Relationship between CCA-ICA angle and plaque composition

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Aims and objectives

The aim of our study is to demonstrate whether there is a relationship between the angle of Common Carotid Artery (CCA) and Internal Carotid Artery (ICA) and atherosclerotic plaque composition in terms of Fat, Mixed, Calcific plaque and plaque volume. Plaque composition analysis by MDCTA has been proved to be a highly reliable tool compared to the histopathology of the plaque, and it is also an important indicator of risk.
Methods and materials

The institutional review board approval for this study was obtained. This is a prospective single institution pilot study enrolling 59 patients, for a total of 118 carotids, who were scheduled to perform a MDCTA of the supra-aortic vessels with a 16-multidetector-row computed tomography (CT) system (Philips Brilliance, Eindhoven, Netherlands).

Patient Population:

The examinations were performed between April 2016 and February 2017 for a total of 118 carotids, 59 patients. Patients were chosen per two main criteria: symptomatic and asymptomatic. Asymptomatic patients are recruited from those patients screened with color-doppler sonography of carotid arteries with the presence of a carotid stenosis greater than 50% (according to the either NASCET[North American Symptomatic Carotid Endarterectomy Trial] or ECST criteria. Other two criteria are the evidence of plaque alteration and insufficient information given by ultrasonography. Patients were considered symptomatic when they suffered TIA or stroke in the past year.

MDCTA Technique

Examinations have been performed within an extent from the aortic arch to the carotid siphon. A basal scan was obtained and was followed by the angiographic phase in which a bolus of 80 mL of contrast medium (Ultravist 370; Bayer, Leverkusen, Germany) was delivered by using a power injector at a flow rate of 5 mL/s. A bolus tracking technique within the ascending aorta (ROI) was used to select the correct timing of the study. Dynamic monitoring scanning of the selected ROI began 6 seconds after the beginning of the intravenous injection of contrast material. The trigger threshold inside the region of interest was set at +80 HU above the baseline. CT technical parameters included the following: matrix 512 x 512; field of view (FOV) 14-19 cm; 180-220 mAs; 120-140 kV. C-filter algorithm was applied.

Plaque composition analysis

To quantify different plaque components at the CT examination all MDCTA scans were read independently by experienced readers using a dedicated offline workstation with a commercially available software (iNtuition; Terarecon, Foster City, California, USA). CTAs were reconstructed in the straightened multiplanar reformatting mode (sMPR) with automatic centerline, adjusted by the reader. A single seed point was generally sufficient to automatically isolate the centerline of the CCA and the ICA, where the plaque generally extends. If the software did not recognize the correct centerline of the wanted vessels, then the operator would manually correct the line. The foot-head section which underwent analysis was then isolated (region of interest [ROI] ) along the bifurcation, since it has been identified that this region with low and oscillating shear stress, and with particular geometry features, is the most suitable for plaque formation. Both patients with and
without a significative stenosis have been taken into account. The "plaque analysis" module of the iNtuition software was then used to delineate the inner and outer walls of the vessel (including the plaque) from surrounding tissue and lumen. The automatic plaque volume and composition quantification was then applied for a tract of 2 cm (+ - 0,5 cm according to the extension of the plaque visually interpreted by the readers) starting from the distal point of the CCA:bifurcation to the proximal ICA. It is in this very segment that the most significative plaques have been found. In only 2 cases plaques had an extension bigger than 2 cm. The patients without plaques visually identifiable were still evaluated for a standardized tract of 2 cm, in order to create some healthy reference. The inner and outer walls of the vessel were then checked and manually corrected by the readers on the axial plane. A set of Hounsfield unit (HU) intensity ranges were then defined and mapped with different colors to visualize various elements of a given voxel. Fatty plaque component has been defined as a Hounsfield unit range between < 30 and 60, fibrotic if HU was in the 60-130 range and calcific if HU was > 130. The volume of each defined tissue category within the ROI was then automatically calculated by the software. In addition, the software also calculated the total vessel volume, the total lumen volume, and the volume between internal and external lumen within the ROI, which as been defined as "plaque volume". The HU intensity ranges selected were based on previous papers. Analysis was performed on the total volume of each type of plaque within the ROI and on the percentage of each type of plaque calculated as a volume of each type divided by the total plaque volume, defined as "plaque percentage".

CCA-ICA angle analysis

To quantify CCA-ICA angles at the CT examination all MDCTA scans were read independently by experienced readers using a dedicated offline workstation (iNtuition; Terarecon, Foster City, California, USA). According to the reader preferences and to the geometric configuration of each carotid the angles were measured with a Multiplanar Intensit Projection (MIP) reconstruction or with a 3D surface rendering with the automatical bone removal tool. The axis of the CCA was then traced first and the line prolonged cranially for some centimeters in order to allow the mesuration of the angles between ICA, ECA and CCA. If the CCA had a curved path, then the axis considered was the one of the last bit of the vessel before the bifurcation. The reader could be helped in the process by the centerline traced with the modalities described in the previous paragraph. The axis of the first bit of ICA was then traced at its origin. The angle between the first tract of the ICA and the CCA was then measured with the "angle measurement" tool of the software tracing two parallels line to the axis previously drew.

Statistical Analysis

Statistical analysis was performed with the SPSS 13.0 statistical package (SPSS Inc., Chicago, IL). The variables relationship was calculates using Correlation Coefficient r. A P value < .05 was regarded to indicate statistical significance association.
Fig. 4: Angle measurement on a MIP reconstruction

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Fig. 5: CAD plaque composition detection on an axial plan

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Fig. 6: Angle measurement on a volumetric reconstruction

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Results

Of the 119 carotids analysed, in 9 cases the image quality was insufficient, due to dental hardware which made the semiautomatic plaque quantification measurement impossible. In 3 cases the stenosis was total and there was an occlusion of the vessel; these patients have been excluded as well from the calculations.

In 21 cases the stenosis was significant according to the NASCET criteria (stenosis > 50%). There is almost no correlation between the angle value and the fatty plaque percentage ($r = -0.005784$, significance level $p = 0.9533$). The correlation coefficient between the angle value and the calcified plaque percentage is 0.1456. The biggest correlation is between CCA-ICA angle values and a plaque composed mainly of fibrous HU voxels ($r = 0.2130$, significance level $p = 0.0375$).
Fig. 1: MIXED PLAQUE Correlation coefficient $r = 0.2130$ Significance level $P = 0.0375^*$
95% Confidence interval for $r$ 0.01928 to 0.3530

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Fig. 2: FATTY PLAQUE Correlation coefficient $r = -0.005784$ Significance level $P = 0.9533$
95% Confidence interval for $r$ -0.1972 to 0.1861

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Fig. 3: CALCIFIED PLAQUE Correlation coefficient $r = 0.1456$ Significance level $P=0.1385$ 95% Confidence interval for $r$ $-0.04744$ to $0.3281$

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Conclusion

Among the three different type of plaque composition analysed we have found a strong correlation between the CCA-ICA angle and the presence of a fibrotic plaque. The bigger the angle the highest is the probability to find a fibrotic plaque, compared to a plaque which is purely calcific or purely fatty. This could be related to the flux and the wall shear stress changes in different angles bifurcation. Further studies with different techniques are needed to analyse histopathologically and to further confirm these data.


