Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/jptcp.v31i6.6717

IMPACT OF CONVOLUTION FILTERS ON CORONARY PLAQUE CHARACTERIZATION IN MULTISLICE COMPUTED TOMOGRAPHY

Dr. Ayesha Erum Hadi[1*], Mandeep Kaur[2], Alvin Khangembam[3], Mohit Lakkimsetti[4], Tariq Rafique[5], Naseem Tariq[6]

[1*]Junior Resident, Dr D.Y Patil Medical College, Hospital and Research Centre, Pune, India,
[2]Department of Diagnostic Radiology MD, Department of Internal Medicine, HCA Capital Regional Med Center Tallahassee Florida 32308, USA
[3]MBBS, NEIGRIHMS, Department of Internal Medicine, India
[4]MBBS, Department of Internal Medicine, Mamata Medical College, Khammam, India
[5]Assistant Professor Dadabhoy Institute of Higher Education, Karachi, Pakistan
[6]Associate Assistant Editor, Research Journal of Innovative Ideas and Thoughts

***Corresponding Author:** Dr. Ayesha Erum Hadi
*Junior Resident, Dr D.Y Patil Medical College, Hospital and Research Centre, Pune, India, Department of Diagnostic Radiology

ABSTRACT:

Objective: This study aims to evaluate the impact of different convolution filters on the variability of coronary plaque attenuation in ex vivo left coronary arteries imaged using Multislice Computed Tomography (AC-CTMS).

Methods: The research involved three post-mortem left coronary arteries, each introduced with a diluted contrast medium and imaged under standardized conditions using four convolution filters (B30f, B36f, B46f, B60f). Identification of plaque and attenuation measurements in Hounsfield Units (HU) were performed across various regions of interest (ROIs), including the Lumen, surrounding Oil (simulating epicardial fat), and calcified and noncalcified plaque components.

Results: The study found significant variability in attenuation values across the convolution filters ($p<0.001$). Statistical analysis revealed marked differences in the precision of structural differentiation between the plaque components based on the sharpness of the filter used. The sharper filters (B46f, B60f) provided more transparent and abrupt transitions among different plaque structures than the softer filters (B30f, B36f).

Conclusions: Convolution filter selection critically affects the attenuation values of coronary plaques in AC-CTMS and subsequently influences the accuracy and reliability of plaque characterization. The results underscore the need for careful selection of convolution filters in clinical settings to enhance the assessment of coronary artery disease and plaque vulnerability. Further research with more diverse samples is essential to confirm these findings and their applicability in clinical practice.

KEYWORDS: Coronary plaque attenuation, Multislice Computed Tomography (AC-CTMS), Hounsfield Units (HU), Regions of interest (ROIs), Lumen, Epicardial fat, Calcified Plaque, Noncalcified Plaque.

Introduction:

Many studies in the literature suggest that the composition and morphology of the coronary atherosclerotic Plaque represent essential factors in predicting its stability and clinical behaviour concerning the degree of stenosis. Quantitative and qualitative information (e.g., lumen diameter, wall thickness, and morphology) can be obtained using intracoronary ultrasound (ICUS). This technique has been approved by the Food and Drug Administration (FDA) as the gold standard for evaluating coronary plaques (Tassiopoulou, Koukiou et al. 2024).
Numerous non-invasive techniques have been used to identify and characterize coronal plaques. The literature reports that Magnetic Resonance Imaging (MRI) can identify and describe the lipid pool in the atherosclerotic plaques of the carotid arteries and, in some preliminary studies, also of the coronary arteries. Coronary Angiography using Multislice Computed Tomography (AC-CTMS) has demonstrated promising potential in identifying, quantifying, and characterizing plaques in the coronary arteries. However, numerous aspects remain unexplored.

Table 1: Overview of Techniques for Coronary Plaque Evaluation

Technique	Modality	Primary Use	Approval Status	Reference
Intracoronary Ultrasound (ICUS)	Invasive	Evaluating lumen diameter, wall thickness, plaque morphology	FDA-approved gold standard	Tassiopoulou et al., 2024
Magnetic Resonance Imaging (MRI)	Non-invasive	Identifying and characterizing lipid pools in plaques	Not specified	Tassiopoulou et al., 2024
Coronary Angiography with Multislice Computed Tomography (AC-CTMS)	Non-invasive	Identification, quantification, and characterization of plaques	Preliminary studies	Su, 2024

Table 2: Current Challenges and Research Focus Areas

Technique	Research Focus or Challenge	Methodological Issues Addressed	Reference
MRI	Preliminary studies on coronary arteries	Not specified	Tassiopoulou et al., 2024
AC-CTMS	Variability of coronary plaque attenuation in ex vivo models	Effect of different convolution filters on attenuation measures	Su, 2024

In particular, numerous questions require an answer to the methodological problem of evaluating coronary artery plaques using AC-MSCT. The present study addresses the issue of the variability of coronary plaque attenuation when measured with AC-CTMS in a model. Ex Vivo varying the convolution filters (Su 2024).

Material and methods

Operating pieces

Three left coronary arteries were removed during the autopsy. The removal was performed 1 cm proximal to the bifurcation of the circumflex artery for a length of 4 cm. To remember the orientation of the arteries after their removal, the anterior side of the artery was coloured black and the left side green. The coronary arteries were removed from two patients (both male, aged 78 and 63 years) who died from non-cardiovascular diseases and from one patient (female, aged 73 years) who died from ischemia by card. The study was approved by the Ethics Committee of the institution in which it was conducted (Omori, Matsuo, et al., 2023).
The surgical pieces were prepared and examined separately. Each coronary artery was prepared by introducing and fixing two cannulas with surgical wire, one at the proximal end (in the left main coronary artery) and one at the distal end (in the anterior descending artery). The circumflex artery was previously closed at its end with a surgical wire (Kobeisy, Ali, et al.).

Contrast medium

A physiological solution diluted with contrast medium (Iomeprol 400 mg I/mL, Bracco, Milan): 1/80 was used as an intravascular contrast medium. The Attenuation value of the solution introduced into a 10 ml syringe was obtained after performing an MSCT scan on the sample, tracing a region of interest (ROI). The value was reported as the mean and standard deviation of the attenuation within the ROI: 298.4±3.4 HU (Guilenea, Casciaro et al. 2024).

Preparation of the set for experimentation

The preparation of the set for the experimentation also included a tray of low-density material filled with vegetable oil to simulate the epicardial fat, inside which the coronary arteries were immersed. After positioning the coronary artery inside the tray, the solution was injected through the cannula previously placed at the proximal end of the operating piece using a 10 ml syringe. The introduction was suspended when the solution was seen coming out of the surgical piece (Ghassel 2024).

Scanning parameters

Each AC-CTMS scan (Sensation 16, Siemens, Forchheim, Germany) was performed after introducing the contrast solution into the coronary Lumen. All scans were performed with the following parameters: slices/collimation 16/0.75 mm, rotation time 375 ms, advance/rotation 3.0 mm (pitch 0.25), kV 120, mAs 500, effective thickness layer size 1 mm, reconstruction increment 0.5 mm, FOV 100 mm {Ezponda, 2023 #360}.

Data preparation

An expert radiologist loaded the image datasets into a dedicated workstation (Leonardo, Siemens ing performed an MSCT scan of the specimen and traced a region of interest (ROI). The value was recorded as the mean and standard deviation of the attenuation within the ROI: 298.4±3.4 HU {Etter, 2023 #362}.

Data collection

A radiologist performed all measurements. Each surgical specimen was evaluated for the presence of coronary atherosclerotic plaques. A coronary atherosclerotic plaque was defined when the coronary wall thickened after introducing the contrast medium solution, distinct from the surrounding hypodense medium (Oil) and the Lumen. The plaques were analyzed regardless of their size. The operator loaded the four datasets for each convolution filter of the same surgical piece on the screen of a workstation divided by 2·2 by scrolling through the datasets in parallel and using the predefined range of the attenuation window (width of the window = 700 HU; centre of the window = 140 HU) (Tassiopoulou, Koukiou, et al. 2024).

When a plaque was identified, the operator traced four regions of interest (ROI): one for the solution present in the Lumen of the vessel (defined as Lumen), one for the noncalcified component of the coronary Plaque (defined as Plaque), one for the calcific one (defined as Calcium) and one for the medium surrounding the vessel (defined as Oil). The ROIs were traced in the largest possible size, paying particular attention to excluding the edges of any structure other than the one examined (e.g., for the Lumen, the walls of the vessel, the Plaque the Lumen, and calcifications, etc.) to eliminate the interpolation and partial volume effects. The first 4 ROIs were traced in the dataset with the B30f convolution filter and reproduced in the image data sets for each convolution filter. The mean and standard deviation of the attenuation value were then reported for each ROI (Su 2024).

Statistical analysis

Attenuation values were presented as mean and standard deviation. The statistical evaluation was performed with dedicated software (SPSS 11.5, SPSS Inc., and attenuation values with the increase in the convolution kernels are evident. B30f, B36f, B46f, and B60f – for each coronary artery, using the following parameters: slice thickness 1 mm, reconstruction increment 0.5 mm, and FOV 50 mm (Tassiopoulou, Koukiou et al. 2024).

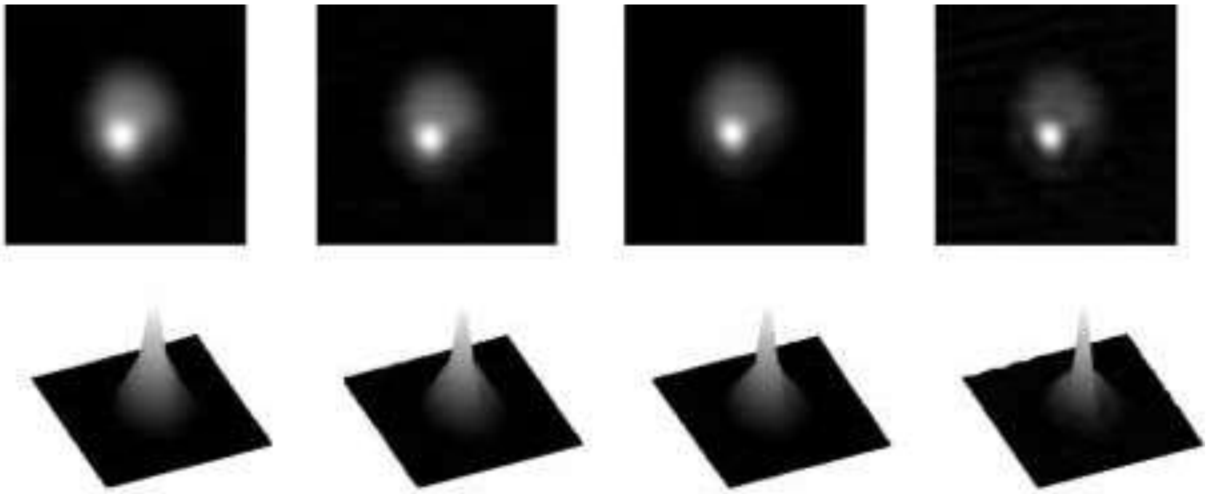

Fig. 2. — Axial sections of the ACS orthogonal to its long axis. Below are four sections of a coronary artery that apply four convolution filters: B30f, B36f, B46f, and B60f. Each reconstruction includes all four structures (Lumen, Oil, Calcium, and Plaque) examined in terms of attenuation value. Each section was reworked using dedicated evaluation software of the images and reported on a surface graph whose x and y axes correspond to the occupied surface and the atte value of each structure. The graphs demonstrate how the increase in convolution filters is associated with an increasingly evident and abrupt transition between one structure and the one next to it (Omori, Matsuo, et al., 2023).

Orthogonal axial section of the left coronary artery along its long axis. The four sections of a coronary artery are shown with the application of the four convolution kernels: B30f, B36f, B46f, and B60f. The four structures studied (Lumen, Oil, Calcium, and Plaque) in attenuation value are included in each reconstruction. Each section was processed with a dedicated program for image assessment and recorded in a graph whose x and y axes represent the surface occupied and the attenuation value of each structure. The charts show how the increasing sharpness of the convolution kernels is associated with an increasingly evident and abrupt passage between one structure and its neighboring structure (Kobeisy, Ali, et al.).

Results

All 29 levels where Plaque was present were measured. Four convolution filters (116 layers) were applied for each layer, and 4 ROIs (464 samples) were drawn and sampled. The results are summarized in Table I. The averages of the attenuation values obtained for all the samples were 244.7±21.3 HU for the Lumen, 116.8±51.7 HU for the Plaque, 860.1±439.4 HU for the Calcium, and –124.7±4.7 HU for Oil. The values were all significantly different ($p<0.05$) (Guilenea, Casciaro et al. 2024).

The averages of the attenuation values of the four structures for each convolution filter are reported in Table I and Figure 1. Considering the attenuation values measured for each structure by applying the four different convolution filters, significant differences were found ($p<0.001$) if compared for Lumen the filters: B30f/B36f, B30f/B60f, B36f/B46f, B36f/B60f and B46f/B60f; for Oil the filters: B30f/B36f, B30f/B46f, B30f/B60f, B36f/B46f, and B46f/B60f); for the calcific component of the Plaque all the convolution filters; for the non-calcific component of the Plaque the fil The measurements of the mean attenuations of each structure were compared with the T-test and their correlation was assessed with the Pearson test. Values of $p<0.05$ were considered statistically significant (Ghassel 2024).

Discussion

The identification and, above all, the characterization of the components of a coronary plaque in asymptomatic patients is essential to obtain risk stratification and, therefore, predict a possible acute coronary event. It is widely accepted that the primary cause of sudden cardiac death is the rupture of coronary atherosclerotic plaques with subsequent thrombosis, vascular occlusion, and ventricular fibrillation. Many studies have documented the possibility of AC-CTMS to visualize coronary Plaque.

Many factors are believed to influence the accuracy of coronary plaque measurement. The partial volume and interpolation influence the image quality, mainly when there are calcifications in the context of the vessel wall and contrast medium in the vessel lumen. In computed tomography, reconstruction using an approximate method is carried out using filtered back projection (filtered back projection). The filter applied to the reconstructed raw data is represented by a convolution, a product between two functions. The first is the signal obtained for each projection in a given gantry rotation angle and a predetermined function. The kernel of the convolution represents the second. The convolution algorithm can also be applied to a radiological image and allows one to obtain an image composed of pixels (picture elements) whose values are determined starting from the surrounding pixels and through the convolution kernel. This type of operation allows you to enhance or reduce specific signal characteristics. A classic example is represented by the application during the reconstruction phase of a convolution algorithm to evaluate the bone or lung, which enhances the details, albeit with increased image noise. On the contrary, less pronounced convolution nuclei allow for obtaining a less defined image in terms of spatial resolution but with a more excellent contrast/noise ratio (Su 2024).

The first limitation of the study is the lack of an analysis of intra- and inter-observer variability. A second limitation is linked to the fact that the arteries examined come from patients of advanced age, which determines a high prevalence of calcifications. Finally, the number of coronary arteries analyzed is low (n=3), but this is compensated by a high sampling frequency (n=464) (Tassiopoulou, Koukiou et al. 2024).

Our study shows how the use of different convolution filters influences the accuracy of AC-CTMS in the identification and differentiation of the composition of coronary atherosclerotic plaques with a linear pattern. The use of increasingly higher convolution filters determines a linear increase in the average attenuation value net of the Plaque when comparing all kernels, and regarding the noncalcified component of the Plaque when comparing kernels B30f/B36f, B30f/B46f and B30f/B60f. The noncalcified component of the Plaque showed a significant difference ($p<0.05$) when comparing kernels B46f and B60f. The comparison between the remaining kernels for the different structures (B30f/B46f for the Lumen, B36f/B60f for the Oil, and B36f/B46f and B36f/B60f for the noncalcified component of the Plaque) did not yield statistically significant differences ($p>0.05$) {Ezponda, 2023 #360}.

Conclusions

Different convolution filters significantly modify the attenuation value of the coronary atherosclerotic plaques' various components, influencing the AC-CTMS's accuracy in determining the coronary Plaque's morphological characteristics. In this sense, therefore, other studies must be directed in the future to standardize the technical parameters used in the evaluation and correct characterization of the components (Ghassel 2024)

References

1. Ghassel, S. (2024). Artificial Count Enhancement of Lung Scintigraphic Images Using Deep Learning Techniques, Université d'Ottawa/University of Ottawa.
2. Guilenea, F. N., et al. (2024). "Automatic thoracic aorta calcium quantification using deep learning in non-contrast ECG-gated CT images." Biomedical Physics & Engineering Express **10**(3): 035007.
3. Kobeisy, M. A., et al. "Incidence and Prevalence of Acute Kidney Injury In Critically Ill Patients."

4. Omori, H., et al. (2023). "Determination of lipid-rich plaques by artificial intelligence-enabled quantitative computed tomography using near-infrared spectroscopy as reference." Atherosclerosis **386**: 117363.
5. Su, M. (2024). "Novel intravascular ultrasound transducers."
6. Tassiopoulou, S., et al. (2024). "Algorithms in Tomography and Related Inverse Problems—A Review." Algorithms **17**(2): 71.
7. Ghassel, S. (2024). Artificial Count Enhancement of Lung Scintigraphic Images Using Deep Learning Techniques, Université d'Ottawa/University of Ottawa.
8. Guilenea, F. N., et al. (2024). "Automatic thoracic aorta calcium quantification using deep learning in non-contrast ECG-gated CT images." Biomedical Physics & Engineering Express **10**(3): 035007.
9. Kobeisy, M. A., et al. "Incidence and Prevalence of Acute Kidney Injury In Critically Ill Patients."
10. Omori, H., et al. (2023). "Determination of lipid-rich plaques by artificial intelligence-enabled quantitative computed tomography using near-infrared spectroscopy as reference." Atherosclerosis **386**: 117363.
11. Su, M. (2024). "Novel intravascular ultrasound transducers."
12. Tassiopoulou, S., et al. (2024). "Algorithms in Tomography and Related Inverse Problems—A Review." Algorithms **17**(2): 71.