Al-Azhar Med. J. (cardiology). *Vol. 52(3), July, 2023, 791 - 802*
DOI: 10.21608/amj.2023.315117
https://amj.journals.ekb.eg/article_315117.html

COMPARISON OF CORONARY ARTERY PLAQUE COMPOSITION BETWEEN DIABETIC TYPE II AND NON-DIABETIC PATIENTS USING MULTISLICE CT ANGIOGRAPHY

By

Mohammed Roshdi Ibrahim, Ahmed Mohammed Fahmy, Al-Hussein Mustafa Zahran and Hossam Al-Adl Al-Adl*

Departments of Cardiology and Internal Medecine*, Faculty of Medicine, Al-Azhar University

Corresponding author: Mohammed Roshdi Ibrahim,

E-mail: dr.mohammed.roshdi@gmail.com

ABSTRACT

Background: Diabetes mellitus (DM) is a major contributor to coronary artery disease (CAD). CAD is the major cause of morbidity and mortality in diabetic patients. Risk stratification of patients with diabetes is very important to plan the management and to follow the clinical status of those patients over time. This can be done non-invasively using multi-slice computed tomography (MSCT) coronary angiography.

Objective: To evaluate the differences in the extent and composition of coronary plaques in diabetic patients type ll and non-diabetic patients using MSCT coronary angiography.

Patients and methods: Eighty patients were involved in our prospective study, and divided into two equal groups: Group 1 contained diabetic patients, and Group 2 contained non-diabetic patients. Those patients are matched in age, sex, and other risk factors presented with chest pain and referred for multi-slice computed tomography (MSCT) angiography at the National Heart Institute during the period from November 2019 to August 2020.

Results: Diabetic patients were associated with a significantly higher coronary plaque burden and more obstructive plaques. Also, significantly more non-calcified plaques in combination with less mixed plaques were observed in patients with diabetes. However, there was no significant difference in number of calcified plaques between diabetic and non-diabetic patients.

Conclusion: MSCT can be used effectively for risk stratification of patients with diabetes. It may be useful in detecting lipid plaques that are at high risk for rupture leading to myocardial infarction.

Keywords: Coronary Artery Plaque, Diabetic Type II and Non-diabetic, Multislice CT Angiography.

INTRODUCTION

At present, 200 million people have diabetes mellitus worldwide while its prevalence is expected to continue increasing exponentially. A close relationship between type 2 diabetes and the development of coronary artery disease (CAD) exists and cardiovascular disease is the main cause of death in this patient population *(Arad et al., 2010)*.

Non-invasive testing, including myocardial perfusion scintigraphy and dobutamine stress-echocardiography, has been used to detect CAD in diabetic patients and a clear association between abnormal test results and worse outcome

has been demonstrated similar to the general population. Nonetheless, after normal findings, still elevated event rates are observed in diabetic patients as compared to non-diabetic individuals, indicating a need for further refinement of prognostification in this population *(De Araújo Gonçalves et al., 2013)*.

The higher event rates in patients with diabetes as compared to patients without diabetes could be related to differences in coronary plaque burden and composition. Therefore, direct visualization of coronary plaque burden could be a useful tool for risk stratification. Indeed, using invasive techniques, a considerably higher extent of CAD and plaque burden has been demonstrated in the presence of diabetes *(Henneman et al., 2012)*.

Atherosclerosis has been non-invasively assessed in patients with type 2 diabetes using coronary calcium scoring revealing extensive atherosclerosis. Coronary calcium scoring may seriously underestimate coronary plaque burden as non-calcified lesions are not recognized *(Murray and Palmer, 2011)*.

Contrast-enhanced multi-slice computed tomography (MSCT) coronary angiography has become available which allows, in contrast to calcium scoring, detection of both calcified and non-calcified coronary lesions. As a result, the technique potentially allows a more precise non-invasive evaluation of coronary atherosclerosis, which in turn could be valuable for improving risk stratification *(Kawamori et al., 2013)*.

The aim of the present study was to evaluate the differences in the extent and composition of coronary plaques in diabetic patients and non-diabetic patients using MSCT coronary angiography.

PATIENTS AND METHODS

Eighty patients were involved in our prospective study, and divided into two equal groups: Group 1 contained diabetic patients, and Group 2 contained non-diabetic patients. Those patients were matched in age, sex, and other risk factors presented with chest pain and referred for MSCT angiography at the National Heart Institute during the period from November 2019 to August 2020.

Inclusion criteria: All symptomatic patients presented with recurrent exertional chest pain (symptoms suggestive of CHD) eligible for inclusion in the study and fulfilling: (1) Sinus rhythm, (2) Heart rate less than 70 bpm spontaneously or Beta blocker induced, (3) Hold breath for more than 20 seconds, and (4) weight less than 150 kg.

We selected all the patients with plaque burden discovered by MSCT.

Exclusion criteria: Respiratory failure, decompensated heart failure, presence of arrhythmias, patients presented with acute coronary syndrome (ACS), hypersensitivity to iodinated contrast agent, history of allergies or allergic reactions to other medications, impaired renal function (serum creatinine $\geq$ 1.5 mg/dl), hyperthyroidism, morbid obesity, previous coronary stenting, and previous coronary artery bypass grafting (CABG).

An approval of the study was obtained from Al- Azhar University academic and ethical committee. Every patient signed an informed written consent for acceptance of the operation.

All the patients were subjected to the following:

- Personal data collection and risk factors assay such as age, gender, presence or absence of hypertension, diabetes, smoking, dyslipidemia and family history of IHD.
- Clinical examination including vital signs with general, chest, and cardiac examination.
- 12- Lead ECG.
- Routine lab investigations:
    1. Blood glucose level for patients not known to be diabetic: Diabetes was diagnosed according to the criteria set by American Diabetes Association: (a) Symptoms of diabetes and casual plasma glucose level of ≥ 200 mg/dl. (b) Fasting plasma glucose level of ≥ 126 mg/dl.
    2. Serum creatinine.
    3. Lipid Profile.
    4. Cardiac enzymes to exclude patients with acute coronary syndrome.
- Coronary CT angiography: The CT angiography was performed to all patients utilizing a dual source scanner (Somatom Definition Flash, Siemens) with slice configuration of 64 × 0. 625 mm and gantry rotation time of 330 ms.

Patients were instructed to avoid caffeine and smoking 12 hours prior to the procedure to avoid cardiac stimulation, and to avoid eating solid food 4 hours before the study, and to increase fluid intake prior to the exam.

Patients were instructed to take Beta blocker (oral bisoprolol 5 mg 1 hour before scan) to achieve heart rate control below 70 bpm. which was avoided if HR below 60 bpm, ABP< 100 mm Hg.

A second dose of oral bisoprolol 5 mg was given one hour after the initial one if the heart rate was not satisfactory (above 70 bpm). Some patients needed an additional bolus of intravenous propranolol (1-2 mg).

Patients were instructed how to hold breath, it was crucial for the exam, told and reassured about the side effects of the contrast as warm sensation in the body after injection.

The patients were given a tablet of 5 mg isosorbide dinitrate sublingually before the test which dilated the coronary arteries and increased side branch visualization.

Statistical Analysis:

Data were collected, revised, coded and entered to the Statistical Package for the Social Science (IBM SPSS) version 20. Qualitative data were presented as number and percentages while quantitative data were presented as mean, standard deviations and ranges. Chi-square test, Fisher exact test and Mann Whiteny test were used to compare between qualitative data. While the comparison between two independent groups regarding quantitative data with parametric distribution were done by using independent t-test. The confidence interval was set to 95% and the margin of error accepted was set to 5%. P value < 0.05 was considered significant.

RESULTS

The non-diabetic group included 16 female patients (40%) and 24 male patients (60%) and their ages ranged from 38 to 75 years with mean ± SD (56.4 ± 8.62). The diabetic group included 19 female patients (47.5%) and 21 male patients (52.5 %) and their age ranged from 40 to 73 years with mean ± SD (58.15 ± 6.9).

Each of the diabetic and non-diabetic groups was studied regarding their risk factors, and we found that 52.5% of the non-diabetic patients were hypertensive compared to 47.5% of the diabetic group, 40% of the non-diabetics were smokers compared to 30 % of the diabetic group, 40% of the non-diabetics had a positive family history of CAD compared to 42.5 % of the diabetic group. We selected the patients to be matched in age, sex and risk factors as hypertension, smoking and family history of ischemic heart disease so the relations between diabetic and non-diabetic patients according to these variables were non-significant.

The results of the CT angiography in the diabetic and non-diabetic groups regarding atherosclerotic affection of the coronary arteries. There was a significant increase in LCX & RCA affection in the diabetic group (27.5% & 22.5% respectively) compared to the non-diabetic group that was 12.5% & 10 % respectively. A borderline significant relation in LAD affection in the diabetic Group (97.5%) compared to the non-diabetic group (90%). No significant relation in LM affection between the diabetic group (10%) and the non-diabetic group (5%).

The distribution of atherosclerosis there was a significant difference in the plaque distribution between the two groups: 87.5% of patients in the non-diabetic group had only one segment affected compared to 52.5% of patients in the diabetic group. 7.5% of patients in the non-diabetic group had two segments affected compared to 35% of patients in the diabetic group. 5% patients of the non-diabetic group had three or more segments affected compared to 12.5% patients of the diabetic group.

The lipid profile there was: A significant increase in total cholesterol, LDL & triglycerides in the diabetic group compared to the non-diabetic group. Also, there was a significant decrease in HDL in the diabetic group compared to the non-diabetic group **(Table 1)**.

Table (1): Comparison between diabetic and non-diabetic patients regarding age, sex, risk factors, vessels affected, number of segments affected and lipid profile

Parameters \ Groups		Non diabetic (no.=40)		Diabetic (no.=40)		P-value
		No.	%	No.	%	
Sex	Male	24	60 %	21	52.5 %	>0.05
	Female	16	40 %	19	47.5 %	
Age	Mean ± SD	56.4 ± 8.62		58.15 ± 6.9		>0.05
	Range	38-75		40-73		
HTN (no=42)	Negative	19	47.5%	19	47.5%	>0.05
	Positive	21	52.5%	21	52.5%	
Smoking (no=28)	Negative	24	60 %	28	70 %	>0.05
	Positive	16	40 %	12	30 %	
Family history (no=33)	Negative	24	60 %	23	57.5 %	>0.05
	Positive	16	40 %	17	42.5 %	
Vessels affected:						
LM	Normal	38	95%	36	90 %	>0.05
	Diseased	2	5 %	4	10 %	
LAD	Normal	4	10.0%	1	2.5%	>0.05
	Diseased	36	90.0%	39	97.5%	
LCX	Normal	35	87.5 %	29	72.5 %	>0.05
	Diseased	5	12.5 %	11	27.5 %	
RCA	Normal	36	90 %	31	77.5%	>0.05
	Diseased	4	10 %	9	22.5%	
Number of segments affected:						
One Segment		35	87.5%	21	52.5 %	0.003
Two Segments		3	7.5 %	14	35 %	
≥ Three Segments		2	5 %	5	12.5%	
Lipid profile:						
Total cholesterol		187.07±51.02		222.5±57.72		0.003
Triglycerides		133.97±79.08		171.2±72.27		0.001
LDL		118.25±44.14		133.55±41.8		0.046
HDL		53.4±12.8		47.32±12.73		0.026

There was a statistically significant increase in diabetic as compared to non-diabetic patients as regards to calcium score (p-value=0.026). The volume of the plaque was calculated for each patient in the two groups, there was a significant increase in plaque volume in the diabetic group.

The presence of obstructive lesions, showed a statistically significant relation in LAD & RCA affection between the diabetic group (32.5% & 7.5% respectively) and the non-diabetic group (17.5% & 0% respectively). While there was a non-significant relation in LCX affection between the diabetic group (5%) and the non-diabetic group (2.5%).

Plaques were classified according to their type into three groups (non-calcified, mixed and calcified). Diabetic patients had significantly more non-calcified plaques compared to non-diabetic patients. While non-diabetic patients had significantly, more mixed plaques compared to non-diabetic patients. Regarding to calcified plaques there was no significant difference between diabetic and non-diabetic patients **(Table 2)**.

Table (2): Comparison between diabetic and non-diabetic patients regarding calcium score, plaque volume, the presence of obstructive lesions and plaque type

Parameters \ Groups	Non diabetic		Diabetic		P value
	Median	IQR	Median	IQR	
Ca Score	14.5	91	91	107	0.026
Plaque Volume	20	10-30	50	30-100	0.001
	No.	**%**	**No.**	**%**	
Presence of Obstructive Lesions:					
LM	0	0.0%	0	0.0%	>0.05
LAD	7	17.5%	13	32.5%	>0.05
LCX	1	2.5%	2	5.0%	>0.05
RCA	0	0.0%	3	7.5%	>0.05
Plaque type:					
Calcified plaques	14	29.7%	23	35.9%	0.044
Non calcified plaques lipid-rich plaques	13	27.7%	34	53.1%	<0.001
Mixed plaques fibrous plaques	20	42.6%	7	11%	0.002

There was significant positive correlation between blood glucose level and number of segment and number of non-calcified plaques. There was no significant correlation between blood glucose level and number of calcified or mixed plaques **(Table 3)**.

Table (3): Correlation between blood glucose level and number of segments affected, and plaque type among diabetic patients

Parameters \ Random blood glucose		Range	r	P-value
No. of Segments	1	128 – 318	0.554**	**<0.001**
	2	146 – 320		
	3	215 – 352		
Calcified plaques	No	136 – 352	−0.231	0.152
	1	128 – 320		
	2	215 – 237		
Non calcified plaques	No	128 – 310	0.658**	**<0.001**
	1	146 – 320		
	2	186 – 310		
	3	350 – 352		
Mixed plaques	No	128 – 352	-0.150	0.354
	1	136 – 310		

DISCUSSION

All studied groups were presenting with symptoms suggestive of coronary artery disease (chest pain). The study evaluated the coronary plaque burden during the course of symptomatic coronary artery disease and did not include subjects free of atherosclerosis.

As diabetic patients have higher incidence of dyslipidemia *(Chapman et*

al., 2011), were not able to make our chosen groups of diabetic and non-diabetic patients to be matched as regards dyslipidemia. So, regarding to the lipid profile, there was a statistically significant increase in the diabetic group as compared to the non-diabetic group as regards to total cholesterol and LDL. There was a statistically significant decrease in the diabetic group as compared to the non-diabetic group as regards to HDL. This was in agreement with a study of lipid profile levels in diabetics and non-diabetics done *(Nita et al., 2014)*.

Regarding calcium score, the calcium score was significantly higher in the diabetic group than the non-diabetic one. This was in agreement with *Maciej et al. (2012)* who studied the associations between traditional risk factors and the coronary artery calcium (CAC), and higher CAC values were observed in patients with diabetes compared with non-diabetic controls.

In our study we found that atherosclerosis distribution as described by number of the affected segments was significantly higher in the diabetic group compared to the non-diabetic group. These results were matched with *Van Werkhoven et al. (2010)* who studied the prognostic value of computed tomography coronary angiography in diabetic population in comparison with a non-diabetic population, and the number of diseased segments was significantly higher in diabetic patients. *Goraya et al. (2010)* studied the relation between prevalence of coronary atherosclerosis among diabetic and non-diabetic individuals and examined the association between diabetes and coronary atherosclerosis in a geographically defined autopsied population. This study noted that diabetics were associated with a higher prevalence of atherosclerosis and multivessel disease.

Diabetic patients were found to have significantly higher number of obstructive lesions in LAD & RCA. This was in agreement with *Van Werkhoven et al. (2010)* who demonstrated a significantly higher number of obstructive lesions in diabetic patients more than non-diabetic patients. *De Araújo Gonçalves et al. (2013)* noted that the prevalence of obstructive CAD was significantly higher in diabetic patients. *Khazai et al. (2015)* segment stenosis score (SSS), were significantly high in those with diabetes. *Jia et al. (2016)* stated that the number of segments with obstructive disease was higher for patients with diabetes than those without diabetes.

The mean value of the total plaque volume was found to be significantly higher in the diabetic group compared to the non-diabetic group. *Pen et al. (2013)* showed that clinical history of DM was associated with significant plaque burden.

Diabetic patients had higher plaque burden and more extensive atherosclerotic distribution than non-diabetics. That can be explained by the study done by *Nhat-Tu et al. (2012)* who noted that diabetic patients have higher levels of advanced glycation end products (AGEs). AGEs interfere with the protective role of extracellular signal-regulated kinase 5 (ERK-5) and cause the release of oxidizing side products like hydrogen peroxide (H202) that drive free radical production, inflammation and cell damage which in turn accelerates atherosclerosis.

To determine plaque composition according to the mean density of their atherosclerotic plaques (as expressed by Hounsfield unit [HU]), plaques are classified into 3 groups: non-calcified (lipid-rich) plaques (mean density ≤ 60 HU), mixed (fibrous) plaques (ranging from 61 to 119 HU) and calcified plaques (≥ 120 HU) *(Dalager et al., 2011).*

We found that diabetic patients had significantly more non-calcified plaques compared to non-diabetic patients, while non-diabetic patients had significantly more mixed plaques compared to non-diabetic patients. There was no significant difference between diabetic and non-diabetic patients regarding to calcified plaques. A pathological study done by *Moreno et al. (2010)* showed that specimens from patients with diabetes had a larger content of lipid-rich atheromas than in patients without diabetes. *Dhawan et al. (2010)* stated that a thin inflamed fibrous cap (TCFA) (<65μm) covering a lipid-rich necrotic core (>40% of the total volume of the plaque) is a major criteria to characterize vulnerable atherosclerotic plaque which is called "high-risk" or "thrombosis-prone" plaque. *Pundziute et al. (2011)* studied Noninvasive Assessment of Plaque Characteristics with Multislice Computed Tomography Coronary Angiography in Symptomatic Diabetic Patients. This study noted that significant differences were observed in between diabetic and non-diabetic patients since patients with diabetes presented with significantly more segments containing non-calcified plaques. In contrast, plaques in patients with diabetes were less frequently mixed plaques.

Kashiwagi et al. (2011) that mean Hounsfield unit (HU) of thin-cap fibroatheroma (TCFA) of coronary plaques was 35.1 HU, while mean Hounsfield unit of non-TCFA was 62 HU.

We compared our study with study done by *Marso et al. (2010)* who found that there was a greater proportion of intravascular ultrasound-derived thin-cap fibroatheroma (ID-TCFA) in diabetic patients more than non-diabetic patients, while differences in ID-fibroatheroma and ID-fibrocalcific plaque were not significant between the two groups. Also, *Hong et al. (2010)* noted that the presence of at least one thin-cap fibroatheroma (TCFA) and multiple TCFAs were more common in the diabetic group.

Uzoma et al. (2010) found that patients with diabetes had a higher number of coronary segments with mixed plaques compared to non-diabetic patients, whereas no differences were observed for non-calcified and calcified components. This was in disagreement with our results and this may be due to that the sample size of Uzoma's study contained unequal number of each group of diabetic and non-diabetic patients.

Tomizawa et al. (2015) showed that diabetic patients had more calcified plaques than non-diabetic patients, while our study showed that prevalence of calcified plaque did not differ between diabetics and non-diabetics.

Our results showed that there was a statistically significant increase in calcium score in diabetic patients more than non-diabetic patients. Also, the total number of calcified lesions were more in diabetic patients than in non-diabetic patients (no=14). This difference was statistically

non-significant. This may be explained by the small size of sample and such difference may be statistically significant with another study with larger sample size.

Among diabetic patients, we found that patients with higher blood glucose levels have increased number of affected segments, and have more non-calcified (lipid-rich) plaques. However, there was no significant relationship between blood glucose levels and number of calcified or mixed plaques. This was in agreement with *Tomizawa et al. (2016)* who showed that patients with poor glycemic control have a greater number of affected segments and more non-calcified plaques than patients with good glycemic control.

CONCLUSION

Diabetic patients have a significantly higher coronary plaque burden, more non-calcified (lipid-rich) plaques. Diabetic patient, with higher blood glucose levels, have more atherosclerotic plaque burden as having higher total plaque scores, and have more non-calcified (lipid-rich) plaques than patients with lower blood glucose levels have.

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مقارنة بين تركيب اللويحة بالشريان التاجي بين مرضى السكري النوع الثاني والمرضى الغير مصابين بالسكري وذلك بإستخدام الأشعة المقطعية على الشرايين التاجية

محمد رشدي ابراهيم محمد، أحمد محمد فهمي، الحسين مصطفى زهران، حسام العدل*

قسمي القلب والأوعية الدموية، والباطنة العامة*، كلية الطب، جامعة الأزهر

E-mail: dr.mohammed.roshdi@gmail.com

خلفية البحث: يعد مرض السكري من العوامل الرئيسية المساهمة في مرض الشريان التاجي، كما أن مرض الشريان التاجي هو السبب الرئيسي للمراضة والوفيات لدى مرضى السكري. ويعد تصنيف المخاطر لمرضى السكري أمرًا مهمًا للغاية لتخطيط الإدارة ومتابعة الحالة السريرية لهؤلاء المرضى بمرور الوقت، ويمكن القيام بذلك بدون تدخل جراحي بإستخدام الأشعة متعددة المقاطع علي الشرايين التاجية.

الهدف من البحث: تقييم الإختلافات في مدى وتكوين لويحات الشريان التاجي في المرضى الذين يعانون من مرض السكر وغير المصابين بمرض السكر بإستخدام الأشعة متعددة المقاطع علي الشرايين التاجية.

المرضى وطرق البحث: شارك ثمانون مريضًا في دراستنا المستقبلية وتم تقسيمهم إلى مجموعتين متساويتين من المرضى: المجموعة 1 تحتوي على مرضى السكري، والمجموعة 2 تحتوي على مرضى غير مصابين بالسكري. وقد تم مطابقة هؤلاء المرضى من حيث العمر والجنس وعوامل الخطر الأخرى المصاحبة لألم في الصدر وإحالتهم إلى التصوير بإستخدام الأشعة متعددة المقاطع علي الشرايين التاجية في المعهد الوطني للقلب في الفترة من نوفمبر 2019 إلى أغسطس 2020.

نتائج البحث: مقدار التصلب وإنتشاره في الشرايين التاجية أعلي في مرضي السكر ووجود لويحات انسدادية بشكل ملحوظ في مرضى السكر. وظهر

وجود اللويحات غير المتكلسة بشكل ملحوظ في مرضى السكري بينما كانت اللويحات المختلطة أقل في مرضي السكر، وفيما يتعلق بتكوين اللويحة بالشريان التاجي وجدنا أن اللويحات الدهنية موجودة بشكل ملحوظ في مرضى السكر بينما كانت اللويحات الليفية موجودة بشكل ملحوظ في المرضى غير المصابين بمرض السكر.

الاستنتاج: يمكن أن تستخدم الأشعة متعددة المقاطع علي الشرايين التاجية بشكل فعال في التقسيم الطبقي للخطر لمرضى السكر, كما أنها قد تكون مفيدة في كشف اللويحات الدهنية التي هي أكثر عرضه لتكوين الجلطات وإصابة عضلة القلب بالاحتشاء.

الكلمات الدالة: لوحة الشريان التاجي، السكري من النوع الثاني وغير السكري، الأشعة متعددة المقاطع علي الشرايين التاجية.