Imaging-anatomy Measurements of Carotid Artery Bifurcation

S Duan[1], J Li[1], L Yang[1], S Lv[1], Y Huang[2]

ABSTRACT

Objective: To have anatomical measurements of carotid artery bifurcation (CAB) with 64-spiral CT angiography (64-SCTA), and provide anatomic basis for related research.

Methods: Imaging data of 92 subjects (45 males, 47 females, the age range 20-82 years old and mean age 48.4±6.1) without pathology of CAB, who underwent 64-SCTA in head and neck from June 1, 2008 to June 30, 2010, were selected from the PACS in our hospital. On the 3D images, the angle and size of CAB were measured, and the statistical comparisons of measurements were made between the bilateral, sex and age groups.

Results: The measurements of CAB were divided into young(≤ 40 yrs) and older (> 40 yrs) groups, that of bifurcation angle is 36.206°±10.210°, 49.343°±16.489° respectively, the inner diameter of common carotid artery (CCA) 6.820±0.635, 6.845±0.838; The proximal inner diameter of internal carotid artery (ICA) is 7.143±0.992, 7.476±1.630 respectively, the enlargement 7.568±1.069, 8.554±1.733, the distal 4.897±0.508, 5.123±0.699; the inner diameter of external carotid artery (ECA) is 4.324±0.580, 4.104±0.638 respectively. There were statistically significant difference in all the measurements between male and female groups, in the bifurcation angle, inner diameters of ICA and ECA between young and older groups and in the bifurcation angle between the left and right ($P < 0.05$).

Conclusions 64-SCTA with 3D image post-processing technique can clearly observe and show the CAB. All of CAB measurements will provide the objective basis for applied anatomy, imaging diagnosis and surgery treatment.

Keywords: Carotid artery bifurcation; Imaging anatomy; measurement; three-dimensional CT

From: [1]Medical Imaging Department, [2]Neurosurgery Department, Zhongshan Hospital of Xiamen, University, Xiamen 367004, China.

Correspondence: Dr S Duan, 209 South Hubin Road, Xiamen, 361004, China. Fax: 86-592-2212328, e-mail: xmdsy@xmu.edu.cn

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INTRODUCTION

Blood supply of brains is from the internal carotid artery [ICA] and vertebral artery, of which the ICAs are mainly supply to the anterior 2/3 of brain hemisphere and part of the diencephalon. Studies found that carotid artery bifurcation [CAB] is the predilection sites of many diseases, such as the carotid atherosclerosis, carotid artery aneurysm, carotid body tumor and so on. Its structure or morphology is easy to be affected by the local neurogenic tumor or lymphadenopathy and to directly influence the local blood flow of brain (1-3). Therefore, this study is to measure the CAB with the 64-slice spiral CT Angiography [64-SCTA], and the anatomical data will provide the objective basis for further basic and clinical study on the CAB.

MATERIALS AND METHODS

General information: 92 subjects [Male 45, Female 47; Age range 20-82 yrs, Mean 48.4± 2.5 yrs] were selected from the PACS in our hospital between June 1, 2008 and June 31, 2010, who were performed the 64-SCTA [the CAB without vascular lesion or pushing , impinging by other pathological changes of surrounding structures].The two groups were divided, including 40 cases is in the ≤40 yrs and 52 cases is in the ＞40 yrs. Their scanning data were used to form the 3D images again for the CAB measurements.

Equipments and technique: Sixty-four-slices spiral CT [Light speed VCT, GE, USA], Contrast medium [Omnipaque 300 mgI/mL, shanghai affiliate corpor-ation of GE] and high-pressure syring [MCT-plus, PGH. or Stellant, USA] were used. Examination process includes the following steps:

1. **Ascertainment of delayed scan time:** CT pre-scan with low-dose [120 Kvp, 30 mA] was automatically started after Omnipaque 20ml [A tube] + Normal saline 10ml [B tube] were injected into anterior elbow vein with the rate of 4.0 ml/sec for 8-10sec.Used the scan data, the time-density curve of intravascular contrast medium at the internal carotid artery and peak time were obtained. With the peak time plus 4-6 seconds, that is the delayed scan time.
2. **Scanning parameters and technique:** scanning sequences range from carotid artery root [including part of aortic arch] to the top of skull [including the superior sagittal sinus]. The parameters include Tube voltage of 120 Kvp, Tube current of 250 mA, Pitch of 0.984 or 1.375, Slice thickness of 0.625 mm. Omnipaque 80-90 ml + NS 20ml were injected into anterior elbow vein with the high-pressure syring with 4.0 ml/sec, then the two phase CTA scan was started according to the delayed scan time.
3. **Image process:** Above scanning data were transferred to AW4.2 workstation, then 3D images were obtained with 3D imaging of separating, fusing, opacifying and false-coloring volume rendering [SFOF-VR], multiple planar reconstruction [MPR] and maximum density projection [MIP]. Finally, the anatomical measurements of CAB were done on the VR, MPR and MIP, and their mean act as our measurement (4).
4. **Measurement parameters and statistics**： Measurements of CAB [Fig.1]： the angle of CAB [α] is the biggest angle of the center line between internal carotid artery [ICA] and external carotid artery [ECA]. The diameter of common carotid artery [CCA] is the location at 1.5cm below bifurcation [A]. The diameters of ICA include that of the proximal [B], the enlargement [C] and the distal [D]. The diameter of ECA is the location at 1.5cm above bifurcation [E]. Statistical comparisons were carried out the *t* test with SPSS 16.0 software.

RESULTS

Technique assessment: All the examination parameters were integrated，the subjects' blood vessels were filled very well by the contrast medium. 3DCT images clearly showed the structures of CAB and surrounding structure without obvious artifact, then MRA or DSA images with some shortage [Fig.2-4].

The measurements about CAB: The bifurcation angle range is from 21.3° to 87.6°, the inner diameter of CCA from 4.9 mm to 9.3 mm. The proximal inner diameter of ICA is from 4.5 mm to 13.5 mm, that of the enlargement from 5.3 mm to 13.5 mm and that of the distal from 3.6 mm to 7.4 mm. the inner diameter of ECA is from 2.7 mm to 5.6 mm. Measurements data and comparisons see the Table 1-3.

Table 1: Comparison of measurements between young (40 cases) and older (52 cases) groups

Measurement Parameters	a(°)	A(mm)	B(mm)	C(mm)	D(mm)	E(mm)
≤40	36.2±10.2	6.82±0.64	7.14±0.99	7.57±1.07	4.90±0.51	4.32±0.58
＞40	49.3±16.5	6.85±0.84	7.48±1.63	8.55±1.73	5.12±0.70	4.10±0.64
t	6.260	0.224	1.430	4.474	1.676	2.407
P	<0.05	>0.05	<0.05	<0.05	<0.05	<0.05

Table 2: Comparison of measurements between male (45cases) and female (47cases) groups

Measurement Parameters	a(°)	A(mm)	B(mm)	C(mm)	D(mm)	E(mm)
Male	46.1±15.9	6.98±0.83	7.77±1.48	8.51±1.42	5.19±0.67	4.35±0.67
Female	41.3±14.9	6.70±0.65	6.81±1.11	7.75±1.60	4.86±0.55	4.06±0.54
t	2.144	2.561	4.996	3.404	3.645	3.271
P	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Table 3: Comparison of 92 cases measurements between the left and the right

Measurement Parameters	a(°)	A(mm)	B(mm)	C(mm)	D(mm)	E(mm)
Left	47.4±16.79	6.79±0.74	7.40±1.52	8.33±1.59	5.05±0.68	4.22±0.64
Right	39.83±13.3	6.88±0.77	7.16±1.23	7.92±1.51	4.99±0.59	4.18±0.60
t	3.420	0.751	1.182	1.781	0.558	0.485
P	<0.05	>0.05	>0.05	>0.05	>0.05	>0.05

Statistical results: There were significant differences in all the measurements between male and female, in the bifurcation angle, inner diameters of ICA and ECA between young and older groups and in the bifurcation angle between the left and right （$P < 0.05$）.

DISCUSSION

Research significance: There are some reports of studying on the regional anatomy of CAB by DSA, MRI and US, these observing and measuring results have been broadly applied (3,6). Though the measurements can provide good value for basic research or clinical application, there are some differences among the measurements for the influence from technique itself. In this paper, we used the 64-SCTA scan and 3D post-processing techniques to study on the CAB in vivo, the first is that can act as a new mean for anatomical research, the next is the anatomic measurements can reflect the physiological condition of CAB and posses the characteristic of objectivity. If the measurements of patient were done before operation, the obtained measurements are individual. While doing the anatomic measurements on the cadaver specimens, we find there are some deficiencies, which are amount conditionality of the cadaver specimens, and the measurements can not reflect the physiological function of CAB. At the same time, there are some impact on the Accuracy of measurements for the anatomic technique and objective factors of the cadaver specimen (7-9). With the images of 64-SCTA, it can clearly demonstrate the CAB and the surrounding anatomy bone structure, vein and soft tissues. Obtained measurements can objectively reflect the structure of CAB and the 3D relation to the surrounding structures, and make up for a lack of the other imaging technology. In view of the above advantages, the 3D imaging anatomical measurements can provide reliable basis for disease diagnosis and surgical plan.

Structures and shape of CAB: Internal carotid artery is the main vessel to sustain the blood-supply of brain, there are not a little studies about the relation between CAB's structure and function (10-16), of which include the study on CAB anatomical structure and measurement with multi-imaging techniques, blood fluid dynamics change, and to answer why CAB is easy to form the atherosclerosis and to cause secondary vascular stenosis resulting in ischemic cerebrovascular disease and so on. Our results indicated there are statistically significant differences between male and female, young and older, which accord with these reports (3,7,14), of which CAB bifurcation angle difference, under the age of 40 and more than 40 group, the former is smaller than the latter, may be due to arterial expansion, tortuous, the changes of vessel elasticity and wall thickness with the age. About male and female subjects in anatomical parameters measurement values of the differences were statistically significant ($P < 0.05$), and the males are bigger than females in anatomical measurements may be associated with the male's body type is larger than the female's. In addition, there was significant difference in the left and right CAB bifurcation angle and the left greater than the right, the reason should be explored further. However, it will provide an objective basis for the future clinical research or application about the CAB. At the same time, when doing the therapeutic or functional simulation, the anatomy of individual differences must be taken into account. In addition, there is larger variability of CAB angle, the upper limit is 87.6 ° and the lower limit 21.3 °. Therefore, it will cause a false positive for us to simply rely on the bifurcation angle expansion to judge the CAB lesion, so radiologist must be combined with the cross section of the original image and have a comprehensive analysis in order to improve the diagnostic rate and reduce the rate of misdiagnosis when diagnosing the CAB lesions.

Comparison of imaging techniques: There are many imaging methods in clinical application on diagnosis of the CAB diseases, such as digital subtraction angiography [DSA], magnetic resonance angiography [MRA], CTA and ultrasound [US]. DSA examination as the gold standard has the character of high specificity and sensibility, however, it is expensive, invasive, time-consuming and possible to be with some complications. Moreover, DSA images just show vascular cavity structure, not vascular wall and surrounding structure, which may results in certain limitations for diagnosing the diseases of the wall or out of the wall. US examination is a very cheap technique on vascular lesion and has widely been applied on the CAB, it can be used to make the anatomy morphology observation and blood flow measurement in real time. However, there are some deficiency of low resolution image, of affected by doctor's manipulation and patient's bloodstream (8-10). MRA is extensively used to diagnose the diseases of the CAB, but it is sensitive to the regional flow and cause signal loss for the region of swirl or slow flow. The imaging technique of 64-SCTSA has the character of high specificity, sensibility and quality of image. With the development of 3D imaging, it can be accomplished the separation of target vascular or bone with different color and the fusion them to have the observation or measurement from any angles, which can provide further detailed anatomic data for clinical surgery. There are some reports that indicated diagnostic accuracy of 64-SCTA is similar to that of DSA in diagnosing the vascular diseases and 64-SCTA is confirmed broadly by clinical physician (8-10).

Clinical application and Disadvantages: 64-SCTA is a new，valuable imaging technique to assess the CAB anatomical structure. It is noninvasive with the objective and individual character and not only shows vascular cavity structure, but also the changes of vascular wall surrounding structures. 64-SCTA is very helpful in evaluating CAB stenosis degree and plaque stability, and providing more messages for clinical diagnosing and treating，such as plaque rupture, haemorrhage, thrombosis，calcification，regional aneurysma and so on. Moreover, 64-SCTA can define the lesion from the vascular wall or from pressuring of outside structures, which can give basis for differential diagnosis on the CAB lesions and identify the increasing causes of bifurcation angle with combined cross-sectional original image information and multidirectional observation. By measuring the CAB or showing the 3D relation between CAB and lesions, or the carotid artery contour and fat space, we can judge if the mass impinge the carotid artery and provide basis for designing the vascular stent or surgery plan (17-20). Of course, there are some shortcomings in this research, for example, the research subjects does not consider the bifurcation structure changes from the influence factor of blood lipids, blood pressure, blood glucose, smoking, drinking and other. In addition, the samples of study subject are small, it is necessary for multicenter larger sample research and statistics to reveal the anatomical features of Chinese normal CAB.

Competing interests: None declared.

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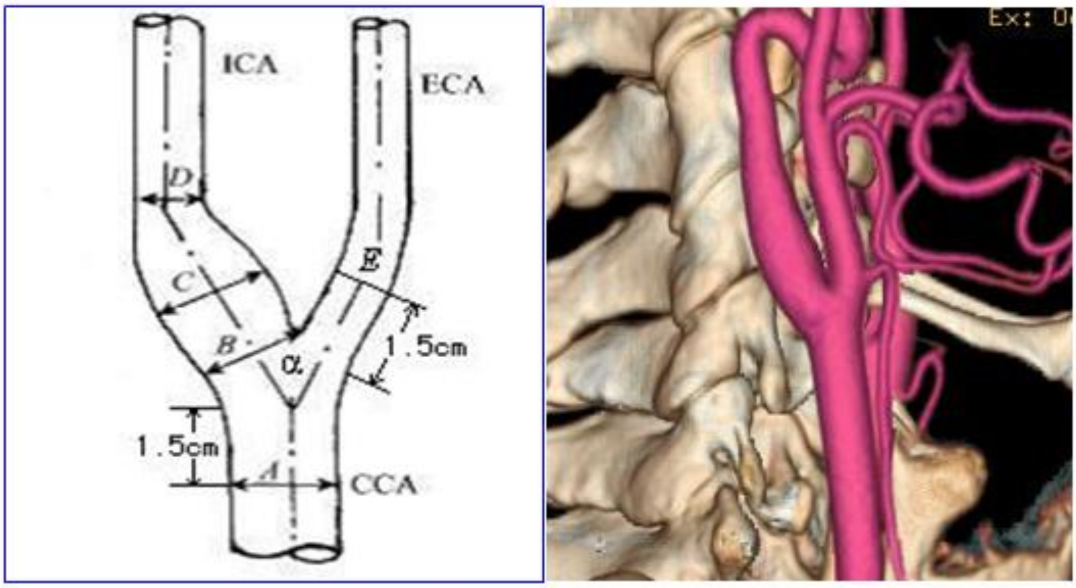
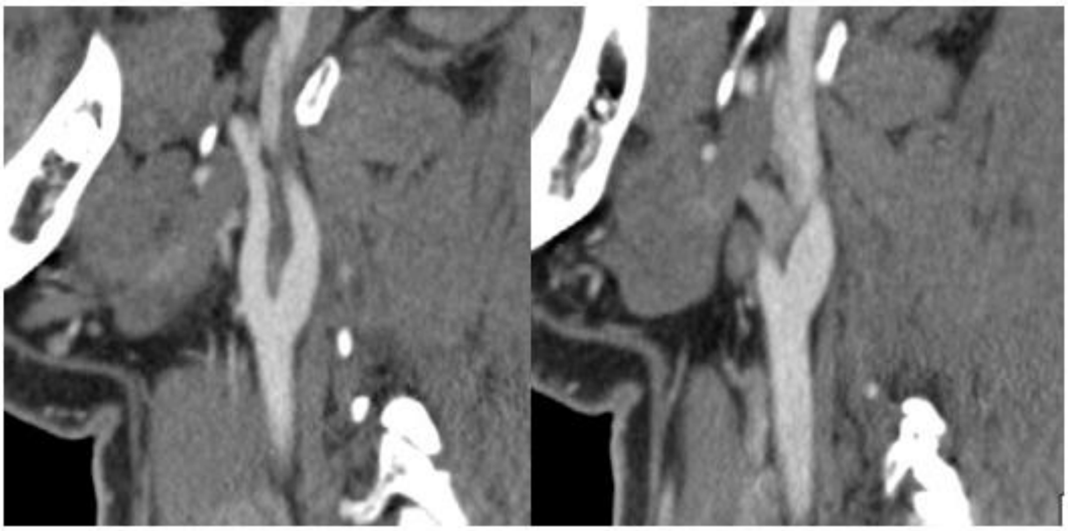


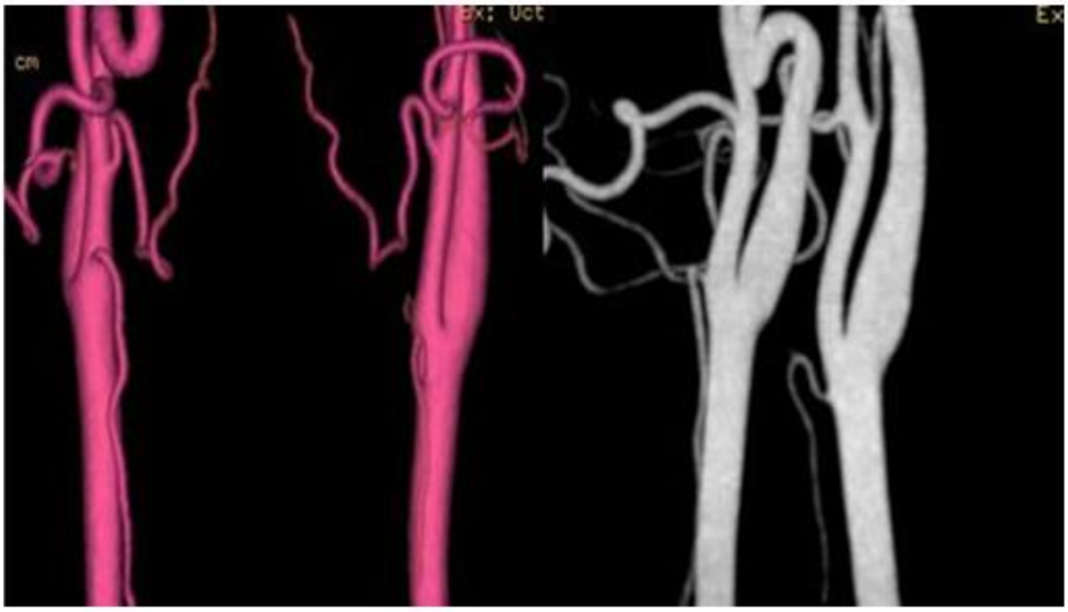
A B

Fig.1A: is the measurement of CAB on the diagram. (α: the angle of carotid bifurcation; CCA: common carotid artery; ICA: internal carotid artery; ECA: external carotid artery; A: diameter of CCA(about 1.5cm below bifurcation); B:proximal diameter of ICA; C: width of ICA enlargement; D: distal diameter of ICA; E: diameter of ECA (about 1.5cm above bifurcation). B is the SFOF-VR image displaying the CAB structure and relation between CAB and surrounding structures.



A B

Fig.2: MPR images clearly displaying the CAB structure and the measuring locations (A measured the ICA and ECA; B measured the CCA).



A B

Fig.3: SFOF-VR image can independently delineate carotid bifurcation anatomy, without the interference of surrounding structures (A). SFOF-MIP image can clearly and directly delineate the calcification of vascular wall (B).

A B

Fig.4: 3DTOF-MRA image can only display CAB anatomy itself, not displaying its surrounding structures, and flow-related signal loss easily lead to the distortion of local anatomy (A). As two-dimensional angiography, DSA can only show vessels themselves, and cannot show three-dimensional relationship between vessels and their surrounding structures (B).