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Retraction

Retracted: *K*-Means Clustering Algorithm-Based Detection of Carotid Atherosclerotic Plaque Using Contrast-Enhanced Ultrasound Images

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

In addition, our investigation has also shown that one or more of the following human-subject reporting requirements has not been met in this article: ethical approval by an Institutional Review Board (IRB) committee or equivalent, patient/participant consent to participate, and/or agreement to publish patient/participant details (where relevant).

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] R. Zhou, R. Zhou, and Z. Zhu, "*K*-Means Clustering Algorithm-Based Detection of Carotid Atherosclerotic Plaque Using Contrast-Enhanced Ultrasound Images," *Scientific Programming*, vol. 2021, Article ID 2223344, 7 pages, 2021.

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Research Article

K-Means Clustering Algorithm-Based Detection of Carotid Atherosclerotic Plaque Using Contrast-Enhanced Ultrasound Images

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The aim of this study was to investigate the diagnostic value of contrast-enhanced ultrasound (CEUS) based on the *K*-means clustering (KMC) algorithm for the vulnerability of carotid atherosclerotic plaque (CAA). In this study, 90 patients with CAA were enrolled into a control group (group A) and an experimental group (group B). The angiography method and KMC-based ultrasound detection were applied to diagnose the CAA patients from the two groups, respectively. The results showed that the sensitivity, specificity, and positive predictive value of patients from group B (92.3%, 90.1%, and 94.8%) for diagnosing CAA were obviously higher than those of patients from group A (81.4%, 88.6%, and 75.3%) ($P < 0.05$). The detection rate of patients from group B (83%, 85%) was dramatically higher than that of patients from group A (65%, 71%) in terms of artery bifurcation and CAA ($P < 0.05$). Besides, patients from group B were more satisfied with their diagnostic method than group A ($P < 0.05$). In conclusion, the ultrasound detection method based on KMC had high sensitivity, specificity, and accuracy in the detection of CAA. In addition, ultrasound detection was better than angiography in the diagnosis of plaque in different parts, and it was worthwhile to apply the ultrasound detection method based on KMC in clinical practice.

1. Introduction

CAA means that there is accumulation of fat in the carotid artery wall, and the calcium-containing substances gradually accumulate in the carotid artery wall as the accumulated fat increases and accumulates, so as to make the local tissue of the carotid artery thicken and harden, and thus there are atherosclerosis plaques inside the blood vessels eventually caused by lesions. Moreover, they are yellow in appearance [1]. The process by which calcium-containing substances deposit on the inner wall of blood vessels and form atherosclerosis is called atherosclerosis in medicine [2]. In the human blood vessels, the carotid artery is a critical artery in the blood circulation of the brain. Therefore, it is easy to cause insufficient blood supply to the brain and cause a series of subsequent complications when atherosclerosis occurs in the carotid artery [3]. At present, the related research on the etiology and pathogenesis of the disease has not yet reached a definite conclusion. It is generally believed that the occurrence of atherosclerosis is mostly due to the inflammatory reaction in the blood vessel, the damage of vascular endothelial cells, and the blood coagulation mechanism [4, 5]. The main patients with atherosclerosis include adult men over 30 years old or patients with dyslipidemia, hypertension, diabetes, and severe obesity. It has a high incidence in China, and the incidence of this disease is increasing with the growth of age. But women have a relatively low incidence of the disease [6]. Clinically, according to the nature of hardened plaque, it can be divided into arterial calcified plaque, ulcerative plaque, intra-plaque hemorrhage, and plaque mural thrombus [7]. Contrast-enhanced ultrasound refers to the intravenous injection of ultrasound contrast agent on the basis of conventional ultrasound, which can effectively enhance the blood flow signals of tissues and organs to better reflect the blood perfusion situation, thus contributing to the diagnosis of diseases. As for the ultrasonic contrast agent, Sono Vue contrast agent is commonly used at present, and its main composition is microbubbles containing SF6 and phospholipid, with an average diameter of 2.5 μm. After peripheral intravenous injection, it can pass through the pulmonary and systemic circulation to reach the target organs. However, it cannot penetrate the vascular endothelium into the tissue space [8]. Therefore, contrast-enhanced ultrasound is pure blood pool contrast, which is the biggest difference from computed tomography (CT) and magnetic resonance (MRI) enhancement [9]. At present, contrast-enhanced ultrasound has been applied to multiple tissues and organs such as liver, kidney, prostate, breast, and thyroid and has different enhancement characteristics for different tissues.

K-means clustering (KMC) is a clustering algorithm for discovering *K* clusters of a given dataset. It can find *K* different clusters and the center of each cluster that is calculated by using the mean value of the data contained in the cluster [10]. The task of the clustering algorithm is to divide the data object into multiple clusters. Each data object is only in one cluster. The data objects in each cluster have high similarity but are not similar with the data objects of other clusters [11]. Clustering refers to the automatic classification of data with similar characteristics in a complex dataset. The more similar the objects in the cluster, the better the clustering effect. It is an unsupervised learning method that does not require advance annotated training set [12]. At present, this algorithm has been extensively applied in medical ultrasound imaging computer-aided diagnosis systems and is used for ultrasound image segmentation because of its ability to react objectively and truthfully to the actual situation of classified samples [13].

In this study, 90 patients with CAA were enrolled into groups A and B. The angiography detection method and the ultrasound detection method based on KMC were employed to diagnose the CAA. The patients from the two groups were tested for serum thyroglobulin (TG) content, diastolic blood pressure (DBP), and the detection rates of plaques in different parts of the artery at the bifurcation and internal carotid artery. The diagnostic value of CEUS based on KMC for CAA vulnerability was judged and analyzed by the above indexes.

2. Materials and Methods

2.1. General Information of Research Subjects. A total of 90 patients with CAA were selected as the research subjects, who were hospitalized from September 2017 to May 2020, including 50 male patients and 40 female patients; the age of the patient was between 55 and 70 years old. The patients were randomly divided into the control group and the experimental group, with 45 cases in each group. The research subjects were rolled into the control (A) group and the experimental (B) group, with 45 cases in each group. In addition, 10 healthy volunteers were selected as controls. The patients from group A received the angiography examinations, and patients from group B underwent the ultrasound examinations based on KMC for diagnosis. This experiment had been authorized by the Ethics Committee of hospital, and the patients and their family members had understood the content and methods of this experiment and agreed to sign the corresponding informed consent forms.

The criteria for inclusion were defined to include patients who were 40–60 years old, had clear consciousness and can cooperate with treatment and sample collection, were confirmed with CAA through the early examinations, had complete clinical data and information, and had no history of mental illness with emotional stability.

The criteria for exclusion were defined to include patients who withdrew this experiment and transferred for treatment due to personal reasons, suffered from other serious diseases or infectious diseases, had incomplete case data, had hypertension, coronary heart disease, or similar surgical treatment, suffered from connective tissue diseases or malignant tumors, and had not received cooperative treatment due to personal or other factors.

2.2. Carotid Artery Ultrasound and Angiography Examinations. The patients from both groups underwent the carotid artery ultrasound and carotid angiography, and they were made to fast the day before and not drink water for 5 hours before the examination. The patients' heart rate (HR) and blood pressure (BP) were checked. In the morning, the vein blood of patients with fasting was collected, the blood lipid, fasting blood glucose (FGLU), and blood uric acid and plasma fibrinogen were measured, and the GLU of patients were monitored 2 hours after eating.

Patients from group A received the carotid angiography examinations. The Siemens AXIOM Artis DTA angiography machine and Seldinger method were adopted to puncture the femoral artery for selective transarterial angiography. The patient took a supine position on the testing table and was disinfected with lidocaine for local anesthesia. First, there was carotid arteriography on the affected side of CAA. Then, patients underwent the super-selective angiography of external carotid artery branch.

Patients from group B received the carotid artery ultrasound examinations, and the GE Vivid7 color Doppler ultrasound instrument was applied with a frequency of 7–10 MHz. The examined patient lied supine on the testing table and tilted the head to one side to fully expose the tested part for inspection. First, the carotid artery was scanned with a transverse probe and displayed by two-dimensional ultrasound. The main inspection items included whether there was plaque in the inner diameter of the blood vessel, around the blood vessel, and the wall of the blood vessel and the determination of the location and size of the plaque. Later, longitudinal detection was conducted. The patient took the anterior and lateral view of the carotid artery for longitudinal detection. The main detection items contained the length and thickness of the detected plaque, the continuity of the lumen intima, blood flow, and fullness of the blood vessel, and detection of stenosis and obstruction.

2.3. Steps of K-Means Clustering Algorithm. The *K*-means algorithm is a clustering method often applied in research, and it mainly distinguishes clusters from the smallest clustering error. Assuming the set $Z = \{z_1, z_2, \ldots, z_M\}, z_n \in R^c$, $(m = 1, 2, \ldots, M)$, the *K*-means algorithm divided the set into clusters according to the clustering criterion, namely, $B_1, B_2, \ldots, B_N$. The clustering error equation of *K*-means algorithm is as follows:

$$F(p_1, p_2, \ldots, p_N) = \sum_{i-1}^{M} \sum_{k-1}^{N} J(z_i \in B_l) \|z_i - n_l\|^2. \tag{1}$$

The above equation met $J(Z) = \begin{cases} 1, & Z \text{ is true}, \\ 0, & \text{Other}, \end{cases}$. In the equation (1), $\sum_{i-1}^{M} J(z_i \in B_l)\|z_i - n_l\|^2$ represented the variance within the class. Usually, $F_{\text{sum}} = F(p_1, p_2, \ldots, p_N)$ was applied to simplify the equation. The minimum value of the largest clustering error was calculated by the following equation:

$$F_{\max} = \max_{1 \le l \le N} \sum_{i-1}^{M} J(z_i \in B_l) \|z_i - n_l\|^2. \tag{2}$$

Since the above formula was directly adopted and the operation steps were difficult, an objective function was added to obtain the intra-class weight, as shown in the following equation:

$$F_\lambda = \sum_{l-1}^{N} \lambda_l^q \sum_{i-1}^{M} J(z_i \in B_l) \|z_i - n_l\|^2, \quad \lambda_l \ge 0, \sum_{l-1}^{N} \lambda_l^q = 1, \quad 0 \le \lambda \le 1. \tag{3}$$

Due to different weights of each cluster, the cluster also had to be minimized. The minimization equation for $\lambda_l \ge 0$ could be expressed in the equations (4) and (5).

$$\lambda_l = \frac{\mu_l^{1/(1-q)}}{\sum_{l'-1}^{N} \mu_{l'}^{1/(1-q)}}, \tag{4}$$

$$\mu_l = \sum_{i-1}^{M} J(z_i \in B_l) \|z_i - n_l\|^2. \tag{5}$$

In order to strengthen the stability of the *K*-means algorithm, it was necessary to combine the weight with the memory factor, as shown in the following equation:

$$\lambda_l^{(i)} = \theta \lambda_l^{(i-1)} + (1 - \theta) \left(\frac{\mu_l^{1/(1-q)}}{\sum_{l'-1}^{N} \mu_{l'}^{1/(1-q)}} \right), \quad 0 \le \theta \le 1. \tag{6}$$

2.4. Evaluation Indexes. The KMC-based ultrasound and angiography examination methods were used for the diagnosis of CAA in patients from groups A and B in turn. Besides, the serum TG content, DBP, and the detection rates of plaques in different parts such as blood vessels at bifurcations and internal carotid arteries atherosclerotic plaque should be measured in patients from the two groups. There was a judgement and analysis on the diagnostic value of CEUS based on KMC for CAA vulnerability through the above indexes.

2.5. Statistical Methods. The data of this study were analyzed by SPSS22.0 version statistical software, the measurement data were expressed by mean ± standard deviation ($\overline{x} \pm s$), and the count data were represented by percentage (%). The age, DBP, serum TG content, and detection rates of CAA were compared among patients from the two groups by analysis of variance. $P < 0.05$ meant that the difference was statistically substantial.

3. Results

3.1. Ultrasound and Angiography Images of Carotid Atherosclerotic Plaque. Figure 1 shows an image of a patient with CAA diagnosed by ultrasound. It showed that the thickness of the inner media of the carotid artery wall was greater than 1.2 mm, linear, and uneven, and echo was enhanced. There were eccentrically distributed hypoechoic lipid plaques in the vessel wall, and the area of plaques was large. The area of blood vessels in the plaque distribution was larger. The stenosis rate of the official cavity area was markedly increased, showing obvious positive remodeling. In addition, there was an appearance of superficial calcification and punctate calcification.

Figure 2 shows an image of the diagnosis result of a case with CAA through angiography. It was found that the long distance of the official cavity at the far side of the starting end was narrowed, with a curved thin line shape. Moreover, the collateral circulation was formed around the occluded blood vessel, and the two ends matched the proximal and distal ends of the occluded blood vessel, respectively. The filling and clearance time of the contrast reagent was delayed, the vascular shape was abnormal, and the lumen was narrowed.

3.2. Ultrasound and Angiography Detection of Carotid Atherosclerosis. Figure 3 shows the results of sensitivity, specificity, and positive predictive value of CAA in patients from group B through ultrasound diagnosis based on KMC. It could be found that the ultrasound of KMC had high diagnostic sensitivity and accuracy for CAA. The sensitivity, specificity, and positive predictive value of diagnosis were 92.3%, 90.1%, and 94.8%, respectively.

The sensitivity, specificity, and positive predictive value of CAA in patients from group A are presented in Figure 4. The sensitivity, specificity, and positive predictive value of CAA diagnosis were 81.4%, 88.6%, and 75.3%, respectively. The sensitivity, specificity, and positive predictive value of the KMC-based ultrasound (group B) diagnosis of CAA were greatly higher in contrast to those of the angiographic examination method (group A) ($P < 0.05$).

3.3. Comparison of General Data of Patients from the Two Groups. The patients from both groups with CAA were diagnosed by ultrasound and angiography, and the relevant data and basic information of the patients were collected.

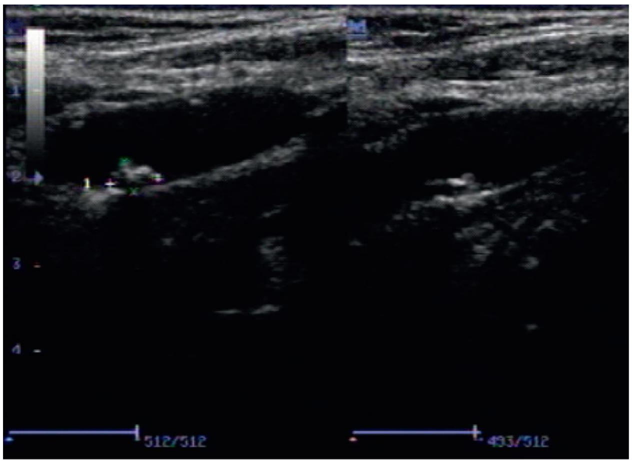

Figure 1: Ultrasound diagnostic image of a patient.

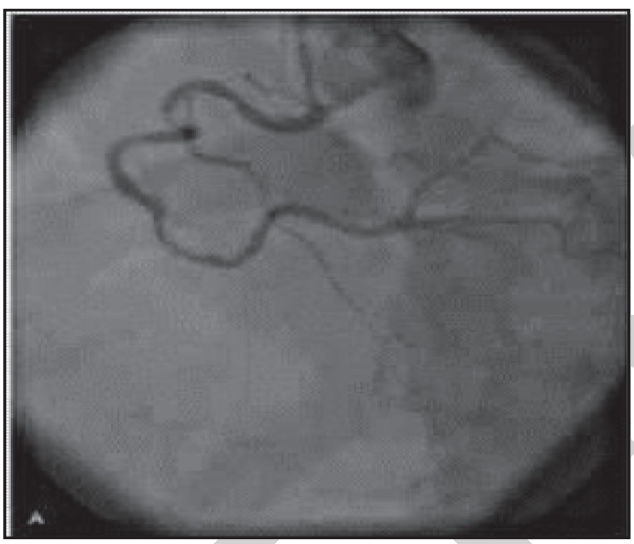

Figure 2: Angiographic image of one patient.

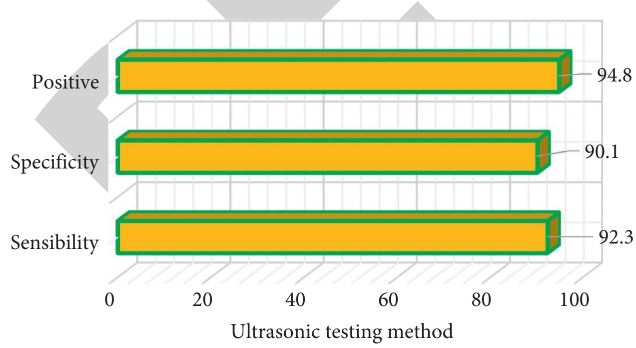

Figure 3: Sensitivity, specificity, and positive predictive value of ultrasound diagnosis.

Figure 5 shows the comparison results of the average age of patients from the two groups. It was found that the patients from the two groups were all 45–55 years old, and there was no statistically obvious difference in the age among patients from both groups ($P > 0.05$).

Figure 6 shows the comparison results of systolic blood pressure of patients from both groups. The systolic blood pressure of patients from groups A and B was 150.2 ± 12.38 mmHg and 149.38 ± 14.6 mmHg, respectively. Thus, the systolic blood pressure of patients from group A was not markedly different from that of group B ($P > 0.05$).

The DBP and serum TG content of patients from the two groups were tested and compared, and the results are shown in Figure 7. It indicated that the DBP of groups A and B was 79.38 ± 8.2 mmHg and 80.1 ± 7.8 mmHg in turn, and the serum TG content of groups B and A was 1.41 ± 0.38 mmol/L and 1.42 ± 0.39 mmol/L, respectively. There was no obvious difference in DBP and serum TG content among patients from the two groups ($P > 0.05$).

Comparison of the total cholesterol (TC) content of patients from the two groups is shown in Figure 8. It suggested that the TC content of groups A and B was 4.58 ± 0.98 mmol/L and 4.49 ± 1.03 mmol/L in sequence. However, the TC content of health people was 4.18 ± 0.95 mmol/L. Therefore, the TC content of patients from both groups had no statistically substantial difference ($P > 0.05$).

3.4. Comparison Results of Detection Rates of Carotid Plaque in Different Parts. Figure 9 shows the comparison results of the detection rates of vascular plaques at the bifurcation of atherosclerotic arteries detected by ultrasound and angiography among patients from groups A and B. The detection rate of group A was 65%, while the detection rate of vascular plaque at the bifurcation of the atherosclerotic artery in group B was 83%. Therefore, the detection rate of vascular plaque at the bifurcation of the atherosclerotic artery in group B was obviously higher than that in group A ($P < 0.05$).

Figure 10 shows the comparison results of the detection rates of the internal carotid artery plaque detected by ultrasound and angiography among patients from groups A and B. From the graph below, the detection rate of internal carotid artery plaque in patients from group B (85%) (experimental group) was dramatically higher than that in patients from group A (71%) ($P < 0.05$).

3.5. Satisfaction of Patients from the Two Groups for Diagnostic Methods. The satisfaction results of the diagnosis method for CAA among patients from group A are shown in Figure 11. Besides, 20% of patients from group A were dissatisfied with the diagnosis method for CAA. The generally satisfied patients accounted for 28%, and there were 52% of patients who were satisfied with the diagnosis method for CAA. As a whole, the satisfaction of patients from group A was low with the diagnosis of CAA by angiography.

Figure 12 shows the results of satisfaction of patients from group B on the diagnosis method of CAA. It was found that the patients from group B who were dissatisfied, generally satisfied, and satisfied with the diagnostic method accounted for 10%, 15%, and 75%, respectively. Patients from group B were more satisfied with the diagnosis of CAA by angiography. Compared with group A, patients from group B were markedly more satisfied with their diagnostic method ($P < 0.05$).

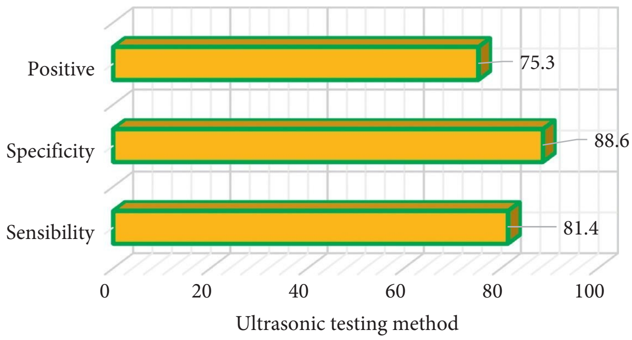

Figure 4: Sensitivity, specificity, and positive predictive value of angiography.

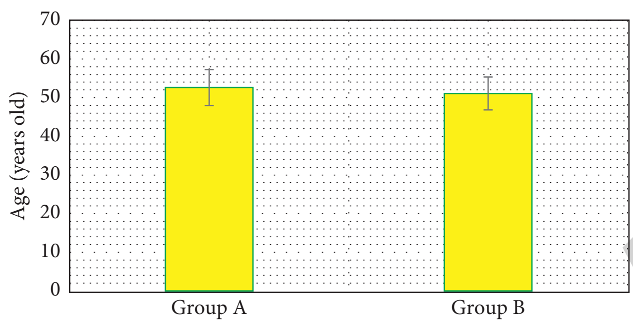

Figure 5: Comparison of the age of patients from the two groups.

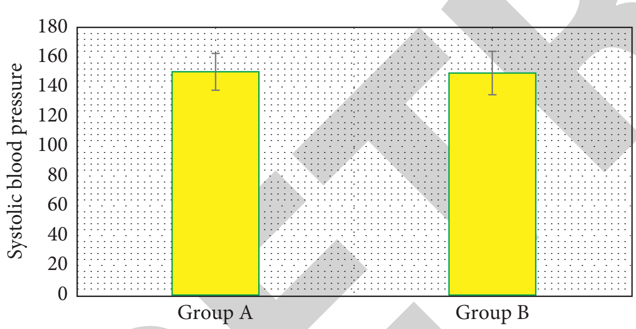

Figure 6: Comparison of the systolic blood pressure of patients from groups A and B.

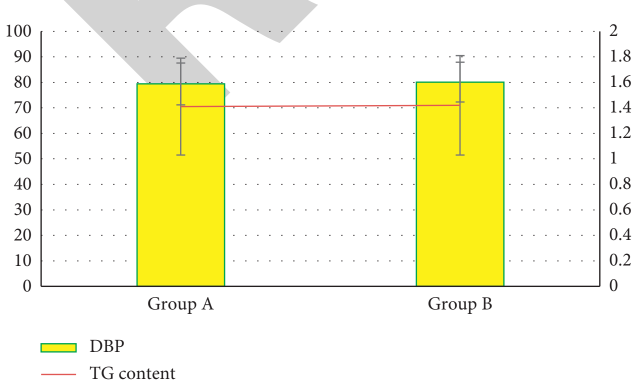

Figure 7: Comparison of DBP and serum TG content among patients from the two groups.

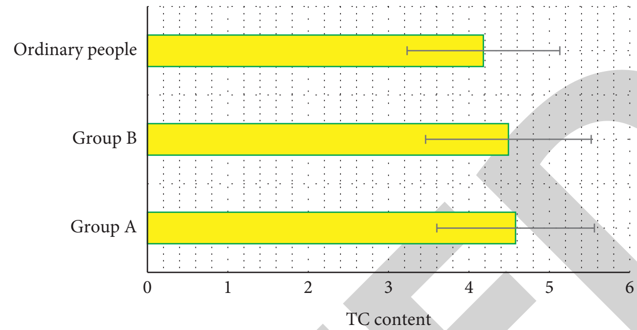

Figure 8: Comparison of the TC content of patients from the two groups.

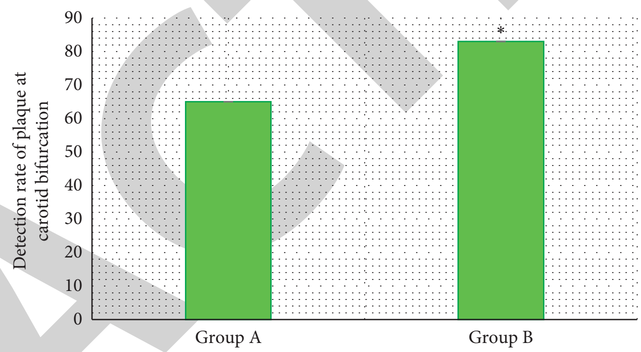

Figure 9: Comparison of the detection rates of vascular plaque at the bifurcation of atherosclerotic artery among patients from the two groups (*meant that the difference was statistically marked in contrast to group A ($P < 0.05$)).

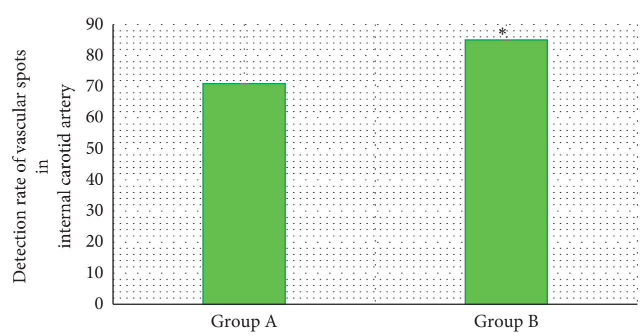

Figure 10: Comparison of detection rates of internal carotid artery plaque among patients from both groups (*indicated that the difference was statistically substantial in contrast to group A ($P < 0.05$)).

4. Discussion

Patients with CAA should be treated with drugs or surgery according to the degree of stenosis [14]. The carotid artery mainly provides blood supply to the front part of the brain. If stenosis or hyperplasia occurs, it will cause blood supply problems in the brain, such as dizziness, vertigo, tinnitus, or transient blackout. It is usually a transient ischemic attack, and a stroke may occur and speech, mobility, and swallowing disorders are caused if it occurs for a long time [15]. The

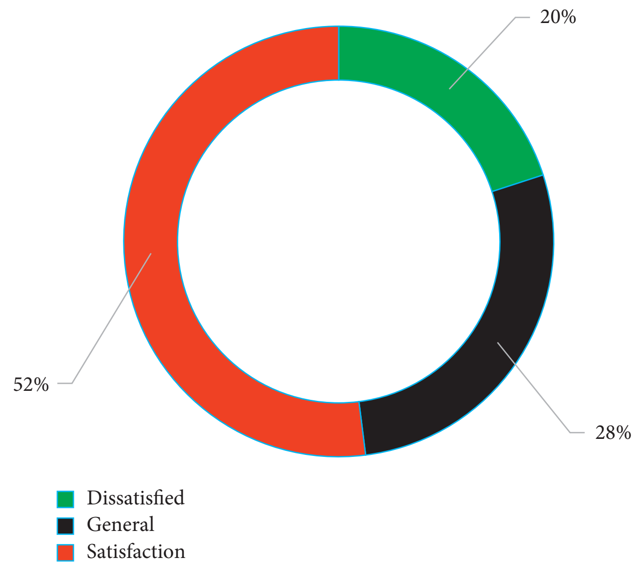

Figure 11: Satisfaction of diagnosis method for CAA among patients from group A.

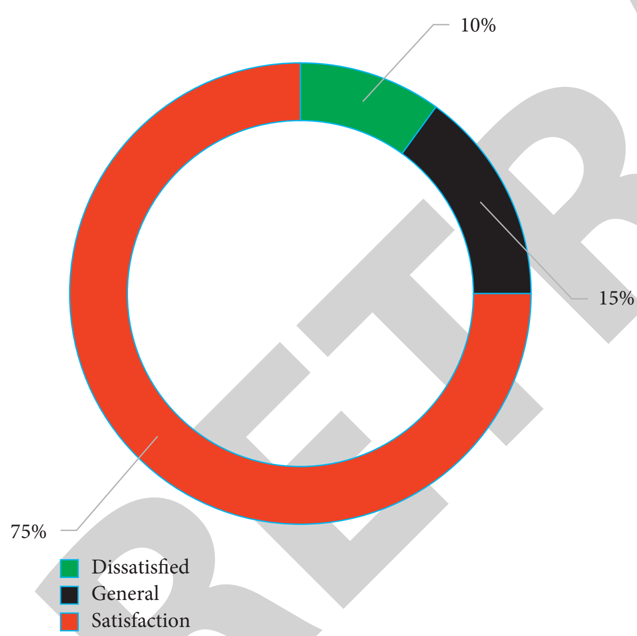

Figure 12: Satisfaction of diagnosis method for CAA among patients from group B.

research results of Lengyel [16] pointed out that if one person suffered from this disease, first, he or she had to determine the degree of stenosis formed by carotid atherosclerosis. If the degree of stenosis was less than 50%, it is needed to be controlled with drugs to prevent the plaque from growing up or falling down and causing subsequent problems. In addition, active treatment was required when the atherosclerotic plaque was greater than 50% or greater than 70%, and its method was stent treatment or carotid endarterectomy surgery [17]. Angiography is an invasive examination method of the cardiovascular system. It is currently widely applied in medicine and clinical treatment. Moreover, it is a low-risk surgery and its research has been relatively mature [18]. However, this method has certain risks in the process of diagnosing CAA. First, there is a greater correlation with the physique of patient. Some patients will have an allergic reaction to the contrast agent of angiography. They will suffer from anaphylactic shock and even die in the serious case, and it is difficult to prevent allergic reactions from happening. Furthermore, some patients do not pay enough attention to the condition, which leads to serious consequences during the angiography process [19].

In this study, patients with CAA were grouped into groups A and B and were treated with angiography detection and KMC-based ultrasound detection in turn to diagnose CAA. The patients from the two groups were also tested for serum TG content, DBP, and the detection rates of plaques in the artery at the bifurcation of the atherosclerotic artery and the internal carotid artery. Besides, the diagnostic value of CEUS based on KMC for CAA vulnerability was judged and analyzed by the above indexes. As a result, the sensitivity, specificity, and positive predictive value of the ultrasound diagnosis of CAA based on KMC in patients from group B were substantially higher than those of the angiography method from group A ($P < 0.05$). The detection rates of internal carotid artery plaque and atherosclerotic plaque in patients from group B increased obviously in contrast to the rates of group A ($P < 0.05$). This was consistent with the research results of Li and Li [20], indicating that the ultrasound detection method based on KMC had high sensitivity, specificity, and accuracy in detecting CAA. Therefore, the diagnostic effect of vascular plaque in different parts was superior to the effect of angiography, and it was worth applying the ultrasound detection method based on KMC to clinical diagnosis of CAA.

5. Conclusion

Patients with CAA were enrolled into groups A and B in this study, with the angiography detection and the KMC-based ultrasound detection in sequence. Then, serum TG content, DBP, and detection rates of plaques in different parts (such as the atherosclerotic bifurcation and internal carotid arteries) were measured in patients from both groups. The diagnostic value of CEUS based on KMC was judged and analyzed in the vulnerability of CAA through the above indexes. The results showed that the sensitivity, specificity, and accuracy of the ultrasound detection method based on KMC were high in the detection of CAA. Ultrasound detection was better than angiography in the diagnosis of vascular plaque in different parts, which showed that it was worth adopting the ultrasound detection method based on KMC to clinical diagnosis of CAA. However, the sample size selected in this study is small, which may have a certain impact on the experimental results, and the representativeness is low. Therefore, the sample size will be increased in subsequent experiments, and the diagnostic value of CEUS based on KMC needs the further analysis and discussion for the vulnerability of CAA. To sum up, the results of this study provide the data support and theoretical basis for clinical diagnosis and treatment of CAA.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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