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Characteristics of coronary artery atherosclerotic plaques in chronic kidney disease: evaluation with coronary CT angiography

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AIM: To determine the characteristics of coronary artery atherosclerotic plaques in chronic kidney disease (CKD) with coronary computed tomography angiography (CTA).

MATERIALS AND METHODS: Sixty-six patients with CKD who underwent coronary CTA were analysed retrospectively. The extent, distribution, and types of plaques and stenosis severity were evaluated. The imaging features were compared between dialysis and non-dialysis groups. In the dialysis group, the imaging features were compared between diabetes and non-diabetes patients.

RESULTS: In total, 152 coronary vessels (2.3±1.3 per patient) and 306 segments (4.6±3.5 per patient) were found to have plaques. The most common diseased coronary vessel was the left anterior descending (LAD) artery (53 vessels, 34.9%) followed by the left circumflex (LCX) artery (39 vessels, 25.7%), and right coronary artery (RCA; 37 vessels, 24.3%) in sequence. The most commonly involved coronary artery segment was the middle segment of LAD artery (14.1%). Calcified plaques (65.9%) were detected more frequently than mixed (25.6%) or non-calcified (8.5%) plaques ($p<0.001$). Among the degrees of coronary stenosis, minimal stenosis (55.8%) was the most common ($p<0.001$). The majority of calcified plaques were non-obstructive plaques ($n=134$, 78.2%), while about half of non-calcified ($n=14$, 63.6%) and mixed plaques ($n=30$, 45.5%) were obstructive plaques ($p<0.001$).

CONCLUSION: A heavy plaque burden was detected in CKD patients at coronary CTA. Non-obstructive calcified plaque was the most common imaging feature. CKD patients with type 2 diabetes mellitus had more obstructive mixed plaques.

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Introduction

Vascular calcification is common in patients with chronic kidney disease (CKD) and is a risk factor for cardiovascular events when the coronary artery is involved.[1] Patients with CKD have a higher prevalence of cardiovascular disease including coronary artery disease, compared with the general population.[2,3] A causal relationship between vascular calcification of the coronary artery and cardiovascular disease seems logical.[4]

Coronary computed tomography angiography (CTA) plays an important role in the non-invasive evaluation of calcification of the coronary artery.[5–7] Many studies on CKD and

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coronary artery calcification have used the calcium score at CT to assess the coronary artery involvement[8–12]; however, few focus on the characteristics and distribution of coronary artery calcification and also the type of atherosclerotic plaque and stenosis severity in patients with CKD. Thus, the features of coronary artery calcification in patients with CKD, the degree of stenosis, and distribution caused by each type of plaque is still unclear. The purpose of this study was to determine the characteristics of coronary artery atherosclerotic plaques in CKD patients by using coronary CTA.

Materials and methods

Patients

This retrospective study was approved by the institutional review board. Informed patient consent was waived due to the retrospective nature of this study. Between June 2011 and September 2018, 47,092 patients underwent coronary CTA at West China Hospital. The inclusion criteria were as follows: (1) clinical diagnosis with CKD or suspected with CKD; and (2) complete clinical data available. A total of 79 patients were found in the database. The exclusion criteria were as follows: no discharge diagnosis of CKD (n=5), poor image quality inadequate for analysis (n=2), and a history of stenting or bypass (n=5). Finally, 67 (67/79, 84.8%) patients were enrolled in this study. The reasons for coronary CTA examination were as follows: chest pain (n=25), chest tightness (n=15), palpitations (n=11), dyspnoea (n=7), preoperative evaluation when aged >65 years old (n=4), and other examinations such as electrocardiogram or myocardial enzyme abnormalities indicating coronary artery disease (n=5). The clinical data of patients included age, sex, body mass index, smoking history, history of dialysis, diabetes mellitus (DM), and hypertension.

CT protocols

All coronary CTA examinations were performed on multidetector CT systems (SOMATOM Definition, Siemens Medical Solutions, Forchheim, Germany; n=5; SOMATOM Definition FLASH, Siemens Medical Solutions, Forchheim, Germany; n=38; and Revolution CT, GE Healthcare, Waukesha, WI USA; n=24). Beta-blockers were not used for to reduce the heart rate. The scanning range was from the tracheal bifurcation to 20 mm below the inferior cardiac apex. A 50–70 ml (dependent on body mass index) bolus of iodinated contrast agent (iopamidol, 370 mg of iodine/ml; Bracco, Shanghai, China) was injected into the antecubital vein at a flow rate of 5 ml/s followed by 30 ml saline at the same flow rate. For the SOMATOM Definition and SOMATOM Definition FLASH systems, scan parameters were 100–120 kV tube voltage (adapted to body mass index), 220 mAs tube current, 64/128×0.5 mm collimation, and 0.33–0.4 seconds rotation time. For the Revolution CT system, the tube voltage and tube current were set automatically by kV Assist and Smart-mA based on the scout image of the patients, other imagine parameters were 256×0.625 mm collimation and 0.28 seconds rotation time.

All images were acquired during a single inspiratory breath hold of 10 seconds, while the electrocardiogram was registered simultaneously. Images were reconstructed most often in the diastolic phase, as this is typically the phase showing the least motion artefacts; however, additional reconstructions were made throughout the entire cardiac cycle, when needed.

Depending on the patient's residual kidney function, the following methods were used to prevent further kidney function deterioration: adequate pre- and post-procedural hydration, and in haemodialysis patients, the scan was performed on the day prior to the next dialysis session.

Effective radiation dose (ED) for each CT examination was calculated as the dose–length product (DLP) multiplied by a conversion coefficient for the chest (k = 0.014 mSv/[mGy·cm]).[13] The median±quartile of DLP and ED of the CCTA was 213.8±106.5 and 3±1.5 in 67 patients, respectively.

Image analysis

Coronary CTA image analysis was performed by two experienced cardiovascular radiologists each with 5 years of experience. Discrepancies in their interpretations of stenosis were resolved in consensus. The diagnostic images with optimal quality were transferred to an off-line postprocessing workstation (Syngo-Imaging, Siemens Medical Solution Systems, Forchheim, Germany) for image analysis. Alternative image reconstruction methods for evaluation of coronary artery plaques included maximum intensity projection, multiplanar reconstruction, curvature planar reconstruction, and volume rendering.

The number of diseased coronary vessels and segments, the number and types of plaques, and degree of stenosis were evaluated. In this study, coronary arteries were divided into four branches: left main (LM), left anterior descending (LAD), left circumflex (LCX), and right coronary artery (RCA). According to the American Heart Association standard, the left and right coronary arteries were divided into 15 segments.[14] In the present study, all segments were analysed: in the RCA segments 1–4; in the LM segment 5; in the LAD segments 6–10, and in the LCX segments 11–15 (Fig 1). Plaques were classified as calcified plaque (plaques with higher CT attenuation than the contrast-enhanced lumen); non-calcified plaque (plaques with lower CT attenuation than the contrast-enhanced lumen without any calcification) and mixed plaque (non-calcified and calcified elements in single plaque).[15] The interpretability of coronary artery segments was assessed. All segments <1.5 mm in diameter were excluded from evaluation. A total of 163 segments (16.2%) were excluded. The interpretability of each plaque within vessel with a diameter of >1.5 mm was analysed before accessing the degree of stenosis. Uninterpretable plaque was noted when the severity of stenosis in calcified plaque could not be assessed due to blooming artefacts. The degree of stenosis was assessed based on a classification system suggested by the Society of Cardiovascular Computed Tomography: no visible stenosis (0%), minimal stenosis (1–24%), mild stenosis (25–49%), moderate stenosis (50–69%), severe stenosis (70–99%), and

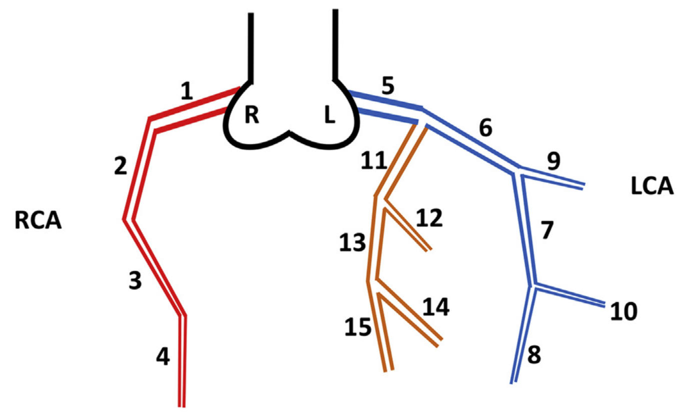

Figure 1 Coronary segments: 1 proximal segment of right coronary artery (RCA); 2 middle segment of RCA; 3 distal segment of RCA; 4 posterior descending artery from RCA; 5 left main coronary artery; 6 proximal segment of left anterior descending artery (LAD); 7 middle segment of LAD; 8 distal segment of LAD; 9 first diagonal branch; 10 second diagonal branch; 11 proximal segment of left circumflex (LCX); 12 first obtuse marginal branch; 13 distal segment of LCX; 14 left posterior-lateral branch; 15 posterior descending artery from LCX.

occlusion (100%).[16] In addition, the lesions were also classified as obstructive and non-obstructive using a 50% threshold.[6,9] The length of plaque was assessed for each lesion. For lesions with length ≥3mm, the length was measured on the curvature planar reconstruction image and mean length of the two measurements were recorded (Fig 2). For spot-like lesions (the length <3mm), the numbers of lesions were recorded.

Statistical analysis

Clinical data, number of diseased coronary vessels and segments, length, types of plaques, and degree of stenosis were analysed statistically in each patient. Normally distributed continuous variables were expressed as mean ± standard deviation (as assessed by the Kolmogorov–Smirnov test) whereas non-normally distributed continuous variables expressed as median (range) and categorical variables as number and percentage. Continuous data were compared using independent sample *t*-test (for normally distributed variables) or the Mann–Whitney *U*-test (for non-normally distributed variables). Categorical data were compared using the chi-square test. Multivariate analysis of variance (MANOVA) was used to determine associations between clinical factors and characteristics of plaque. Multivariate logistic regression was used to examine factors associated with characteristics of plaque. All statistical analyses were performed on SPSS (version 19.0, SPPS. Chicago, IL, USA). Two-tailed *p*-value of <0.05 was considered statistically significant.

Results

Clinical characteristics of patient population

Among the 67 patients included in this study, a total of 58 patients had positive coronary CTA results, and nine patients had negative coronary CTA results. The baseline clinical data of the 67 patients are summarised in Table 1. There was no significant difference in age, sex, smoking history, dialysis history, and DM history between the two groups (all $p>0.05$) except for the history of hypertension ($p<0.05$). The proportion of hypertension patients in the positive group was higher (72.4% versus 33.3%), but the duration of the disease was shorter (120 versus 216 months) compared with the negative group.

Extent and anatomical distribution of coronary artery plaques

A total of 152 coronary vessels (2.3±1.3 per patient; range 1–4) and 306 segments (4.6±3.5 per patient; range 1–13) were found to have plaques. The majority of patients had multi-vessel disease (47/58, 81%) rather than single vessel disease (11/58, 19%). The most common diseased coronary vessel was the LAD artery (53 vessels, 34.9%) followed by LCX artery (39 vessels, 25.7%), RCA artery (37 vessels, 24.3%), and LM (23 vessels, 15.1%) in sequence. The most common involved coronary artery segment was the middle segment of LAD artery (43/306, 14.1%) followed by the proximal segment of LAD artery (42/306, 27.8%) and the proximal segment of RCA (33/306, 10.8%). In all patients, no lesions were detected in segment 14 and segment 15. The anatomical distribution of plaques in each type is shown in Fig 3. Calcification was also found in the aortic valve (18 cases, 26.9%), mitral valve (14 cases, 20.9%), and left atrial wall (2 cases, 3%). There was no valvular stenosis or regurgitation in all cases with cardiac valvular calcification confirmed at echocardiography or final clinical diagnosis.

Types of coronary artery plaque and degree of coronary stenosis

A total of 258 lesions (4.17±2.48 per patient; range 1–9) were analysed. The different types of plaques and degrees of coronary stenosis in each type are shown in Table 2. Calcified plaques (65.9%, Fig 4a) were more frequently detected than mixed (25.6%, Fig 5a) or non-calcified (8.5%, Fig 5b) plaques ($p<0.001$). Among the degree of stenosis, minimal stenosis (55.8%) was the most common ($p<0.001$). There were more uninterpretable lesions in calcified plaques than mixed or non-calcified plaques (20% versus 10.2%; $p<0.001$). The majority of calcified plaques were non-obstructive plaques ($n=134$, 78.2%), while about half the non-calcified and mixed plaques were obstructive plaques ($n=14$, 63.6% and $n=30$, 45.5%; all $p<0.001$).

Correlations between clinical history and characteristics of plaques

According to the history of dialysis, the plaques were divided into the dialysis group and non-dialysis group (Table 3, Fig 6a). The length of plaque in the dialysis group was longer than non-dialysis group (2.55±0.22 versus 1.64±0.23 cm, $p=0.01$). The constituents of the plaque type were statistically different. The dialysis group had a higher

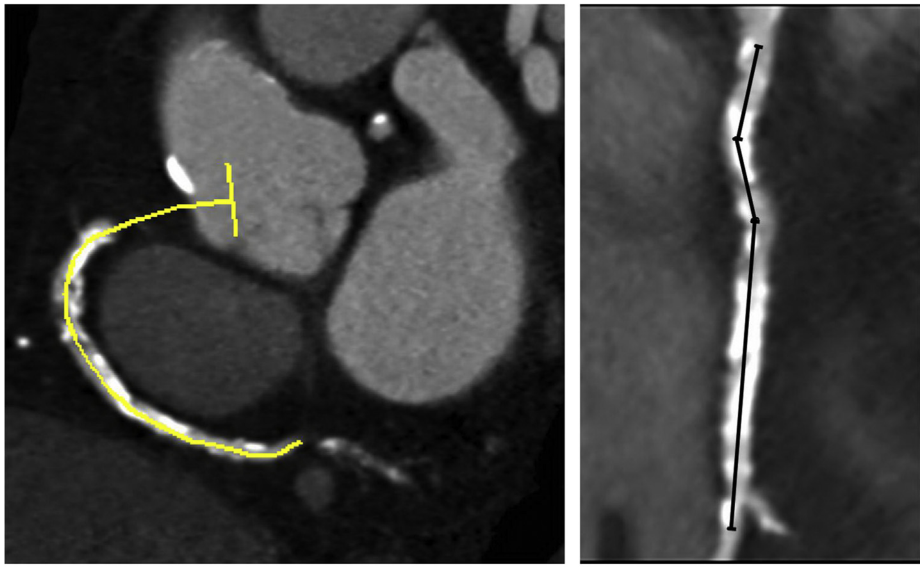

Figure 2 Measurement of calcified plaque length. (a) Multiplanar reconstruction CT image of RCA for drawing the centre line of curvature plane reconstruction (curved line). (b) Curvature planar reconstruction CT image of RCA generated from the curved centre line in (a). Measurement of length was performed manually by drawing straight lines on this image using the two-dimensional distance tool in the workstation. The length of the plaque was the sum of the length of three black lines in this RCA.

proportion of calcified plaque (76.2%), whereas the non-dialysis group had more non-calcified (17%) and mixed plaque (35.1%). The dialysis group had more non-obstructive plaque than the non-dialysis group (n=115, 70.1% and n=54, 57.4%; p=0.04). There was no significant difference between the dialysis and non-dialysis groups in uninterpretable plaque. The lesions in the dialysis group were also divided into three sub-group according to the tertile of duration of dialysis (Fig 6b). The length of plaque increased gradually with duration of dialysis.

According to history of DM in the dialysis group, lesions were divided into the DM group and non-DM group (Table 4). There were statistically significant differences in length of lesion, duration of dialysis, and vessel obstruction (all $p<0.05$). Lesions in DM patients (Fig 7) were shorter than non-DM patients (1.65±1.67 versus 2.53±3.04 cm, p=0.02). DM patients also had a shorter history of dialysis (31.39±3.19 versus 76.81±6.64 months, $p<0.001$). The proportion of obstructive plaque was higher in DM patients (n=16, 21.1% versus n=5, 5.7% in non-DM group, p=0.003); however, the constituent of the plaque type in DM and non-DM group had no statistically difference (all $p>0.05$).

The associations between clinical factors and characteristics of plaque were shown in Table 5. There were no associations between clinical factors and the type of plaque ($p>0.05$) except for association between dialysis and type of plaque (p=0.049). No associations were found between all factors and obstruction. According to the result of multivariable logistic regression (Table 6), dialysis is a risk factor for calcified plaque (OR=2.778, p=0.001).

Table 1
Baseline clinical characteristics of patients with chronic kidney disease (CKD) who underwent coronary computed tomography angiography (CTA).

Characteristics	Positive group	Negative group	p-Value
Number of patients	58	9	
Age (years)	64±11.7 (20–83)	60 (30–78)[a]	0.51
Male/Female	36/22	6/3	0.55
Body Mass Index (kg/m^2)	23±4.1 (14.2–31.6)	19.8 (17.8–23.5)[a]	0.20
Current or pervious smoker	20 (34.5)	6 (66.7)	0.17
Dialysis	37 (63.8)	7 (77.8)	0.34
Duration of dialysis (months)	36 (1–228)[a]	18.6±17.1 (3–48)	0.13
Diabetes mellitus	25 (43.1)	3 (33.3)	0.43
Duration of type 2 diabetes mellitus (months)	178.1±76.0 (48–360)	144 (48–168)[a]	0.22
Hypertension	42 (72.4)	3 (33.3)	0.03
Duration of hypertension (months)	120 (1–480)[a]	216 (144–600)[a]	0.00

Data are expressed as means ± SD (range) [normally distributed] or median (range) [non- normally distributed] or numbers (%).
Positive = one or more coronary plaques were detected on CTA. Negative = no coronary plaque was detected on CTA.
[a] Non- normally distributed variables.

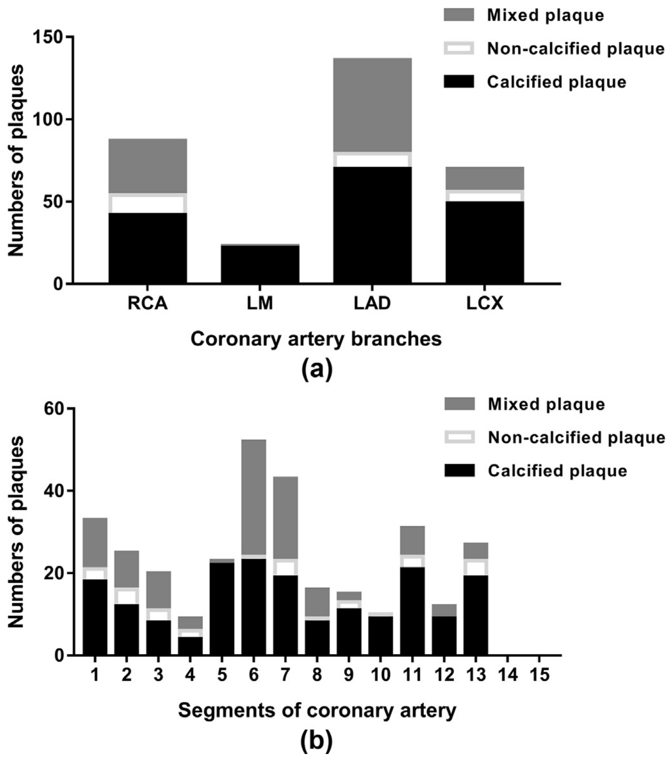

Figure 3 Anatomical distribution of plaques. (a) Distribution of plaques in four branches: RCA, LM, LAD, and LCX. The LAD was the most common location for each type of plaque with calcified plaque the most frequent type. (b) Distribution of plaques in each segment of the coronary artery. The proximal segment of the LAD (segment 6) was the most common location followed by the middle segment of the LAD (segment 7). No lesions were detected in segments 14 and 15.

Discussion

Cardiovascular disease is an important cause of death among patients with CKD. At present, the pathophysiological mechanism of cardiovascular injury in patients with CKD is still unclear; however, many studies have shown that there are a variety of CKD-specific cardiovascular disease risk factors, such as inflammation, anaemia, volume overload, oxidative stress, renin–angiotensin system, sympathetic nerve system, uraemic toxins, and CKD mineral bone disorder.[17] Vascular calcification, which is associated with vascular stiffness, is much more frequent in CKD patients, especially in dialysis patients. A long duration of dialysis, hyperphosphataemia, hypercalcaemia, hyperparathyroidism, use of high-dose vitamin D, and hypoalbuminaemia represent known risk factors for vascular calcification progression in dialysis patients.[4,18] According to the previous research, cardiovascular mortality is strongly associated with vascular calcification in end-stage renal disease (ESRD).[19–21] In the present study, the CKD patients had a heavy plaque burden that was mainly distributed in the LAD artery and proximal segment of each coronary vessel. Analysis of plaque composition revealed a relatively high proportion of calcified plaques. Regarding stenosis severity, about half of the detected lesions were minimal stenosis. Thus, the most common imaging features of coronary artery lesions in patients with CKD were non-obstructive calcified lesions. For most patients, the severity of coronary artery stenosis was not consistent with symptoms such as chest pain, chest tightness, and palpitations.

There were also nine patients with negative coronary CTA results, although each patient had clinical symptoms. The demographic features and clinical information in negative patients were similar to positive patients except for hypertension; however, the bias of the small sample size of negative patients should be considered. The CTA results indicate that clinical symptoms in these negative patients may not be caused by coronary artery disease. Thus, in patients with positive symptoms and non-obstructive lesions or normal coronary arteries in negative cases, non-atherosclerotic causes of the clinical manifestations of these CKD patients should be considered. Whether diffuse myocardial fibrosis in patients with CKD and ESRD might lead to these manifestations is still unclear.[22,23]

Much of the research on coronary CTA in CKD and ESRD patients has shown that CT calcium scores in these patients were high, especially in dialysis patients.[9,10,24,25] Few studies have focused on the specific morphology of atherosclerotic plaque. In the present study, lesion length was longer in dialysis patients than non-dialysis patients. Moreover, the length of plaque increased gradually with duration of dialysis, indicating that these patients have a heavy plaque burden and the morphology of calcification is different from the general population. Coronary artery calcification in CKD patients with dialysis often involves along a continuous segment of the vessel, which is rare in other populations.[6,26]

There are two forms of vascular calcification in CKD: atherosclerotic calcification within neo-intimal plaques and medial calcification within the smooth muscle layer that can occur in the absence of atherosclerosis.[2,4,27] Arterial medial calcification might be result from disruption in bone and mineral metabolism in patients with CKD.[28,29] The prevalence and progression of this form of vascular calcification increases rapidly once patients are on dialysis.[30,31] According to the imaging morphology of vascular calcification in CKD patients, especially in the dialysis group in the present study, the calcified elements of plaque might mainly result from the calcification of the medial arterial wall or both medial and intimal arterial wall. In either case, calcification of the medial arterial wall

Table 2
Different types of plaque and degree of stenosis.

	Types of plaque			Total
	Calcified	Non-calcified	Mixed	
Uninterpretable	34	1	8	43
Degree of stenosis				
Minimal stenosis (1–24%)	128	4	12	144
Mild stenosis (25–49%)	6	3	16	25
Moderate stenosis (50–69%)	1	8	11	20
Severe stenosis (70–99%)	1	6	19	26
Total	170	22	66	

Data are expressed in numbers.

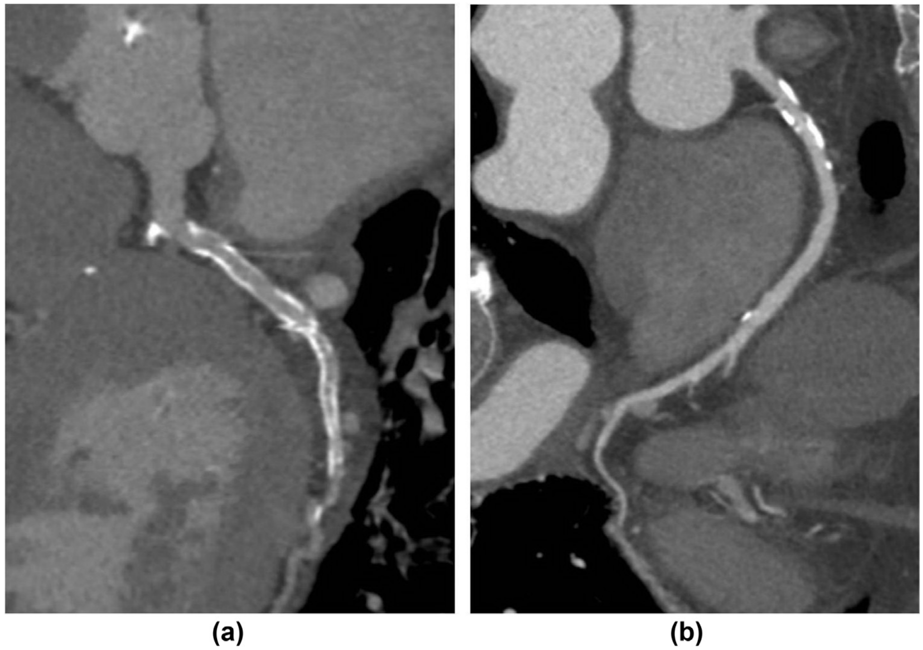

Figure 4 Calcified plaques in patients with and without CKD. (a) A 46-year-old woman with a history of 8 years of haemodialysis for CKD. The patient had coronary CTA for angina. Curvature planar reconstruction CT image of the LCX artery shows diffused continuous calcification with minimal stenosis of the vessel. (b) A 79-year-old woman without history of CKD underwent coronary CTA due palpitations. Curvature planar reconstruction CT image of the RCA shows several calcified plaques in the proximal segment of the RCA with minimal stenosis.

is an important factor in the imaging morphology of vascular lesions in CKD patients, especially in dialysis patients, which is different from that in other populations. Non-calcified plaques and mixed plaques are not as frequent as calcified plaque in CKD patients, especially non-calcified plaque. To the authors' knowledge, few imaging studies have focused on the morphology and distribution of these types of plaques. The mechanism and

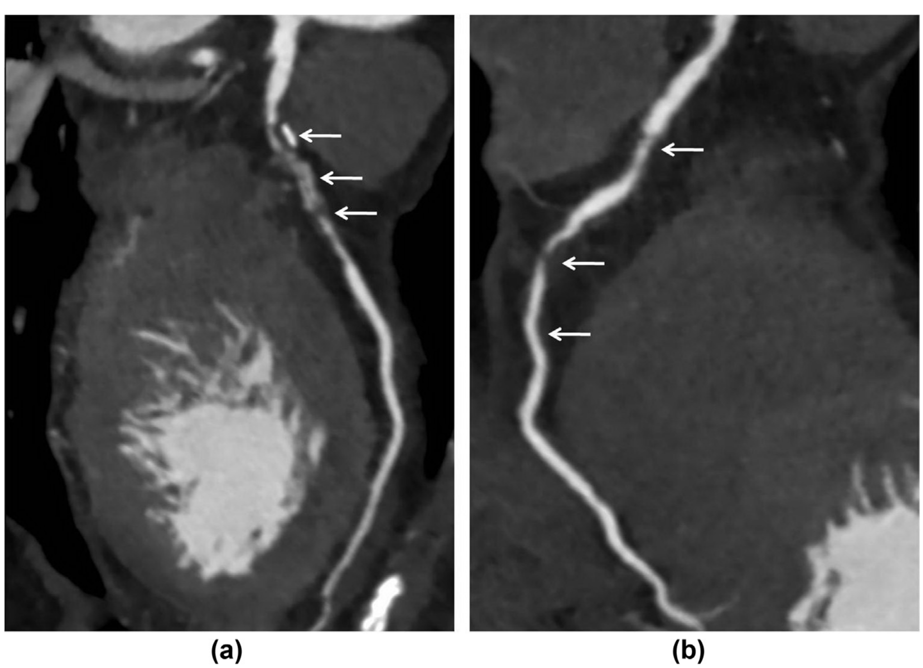

Figure 5 Mixed and non-calcified plaques in a 62-year-old woman with CKD for 9 years without a history of dialysis. The patient underwent coronary CTA for palpitations. (a) Curvature planar reconstruction CT image of the LAD artery shows several mixed plaques (white arrows) in the proximal segment of the LAD with severe stenosis. (b) Curvature planar reconstruction CT image of the RCA shows several non-calcified plaques (white arrows) in the proximal and middle segments of the RCA with mild to severe stenosis.

Table 3
Correlations between dialysis and characteristics of plaque.

	Dialysis (n=164)	Non-dialysis (n=94)	p-Value
Length of lesion (cm)[a]	2.55±0.22 (n=135)	1.64±0.23 (n=64)	0.01
Type of plaques			
Calcified	125	45	<0.001
Non-calcified	6	16	<0.001
Mixed	33	33	0.008
Uninterpretable	28	15	0.82
Obstructive	21	25	0.005
Non-obstructive	115	54	0.040

Data are expressed as means ± SD or numbers.
[a] Spot-like lesions were excluded.

clinical significance of these plaques is still undetermined and further research is needed.

It is well known that DM patients had a higher incidence of coronary artery calcification than the general population.[32–34] Other risk factors for coronary artery calcification include age and CKD, which are also related to DM. Atherosclerosis, which leads to narrowing of the arterial walls throughout the body, is the most important pathological mechanism underlying the vascular complications of DM. Atherosclerosis in DM could result from endothelial dysfunction via various mechanisms, such as hyperglycaemia, insulin resistance, hyperamylinaemia, inflammation, changes in coagulation and fibrinolysis processes, dyslipidaemia, and hypertension.[35] In the present study, nearly half of the CKD patients had a history of DM. The result showed that DM patients undergoing dialysis had more mixed plaques and obstructive plaques than non-DM patients undergoing dialysis. Moreover, lesion length in DM patients was shorter. This result is different from what was anticipated: DM patients on dialysis should have a higher plaque burden and thus lesion length should be longer than non-DM patients on dialysis. This might be caused by differing durations of dialysis and the types of plaque. The duration of dialysis in non-DM patients was statistically longer than DM patients. Second, obstructive mixed plaques were the most common type in DM patients whereas non-obstructive calcified plaques were seen in non-DM patients. Calcified plaque is more likely to involve the long segment of vessels rather than lumen stenosis, whereas lesions with non-calcified elements favoured lumen stenosis. Therefore, DM patients had a higher total plaque volume and higher degree of coronary stenosis, but shorter in the lesion length.

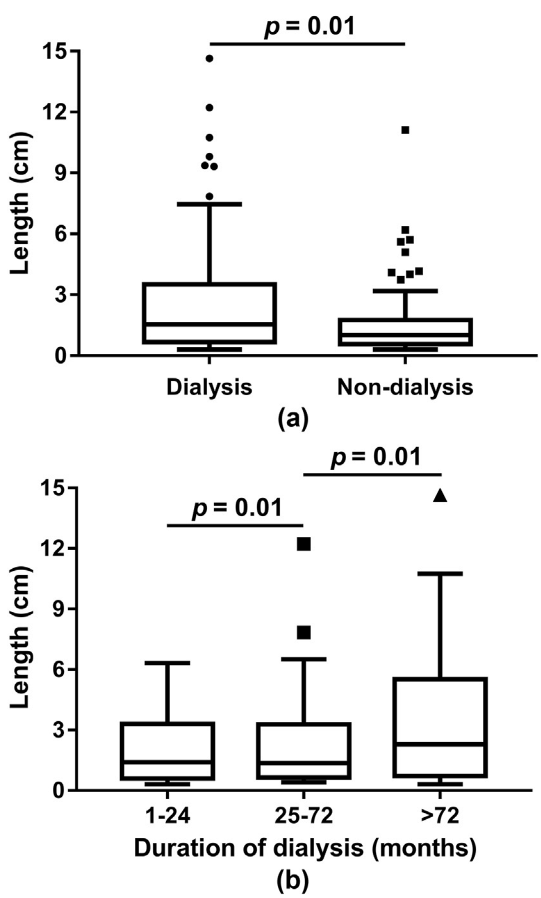

Figure 6 Correlation between dialysis and length of plaque. (a) The length of plaque in the dialysis group was longer than the non-dialysis group. (b) The length of plaque was different between the subgroups with differing durations of dialysis. Plaque length was positively correlated with duration of dialysis.

According to the MANOVA and multivariate logistic regression results, there was an association between dialysis and type of plaque. This is consistent with previous studies that dialysis patients are inclined to develop calcified plaques; however, no associations were found between other single or multiple factors and characteristics of plaque. There was no association between DM and characteristics of plaque according to the present study. This result is inconsistent with previous studies. Previous studies on DM and coronary atherosclerotic plaque have mainly focused on DM patients, whereas the present study focused on CKD patients. The total sample size included in the present study was small; moreover, there were fewer cases of DM. Therefore, no association between DM and plaque characteristics were found in the present study. A correlation might be found if the sample size was large enough.

A major limitation of the present study is that coronary CTA in not a routine examination for CKD. The inclusion population of the present study does not represent the majority of patients with CKD. In West China Hospital, coronary CTA is only scheduled for CKD patients with cardiovascular symptoms or for preoperative evaluation of

Table 4
Difference of lesion feature between DM and non-DM patients in dialysis population.

	DM group (n=76)	Non-DM group (n=88)	p-Value
Length of lesion (cm)[a]	1.65±1.67	2.53±3.04	0.02
Duration of dialysis (month)	31.39±3.19	76.81±6.64	<0.001
Type of plaques			
Calcified	54	71	0.15
Non-calcified	2	4	0.52
Mixed	20	13	0.07
Uninterpretable	15	13	0.40
Obstructive	16	5	0.003
Non-obstructive	45	70	0.005

Data are expressed as means ± SD or numbers.
DM, diabetes mellitus.
[a] Spot-like lesions were excluded.

Figure 7 Curvature planar reconstruction of RCA in a 74-year-old man with CKD and DM for 20 years and 24 years, respectively. The examination was scheduled for angina. There are lots of mixed plaques (white arrows) in the proximal, middle, and distal segments of the RCA with moderate to severe stenosis.

patients mainly due to safety assessments before anaesthesia. Therefore, a selection bias is inevitable in this study; however, previous studies using CT calcium score for accessing coronary lesions could not reflect the comprehensive features of the plaques in these patients. The present study has clinical significance in increasing the understanding of imaging characteristics of atherosclerotic plaques in CKD. Another limitation is that traditional coronary angiography results, which is the reference standard in terms of degree of coronary stenosis, are lacking. The most frequent detected plaque type in the present study is calcified plaque, which might impact the accuracy in accessing the degree of stenosis due to blooming artefacts; however, most calcified plaques in the present study resulted in minimal stenosis, thus, assessment of the degree of stenosis in such lesions is reliable.

In conclusion, coronary CTA detected a heavy plaque burden in CKD patients. Non-obstructive calcified plaque was the most common imaging feature. Dialysis was a risk factor in the progression of coronary calcification with the duration positively related to lesion length. CKD patients with DM had more obstructive mixed plaques. In the present series, the coronary plaques of most symptomatic patients with CKD were non-obstructive. Whether symptoms are caused by coronary lesions or CKD-related cardiomyopathy should be further studied.

Table 6
Multivariate logistic regression of dialysis and type of plaques.

Dependent variables	Odds ratio	p-Value
Calcified plaque	2.778 (1.538–5.025)	0.001
Non-calcified plaque	0.375 (0.131–1.078)	0.068
Mixed plaque	-	-

Data in parenthesis are 95% confidence intervals.

Table 5
Multivariate analysis of variance associations between clinical factors and characteristics of plaques.

Clinical factors	Characteristics of plaques	
	Type of plaques	Obstruction
Dialysis	0.049	0.902
Diabetes mellitus	0.611	0.105
Hypertension	0.619	0.353
Dialysis + diabetes mellitus	0.861	0.114
Dialysis + hypertension	0.947	0.421
Diabetes mellitus + hypertension	0.252	0.102
Dialysis + diabetes mellitus + Hypertension	-	-

Data are p-values.
Obstruction=degrees of stenosis ≥50%.

Conflict of interest

The authors declare no conflict of interest.

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