrasound image in real time. When the intima-media in the test frame is completely filled with green, the operator should control the standard deviation (SD) < 20. The instrument automatically calculates the average value of six cardiac cycles of the IMT measurement results, and completes the acquisition and storage of carotid artery images; (3)In the same place of the above acquisition, use QAS for automatic measurement. When the instrument repeatedly displays 6 stable and qualified measurement values, freeze the image and record and save the measurement values in the system (Figure 1). The QAS software can automatically track the vessel wall motion trajectory and analyze and obtain the carotid artery elasticity parameters (Figure 2), in which α, β and PWV represent the degree of arterial stiffness, and the increase of the value represents the decrease of arterial elasticity; the increase of DC represents the increase of arterial elasticity; AIx is usually inversely proportional to the increase or decrease of vascular elasticity, which increases with the decrease of vascular elasticity, and is an important reference to measure arterial compliance.

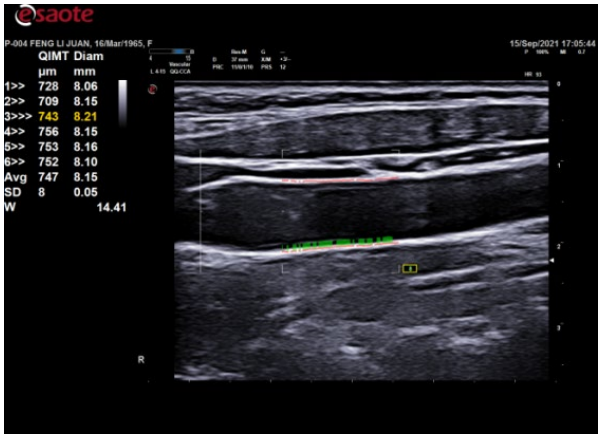

Figure 1: Vascular intima-media measurement and vascular function evaluation system

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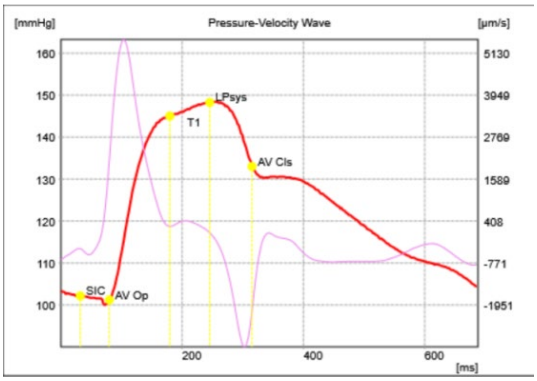

Figure 2: Data and waveform diagram obtained by QAS analysis software

2.5. Statistical Analysis

The above collected data were analyzed by SPSS19 software, the measurement data were expressed as $x \pm s$, and the independent sample t test was used for inter-group comparison. The difference was statistically significant when $P < 0.05$.

3. Consequence

In this study, there was no significant difference between the left and right sides of the common carotid artery in all subjects ($P > 0.05$). Therefore, the next thing to be studied is the parameters of the left carotid artery.

Comparison of general condition and ultrasound parameters in each group: The results showed that IMT, α, β and PWV were significantly increased and DC was significantly decreased in the plaque group compared with the control group ($P < 0.05$). There was no significant difference in AIx, age and gender between the plaque group and the control group ($P > 0.05$) (Table 1).

Table 1: Comparison of IMT and QAS related parameters between the two groups (x±s)

Grouping	QIMT(um)	DC(1/KPa)	α	β	PWV(m/s)	AIx
Plaque Group	743.87±145.00	0.015±0.005	5.85±1.86	11.90±3.73	8.20±1.27	14.88±11.76
Control Group	618.42±88.8▲	0.019±0.007▲	4.63±1.31▲	9.44±2.64▲	7.18±1.10▲	14.31±12.15

▲:$P<0.05$, Compared with Plaque group

4. Discuss

IMT reflects the thickness of carotid artery wall, which is not only an early indicator of atherosclerosis in young and middle-aged people, but also an independent predictor of increased risk of cardiovascular and cerebrovascular diseases[3,4]. In the early stage of atherosclerosis, the morphological changes of the vascular wall are mainly manifested by the thickening of the intima-media and the narrowing of the lumen; the functional changes of the vascular wall are mainly manifested by the decrease of the elasticity of the vascular walls and the abnormal systolic and diastolic functions. Increased carotid intima-media thickness (IMT) and decreased elastic function of the vascular wall have received increasing attention as useful signs of early damage in atherosclerotic vascular disease. In this study, compared with the control group, the carotid IMT, α, β and PWV of the plaque group were increased, and the DC was significantly decreased.Plaque causes a decrease in the elasticity of the carotid artery, which coincided with the results of previous studies[5]. Both IMT and PWV are recognized as good predictors of cardiovascular events, but PWV is a parameter to evaluate vascular function, while IMT is a parameter to evaluate vascular morphology, but the change of arterial elasticity is often earlier than that of structure [6], so the increase of vascular wall stiffness is also a marker of early atherosclerosis.

Some scholars have pointed out that arterial plaque formation is one of the manifestations of atherosclerosis.Like intima-media thickness and arterial elastic function, it is an important marker and independent risk factor for cardiovascular and cerebrovascular diseases.However, compared with IMT

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thickening, plaque formation has better correlation and higher predictive value for cardiovascular and cerebrovascular diseases[7,8] .The pathogenesis of atherosclerosis is complex. Most scholars believe that the formation of carotid atherosclerotic plaques is closely related to vascular endothelial cell dysfunction and inflammatory response. Endothelial cells are a single layer of cells attached to the inner wall of blood vessels, which play an important role in maintaining the functions of many tissues and organs in the body.If the function of endothelial cells is impaired, LDL will enter the subendothelial layer, and the injured endothelial cells will release inflammatory factors, which will lead to a series of processes such as oxidative stress, leukocyte adhesion, chronic inflammatory response, and ultimately lead to the formation of as plaques[9,10].Inflammation is involved in the formation of lipid streaks and fibrous plaques in atherosclerotic plaque formation, and can stimulate plaque instability, cause plaque rupture and hemorrhage, and aggravate ischemia and infarction[11].

In addition, AIx was not significantly different between the plaque group and the control group. Studies have shown that AIx is closely related to age and may be a more sensitive indicator of atherosclerosis and risk. In young people, AIx increases significantly with age, but in the elderly population, the rate of AIx increase gradually slows down with age and reaches a plateau after the age of 60[12,13] .The negative linear relationship between AIx and heart rate is obvious. When the heart rate increases, AIx decreases, and the absolute duration of systole will decrease because of the decrease of heart rate, which will lead to the close shift of reflected wave to diastole[14]. AIx in women is significantly higher than that in men, which is limited by the difference in height. Short arterial tree makes the pulse wave reflection point closer to the heart. The height of women is lower than that of men, which leads to the earlier superposition of reflection wave with forward wave and the increase of AIx[13,15,16].

Carotid atherosclerosis (CAS) plaque is a lesion found by means of modern imaging, and there is no record of CAS plaque in TCM ancient books. CAS belongs to the syndrome of deficiency in origin and excess in superficiality.The disease is located in the blood vessels, and its basic pathogenesis is the dysfunction of the viscera, deficiency of qi, blood, yin and Yang, and the intermingling of phlegm-dampness, blood stasis and toxin, which makes the circulation of qi and blood in the vessels not smooth or even blocked, and finally leads to the disease. Professor Ruan Shiyi, a master of traditional Chinese medicine, combined the formation of plaque in modern medicine with the concept of accumulated disease in traditional Chinese medicine, and innovatively put forward the concept of "accumulation in pulse"[17].Accumulation is a general term for a variety of pathological changes caused by the accumulation of visible pathogens in the human body in traditional Chinese medicine. There is a saying in Synopsis of the Golden Chamber: "Accumulation is the disease of the viscera, which will not change in the end." "Jing Yue Quan Shu" summarizes the characteristics of accumulation and the process of its production as follows: "Accumulation is called accumulation, which is gradually formed." "Yi Lin Sheng Mo",a book records: " Those who have lumps on the body, in the middle and under the body are mostly phlegm. " Since ancient times, it has been believed that the pathogenesis of local caking and fixed location is phlegm and blood stasis. Professor Deng Tietao's theory of "phlegm and blood stasis" holds that phlegm is the initial stage of blood stasis formation, and blood stasis is the further development of phlegm[18]. The spleen is the source of phlegm. If the spleen qi is weak, the grain essence will be slightly lost in distribution, and the phlegm will be endogenous, which will block qi movement and lead to blood stasis. Blood stasis can also cause dysfunction of the viscera, failure of the spleen to transport, accumulation of water and dampness into phlegm, and eventually form the syndrome of phlegm and blood stasis. The occurrence of this disease is closely related to the two major pathological factors of phlegm and blood stasis, and contemporary physicians have formed a basic consensus. On the basis of previous theories and the concept of "toxin", some scholars believe that atherosclerosis is the result of the mutual transformation of three pathological products of "phlegm", "blood stasis" and "toxin", and that toxin is the key to disease[19]. During the development of atherosclerosis, phlegm and blood stasis are stagnated for a long time, which can produce phlegm toxin, blood stasis toxin or heat toxin. Although toxin is a pathological product, it can also act on the body as a pathogenic factor, resulting in dysfunction of the viscera, metabolic disorder of body fluid, phlegm-dampness blocking the vessels and blood stasis caused by unsmooth blood circulation,or phlegm stagnates and transforms into heat, and pathogenic heat damages the blood collaterals and causes blood stasis. Phlegm and blood stasis are intermingled, and obstruction of blood vessels results in AS. "Yi Lin Gai Cuo" says: "No matter where, there is Qi and blood … … Qi is invisible and can not agglomerate, and those who agglomerate must have visible blood, which points out that abnormal blood circulation is the key to the pathogenesis of "accumulation". The liver is in charge of regulating the flow of qi, the qi activity is stagnant, the blood circulation is not smooth, and the blood stasis is generated; or overwork and loss of healthy qi of the human body, insufficient biochemical power of qi

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and blood, loss of nourishment of collaterals, and blood stasis caused by stagnation of blood circulation can all affect the functions of the body's viscera, hinder the circulation of qi and blood, generate phlegm and blood stasis, transform into heat and toxin for a long time, and eventually lead to accumulated diseases.

There are some defects in this study:(1) The study did not explore the correlation between AIx and age, heart rate, height, gender, and a more comprehensive randomized controlled study is needed.(2)This study was a single-center observation, with a single case source and a small sample size, which could not reflect the overall situation of carotid plaque patients in China, and further experiments could be conducted in multiple units and large samples.

5. Conclusion

Ultrasound examination of carotid artery is safe, non-invasive and radiation-free, which is more acceptable to everyone. To sum up, the intima-media thickness and stiffness of carotid artery in patients with carotid plaque are increased; the application of ultrasound radiofrequency signal technology can non-invasively quantitatively assess and accurately determine the early atherosclerosis in patients with carotid plaque, which has a very high clinical value in the diagnosis of atherosclerosis.

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