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Study on the carotid atherosclerotic plaque of patients suffering from ischemic cerebrovascular disease by 64 slices CT

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Abstract. – OBJECTIVE: To explore the correlation between the features of a carotid plaque of patients suffering from carotid atherosclerosis and ischemic cerebrovascular disease by 64 slices computed tomography (CT).

PATIENTS AND METHODS: One hundred patients with carotid atherosclerosis were divided into the ischemic event group (n=48) and non-ischemic event group (n=52). The features of the carotid plaque were detected by 64 slices CT.

RESULTS: One hundred and thirteen plaques were found in the ischemic event group. The proportions of fatty, calcified, and mixed plaque were 35.4%, 30.1%, and 34.5%. There are 78 plaques found in the non-ischemic event group. The proportions of fatty, calcified, and mixed plaque were 21.8%, 51.3%, and 26.9%. The distribution difference between the three types of plaques was statistically significant ($p < 0.05$). The proportions of mixed plaque composed mainly of fatty plaque were 64.1% and 23.8%. These two constituent ratios are significantly different from those of statistical processing ($p < 0.01$). There are 10 cases of plaque ulceration out of the 100 cases, among which eight are from the ischemic event group and two cases from the other group. After statistical processing, the incidence rates of plaque ulceration from these two groups are significantly different ($p < 0.05$).

CONCLUSIONS: The 64 slices CT can accurately present the morphological features of the carotid plaque. It indicates that the fatty plaque, mixed plaque composed mainly of fatty plaque and ulcerative plaque can cause ischemic cerebrovascular events.

Key Words:
Computed tomography, Carotid artery, Atherosclerotic plaque, Ischemic cerebrovascular disease.

Introduction

The common causes and mechanisms for cerebral infarction are as follows: hemodynamic disorder due to artery stenosis caused by atherosclerotic plaque and the embolism of the distal artery caused by plaque[1]. The frequently-used clinical method to discover and evaluate atherosclerotic plaque is color Doppler ultrasound[2,3]. With the development of computed tomography (CT) and CT angiography (CTA), CTA has become an effective method of studying the morphological and pathological characteristics of plaque[4]. This report analyzes the distribution and morphological characteristics of the carotid plaque in ischemic and non-ischemic event patients with 64 slices CT.

Patients and Methods

A total of 100 cases of patients suffering from carotid atherosclerosis in this hospital from Sept. 2008 to Oct. 2010 were included in this study. There are 52 cases of the non-ischemic event within the 100 cases. For these 52 patients whose average age is 62.0±6.2 years old, there are 39 male patients and 13 females, 35 cases with hypertension and six cases of diabetes. There are 48 cases of obvious TIA in the carotid artery and acute cerebral infarction, among which there are 31 male patients and 17 females. Their average age is 63.0±5.7 years old. Furthermore, there are 30 cases with hypertension and 11 cases of diabetes. Cases in which patients are suffering from severe stenosis in an intracranial artery, cardiogenic cerebral embolism and other intracranial primary and secondary diseases are excluded.

Inspection Methods

CTA: 64 slices CT inspection method is applied in all the cases. The 64 slices CT generat-

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ed by GE Company is used. It is divided into the carotid artery CTA (the superior border of arcus aortae reaches the 20 mm of intracranial sella region) and the CTA of intracranial and cervical arteries (the superior border of arcus aortae reaches the calvarium). The scanning parameters of the plain scan and angiography are as follows[5-7]: electric tension 100-120 kV, tube current 200-230 mA, pitch 1.37, slice thickness 0.625 mm and reconstruction slice thickness 0.625 mm. 80 mL non-ionic contrast agent iohexol (350 g/L, GE Healthcare, Milwonkee, MI, USA) and double-syringe high-pressure injector are used for angiography and the injection rate reaches 4.5-5.0 mL/s, meanwhile, intelligent starting technology is also applied. All parameters are transmitted to the workstation (GE Medical Image AW4.3) and analyzed. The post-processing techniques includes the following: volume rendering (VR), multiplanar reconstruction (MPR), curved planar reconstruction (CPR) and maximum intensity projection (MIP). The original axial images are used to observe characteristics such as the distribution, form and character of the carotid plaque, the degree of luminal stenosis, calcification and occlusion as well as the performing quantitative measurement on the luminal stenosis. The carotid artery CT and CTA images are measured and evaluated by two physicians based on a blind method. The results are subject to the diagnosis confirmed by these two physicians collectively.

Image Analysis

Segment of carotid artery[8-11] carotid artery is segmented into five segments, and they are the common carotid artery (CCA), furcation region of the common carotid artery, initial segment of internal carotid artery (ICA), ICA extracranial segment and ICA Intra calvarium.

Types of carotid plaque: according to the literature, the plaque is divided into the following types: (1) Fatty plaque: there is an obvious lipid-rich core and it is presented as clear low-density area within the plaque under CT with core CT value less than 50 Hounsfield Unit (HU). (2) Calcified plaque: shown as calcification or with soft tissue, the CT value of calcific part is no less than 120 HU; (3) Mixed plaque: the CT value is 50 to 119 HU and it has more than two constituents, which can be divided into mixed plaque composed mainly of calcified plaque and mixed plaque composed mainly of fatty plaque. The HU values of the plaque in the object regions are measured according to methods in the literature.

The stenosis is classified as mild stenosis (1%-39%), moderate stenosis (40%-69%), severe stenosis (70%-99%) and occlusion with North American Symptomatic Carotid Endarterectomy Standard as a reference.

Statistical Analysis

The SPSS 11.5 software package (SPSS Inc., Chicago, IL, USA) was used to process the data, and enumeration data is tested by χ^2. There is statistical significance when $p < 0.05$.

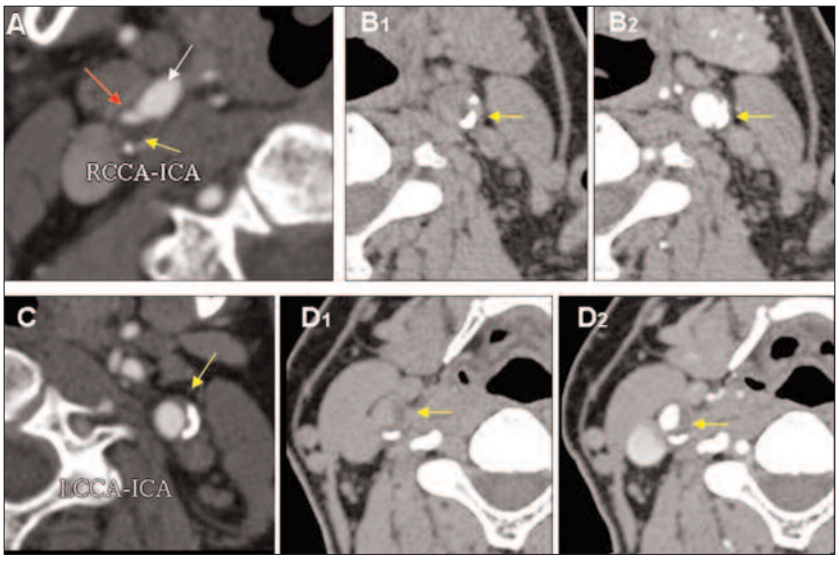

Figure 1. Characteristics of carotid plaque on axial CTA source image of carotid artery.

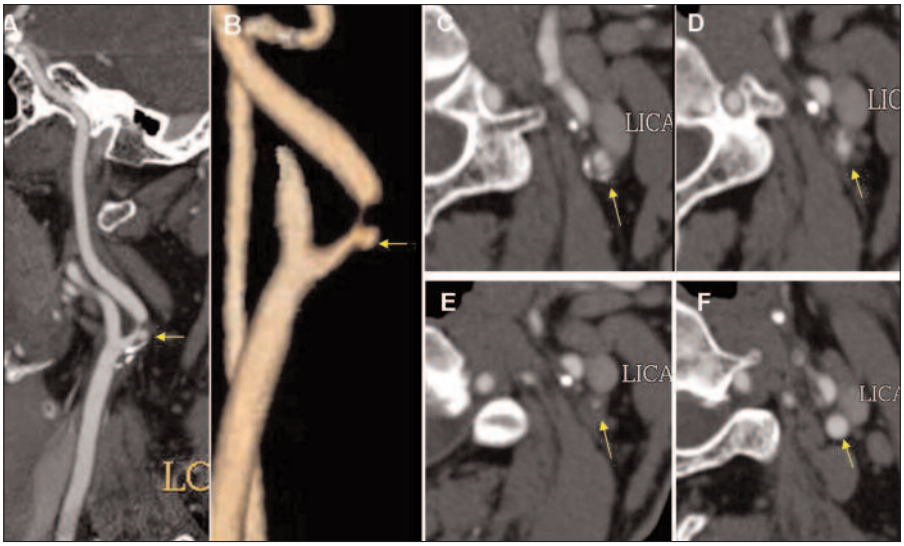

Figure 2. 57-year-old man with cerebral infarction.

Results

Types of Carotid Plaque Tested by CTA

A total of 200 carotid arteries from 100 patients are tested, in which there are 181 plaques found. They are mainly distributed in the furcation region of the CCA, the initial segment of ICA, the cavernous sinus region and the siphon region of ICA (Figure 1). There are 113 plaques found in the ischemic event group, among which there are 40 (35.4%) fatty plaques, 34 (30.1%) calcified plaques and 39 (34.5%) mixed plaques. Meanwhile, there are 78 plaques found in non-ischemic event group, among which there are 17 (21.8%) fatty plaques, 40 (51.3%) calcified plaques and 21 (26.9%) mixed plaques. It is of statistical significance for the distribution difference of the three plaque types in these two groups after statistical processing ($p < 0.05$). For the ischemic event group, there are 14 (35.9%) mixed plaques composed mainly of calcified plaque and 25 (64.1%) mixed plaques composed mainly of fatty plaque. For non-ischemic event group, there are 16 (76.2%) mixed plaques composed mainly of calcified plaque and 5 (23.8%) mixed plaques composed mainly of fatty plaque. The difference between these two groups is significant after economic processing ($p < 0.01$).

Carotid Plaque Ulceration and Intraplaque Hemorrhage Tested by CTA

There are 10 cases of plaque ulceration from the 100 cases, which are only presented in moderate and severe carotid artery stenosis cases (Figure 2). And for these 10 cases, there are eight cases from the ischemic event group and two from non-ischemic event group. By statistical processing, the difference in incidence rates of the plaque ulceration in the two groups is significant ($p < 0.05$). There are three cases of intraplaque hemorrhage out of 100 cases, among which there are two cases found in mixed plaque from ischemic event group and one from the non-ischemic event group (Figure 3).

In Figure 1A the yellow arrow shows the fatty plaque at the ends of RICA, the red arrow shows the ICA residual lumen, the white arrow shows the external carotid artery. In Figure 1 B, the yellow arrow shows the RCCA calcified plaque. In B_1: before the angiography; in B_2: after the an-

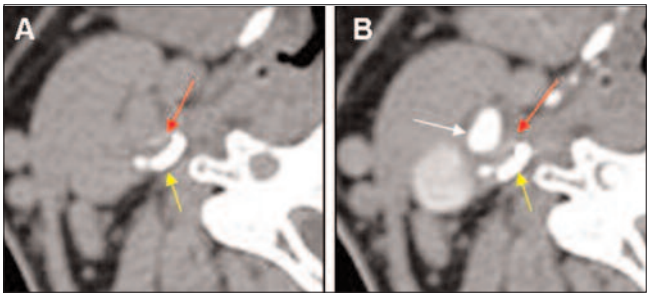

Figure 3. Axial CTA source image in the left carotid bulb.

giography. In Figure, 1 C presents mixed plaques composed mainly of calcified plaque. Figure 1 D shows mixed plaque composed mainly of fatty plaque; in D_1: before the angiography; in D_2: after the angiography.

Figure 2 shows the initial segment of the left ICA of a 57-year-old male cerebral infarction patient. A presents the MIP image in left ICA; the arrow shows the ulceration. B presents VR image in left ICA. The C-F are the original axial images in the left ICA; C and D show the surface of the plaque ulceration, E shows the narrowest part of the residual lumen in the left ICA, F shows the normal segment of the left ICA.

Figure 3 shows the original axial CT image of left CCA carotid bulb of a 69-year-old male patient. A is before the angiography and B are after the angiography; the red arrow shows the intraplaque hemorrhage; the yellow arrow shows the calcified plaque and the white one shows CCA residual lumen.

Discussion

It is common in clinical practice that many severe carotid artery stenosis patients are not suffering from an ischemic stroke while cerebrovascular events happen to some mild stenosis patients[12]. Studies[13] show that the cerebral infarction caused by hypoperfusion due to lumen stenosis is only one small part in the clinical events. However in most cases the cause is cerebral embolism due to the defluvium of plaque. This indicates that for atherosclerotic patients, the constituents and morphology of the atherosclerotic plaque are also observed besides the artery residual lumen. It is helpful to figure out the independent risk factors that cause clinical symptoms by defining the constituents of plaque. As with atherosclerosis in other parts, carotid plaque includes fibrous cap, necrotic lipid core, fibroblast, smooth muscle cell and calcification. With the development of multi-director CT and more precise CT three-dimensional imaging software, CTA can also perform qualitative analysis and quantitative analysis. Constituents of plaque determine the CT value. Plaques are divided into three types according to the CT value measurement of the density of plaque by CTA. They are fatty, mixed and calcified plaque.

The 64 slices CT original axial images combined with reconstruction images are used to observe the character and features of a carotid plaque of patients suffering from ischemic and non-ischemic events. After comparing and analyzing, the results show that there are 113 plaques in the ischemic event group, among which the proportions for fatty, calcified and mixed plaque are 35.4%, 30.1%, and 34.5%. For the mixed plaque, there are 64.1% mixed plaque composed mainly of fatty plaque; there are 78 plaques in non-ischemic event group, among which the proportions for fatty, calcified, and mixed plaque are 21.8%, 51.3%, and 26.9%. For mixed plaque, there are 23.8% mixed plaque composed mainly of fatty plaque. Statistical analysis indicates that there is a significant difference in terms of the distribution of different types of plaque in the two groups. This means that fatty and mixed plaque composed mainly of fatty plaque are both unstable plaques and easy to fall off, resulting in infarction in some blood supplying regions. Studies by Takaya et al[14] show that fatty plaque is rich in lipid and necrotic matter. The increase of necrotic lipid core in the plaque will increase the burden of plaque, which will make plaque easier to rupture and cause ischemia of the distal organs.

Thin slice axial images of 64 slices CT can show the density within the plaque and analyze the constituents of plaque. Meanwhile, the VR, MPR, CPR and MIP reconstruction images can be observed from many different angles. The vessel wall, plaque, and lumen can be observed separately, which can present the shape and ulceration of plaque more comprehensively compared with digital subtract angiography (DSA). Randoux et al[15] uses CTA, magnetic resonance angiography (MRA) and DSA. When observing the plaque ulceration, it shows that the correlation of these three methods is good. The sensitivity and specificity of CTA are 100%. Another study[16] in which CTA, ultrasound, and surgery are compared to analyze stenosis degree, constituents and ulceration of plaque also indicates that the sensitivity and specificity of CTA reach 93.75% and 98.59%, which has more advantages than ultrasound (the sensitivity and specificity are 37.5% and 91.5%, respectively). Therefore, 64 slices CT can present the plaque ulceration in carotid artery well. By carotid artery original axial images of 64 slices CT and VR and MIP reconstruction images, this study has found 10 cases of plaque ulceration in these two groups, among which there are eight cases from the ischemic event group and two from non-ischemic event group. The results show that plaque ulceration is more com-

mon for patients with cerebral apoplexy symptoms, which means that it is easier for a carotid plaque with ulceration to cause ischemic events. For lipid oriented fatty plaque or mixed plaque, the fibrous cap is thin and as a result, the ulceration of plaque and distal arterial embolization are easier to develop, which will cause the infarction of blood supplying regions and TIA[17]. As with atherosclerosis in other parts, the rupture of plaque is regarded as the determinant factor in vascular or ischemic events. Furthermore, intraplaque hemorrhage increases the possibility of plaque rupture. In the past, many researchers believed that magnetic resonance imaging (MRI) is a better method to present fibrous cap and its potential rupture. Nevertheless, a new study[18] on the carotid plaque of cerebral apoplexy and non-stroke patients *in vivo* shows that multi-director CT can clearly mark lipid-rich necrotic core, calcification, hemorrhage and residual connective tissue by using the full-automatic analysis software. Wintermark et al[18] compared the features and pathology of plaques in vivo and in vitro. They found that the coincidence rate of CTA with pathological diagnosis was 72.6%. Although there is overlap for individual pixel readings by using density variation to distinguish different constituents (lipid core, connective tissue, and hemorrhage) and the reliability is limited, there is good correlation between CTA results for big lipid core and intraplaque hemorrhage and pathology. In this study, there are three cases of intraplaque hemorrhage out of 100 cases and among which, two cases had mixed plaque in ischemic event group and one from non-ischemic event group. This incidence rate is significantly lower than that in the foreign literature[19]. Thus, the statistical processing is not performed. The reasons may be like the following two aspects: on the one hand, the stenosis degrees of carotid artery selected in this study are different; on the other hand, the incidence rate of severe stenosis of carotid artery in China is significantly lower than people in Europe and America[20]. Reports[21] show that intraplaque hemorrhage is more common when the artery stenosis is more than 70%. Intraplaque hemorrhage may be one of the signs of unstable plaque because it accelerates the development of atherosclerosis. Compared with stable plaques, there are more newly formed blood vessels in the fatty plaque, and since their brittleness is higher, those vessels are easier to rupture. Therefore, the intraplaque hemorrhage is caused, which will influence the stability of fibrous cap[22,23] and result in cerebrovascular events. However, studies from Saam et al[19] indicate that there is intraplaque hemorrhage in 91% symptomatic patients and 83% asymptomatic patients. Meanwhile, they also believe that whether there is intraplaque hemorrhage is not the most important. What is the key point, is that whether the intraplaque hemorrhage is acute? The incidence rate of acute intraplaque hemorrhage in the symptomatic group is higher than that in the other group. As this point, MR is better than 64 slices CT because it can better distinguish acute hemorrhage. As a result, more researches and studies are needed in terms of the detection of intraplaque hemorrhage by 64 slices CT and the relation between intraplaque hemorrhage and ischemic cerebrovascular disease.

Conclusions

As a noninvasive, easy to repeat and reliable imaging diagnostic technique, the 64 slices CTA can accurately present the morphological features of carotid plaque[24-26]; through comparing results of these two groups, it indicates that fatty plaque, mixed plaque composed mainly of fatty plaque and ulcerative plaque are easier to cause ischemic cerebrovascular events. It is of significant clinical value to predict cerebrovascular events by evaluating morphological features of plaque.

Conflict of Interest

The Authors declare that there are no conflicts of interest.

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