Cholesterol Metabolism in Patients With Hemodialysis in the Presence or Absence of Coronary Artery Disease

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Background: Little is known about the interrelationship between the lipid profile, cholesterol metabolism, and coronary risk factors in patients with hemodialysis (HD) in the presence or absence of coronary artery disease (CAD).

Methods and Results: Ninety-five patients with HD were selected (HD group). Fifty-eight age-, gender-, and body mass index (BMI)-matched patients who had at least 1 cardiovascular risk factor were selected as a non-HD group. Total cholesterol (TC), triglyceride, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), non-HDL-C, and the ratio of LDL-C to HDL-C (L/H) in the HD group were significantly lower than those in the non-HD group. All markers of cholesterol absorption (campesterol/TC, sitosterol/TC, and cholesterol/TC) and the ratio of campesterol to lathosterol in the HD group were significantly higher. In addition, in the HD group, L/H was negatively correlated with lathosterol/TC, campesterol/TC, sitosterol/TC, and cholesterol/TC. Finally, CAD was significantly associated with lathosterol/TC ($P=0.028$), which was positively associated with BMI in the HD group, whereas CAD was significantly associated only with hypertension ($P=0.020$) in the non-HD group.

Conclusions: HD patients showed lower cholesterol concentrations than non-HD patients, and, as compensation, their cholesterol absorption might be accelerated. However, higher cholesterol synthesis, which was correlated with higher BMI, might be an independent predictor for the presence of CAD in HD patients. (*Circ J* 2012; **76**: 1980–1986)

Key Words: Cholesterol; Coronary artery disease; Hemodialysis; Lipids

Patients with hemodialysis (HD) are associated with a marked increase in the incidence of coronary artery disease (CAD).¹ The prevalence and incidence of CAD in HD patients is much higher than that in non-dialysis patients, and current mortality rates are 10 to 20 times greater than those in the general population, and are even higher at younger ages.

HD patients are characterized by a complex plasma dyslipoproteinemic profile.² The most remarkable abnormalities are increased concentrations of plasma triglyceride (TG) and very-low-density lipoprotein,^{3,4} and decreased concentrations of high-density lipoprotein cholesterol (HDL-C).⁵ Interestingly, plasma concentrations of total and low-density lipoprotein cholesterol (TC and LDL-C) in HD patients are usually normal or even subnormal compared to those in controls.^{6,7} Although a higher TC concentration is associated with cardiovascular mortality in non-dialysis patients, a survival analysis indicated that low cholesterol in addition to low body mass index (BMI) and a low mean predialysis blood urea were as-

sociated with increased overall mortality and cardiovascular mortality.⁸ This paradox might be explained by systemic inflammation and/or malnutrition, which are associated with lower cholesterol concentrations and higher mortality in dialysis patients. In fact, Liu et al reported that the inverse association between the TC concentration and mortality in dialysis patients is likely as a result of the cholesterol-lowering effect of systemic inflammation and malnutrition, rather than to a protective effect of a high cholesterol concentration.⁹

Low cholesterol absorption has been associated with a lower rate of total mortality among elderly cardiovascular patients.¹⁰ Impaired cholesterol homeostasis, reflected by lower synthesis and higher concentrations of absorption markers, are highly significant independent predictors of the presence of CAD in participants in the Framingham Offspring Study.¹¹ In addition, previous studies indicated that metabolic syndrome (MetS) is characterized by increased cholesterol synthesis and by low cholesterol absorption.^{12–14} Compared with controls, patients with MetS had significantly lower campesterol and higher la-

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tholesterol concentrations.¹² Cholesterol synthesis was significantly higher and absorption significantly lower in patients with diabetes mellitus (DM) compared with controls.¹⁴ Lally et al reported that DM patients had higher levels of mRNA of Niemann-Pick C1-like 1, which regulates cholesterol absorption, than the control subjects.¹⁵ Although Sutherland et al and Igel-Korcagova et al analyzed the association between cholesterol metabolism and HD, they only considered 11 and 8 HD patients, respectively.^{16,17} Thus, although cholesterol metabolism (absorption and synthesis) has been well-studied under various pathological conditions, except for HD, little is known about overall cholesterol metabolism in HD patients in the presence or absence of CAD.

Therefore, we evaluated the interrelationship between the lipid profile, cholesterol metabolism, and coronary risk factors in HD patients.

Methods

Study Population

A total of 105 consecutive patients with HD from February 2010 to January 2011 (HD group) were enrolled in this study. Patients who were receiving statins (n=8), ezetimibe (n=1), and statin/ezetimibe (n=1) were excluded from the study. We analyzed 95 patients as a HD group. In addition, 100 consecutive patients who had at least 1 cardiovascular risk factor were enrolled as a non-HD group. Patients who were receiving statins (n=33) were excluded from the study. We selected 58 age-, gender-, and BMI-matched patients as a non-HD group. All patients were recruited at Fukuoka University Hospital and Fukushima Hospital. The protocol in this study was approved by the ethics committee of Fukuoka University Hospital, and all individuals gave their informed consent to participate.

Lipid Profile and Evaluation of Cholesterol Metabolism

Serum concentrations of TC, TG, HDL-C, and LDL-C were measured. The ratio of LDL-C to HDL-C (L/H) and non-HDL-C (TC minus HDL-C) were calculated. All blood samples were drawn in the morning after the patients had fasted overnight, and the samples were drawn before dialysis treatment in the HD group. Laboratory data were determined using enzymatic methods. Three plant sterols, campesterol, sitosterol, and cholesterol, were also measured as markers of cholesterol absorption, and an intermediate in cholesterol synthesis, lathosterol, was measured as a marker of cholesterol synthesis by gas chromatography. The ratio of each sterol to TC (sterol/TC) and the ratio of campesterol to lathosterol (campesterol/lathosterol) were calculated.

Evaluation of Past History and Cardiovascular Risk Factors

Clinical data were collected from hospital charts or databases at each hospital by independent clinical researchers according to predetermined definitions. The presence of CAD was defined according to significant coronary stenosis (>50%, at least 1 coronary vessel) by coronary angiography, coronary computed tomography, or the patient's medical records. Peripheral artery disease (PAD) was considered to be present when carotid, aortic, or other PAD was being treated or the patient was scheduled for surgical or endovascular interventions. In all patients, BMI, presence of hypertension (HT), dyslipidemia (DL), DM, and hyperuricemia (HU) were collected as cardiovascular risk factors. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were determined as the mean of 2 measurements obtained in an office setting by the conventional cuff method using a mercury sphygmomanometer. Pa-

Table 1. Patient Characteristics in the HD and Non-HD Groups

	HD group (n=95)	Non-HD group (n=58)
Age, years	68±11	67±8
Male, n (%)	47 (50)	28 (48)
BMI, kg/m ²	22.5±3.3	23.4±3.2
HD		
Dulution (months)	105±84	
Time (min)	239±21	
CAD, n (%)	26 (27)	20 (35)
PAD, n (%)	19 (20)	6 (10)
HT, n (%)	65 (68)	38 (66)
DM, n (%)	31 (33)	26 (45)
HU, n (%)	8 (8)	8 (14)
DL, n (%)	35 (37)	28 (48)
TC, mg/dl	94±49*	135±89
HDL-C, mg/dl	47±13*	53±12
LDL-C, mg/dl	86±30*	125±34
TG, mg/dl	94±49*	135±89
Non-HDL, mg/dl	110±34*	152±35
L/H	2.0±1.0*	2.5±0.8
Lathosterol/TC	0.012±0.008	0.011±0.006
Campesterol/TC	0.037±0.016*	0.023±0.009
Sitosterol/TC	0.022±0.011*	0.012±0.005
Cholesterol/TC	0.021±0.005*	0.014±0.004
Campesterol/Lathosterol ratio	3.9±2.5*	2.7±2.0
HbA _{1c} , %	5.4±0.9*	6.4±1.6
UA, mg/dl	7.5±1.1*	5.2±1.5
Log [hsCRP], mg/dl	3.00±0.73	—
Albumin, mg/dl	3.5±0.3	—
Medication, n (%)		
ARB/ACE-I	55 (58)*	11 (19)
CCB	55 (58)*	18 (31)
α-blocker	9 (10)*	0
β-blocker	26 (27)*	4 (7)
Diuretics	26 (27)*	3 (5)
Insulin	15 (16)*	0
Ethyl icosapentate	23 (24)*	0

Continuous variables are expressed as mean±SD.

BMI, body mass index; HD, hemodialysis; CAD, coronary artery disease; PAD, peripheral arterial disease; HT, hypertension; DM, diabetes mellitus; HU, hyperuricemia; DL, dyslipidemia; TC, total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TG, triglyceride; L/H, a ratio of LDL-C to HDL-C; HbA_{1c}, hemoglobin A_{1c}; UA, uric acid; hsCRP, highly sensitive C-reactive protein; ARB, angiotensin II receptor blocker; ACE-I, angiotensin-converting enzyme inhibitor; CCB, calcium channel blocker.

*P<0.05 vs. non-HD group.

tients who had a current SBP/DBP ≥140/90 mmHg or who were receiving antihypertensive therapy were considered to have HT. Patients with a LDL-C concentration of ≥140 mg/dl, a TG concentration of ≥150 mg/dl, and a HDL-C concentration of <40 mg/dl were considered to have DL. DM was defined using the American Diabetes Association criteria. BMI was calculated as weight (kg)/height (m)². HU was defined as uric acid (UA) ≥7.0 mg/dl.

Statistical Analysis

Statistical analysis was performed using the Stat View statisti-

Table 2. Patient Characteristics in the HD Group

	CAD group (n=26)	Non-CAD group (n=69)
Age, years	68±10	67±12
Male, n (%)	13 (50)	34 (49)
BMI, kg/m ²	24.1±3.7*	21.9±3.0
HD		
Dulution (months)	113±94	101±80
Time (min)	250±25*	234±18
HT, n (%)	18 (69)	47 (68)
DM, n (%)	11 (42)	20 (30)
DL, n (%)	10 (39)	25 (36)
HU, n (%)	3 (12)	5 (7)
TC, mg/dl	157±40	156±36
HDL-C, mg/dl	43±9	48±14
LDL-C, mg/dl	87±34	86±28
TG, mg/dl	109±50	88±48
Non-HDL, mg/dl	114±39	108±32
L/H	2.1±1.1	1.9±0.9
Lathosterol/TC	0.015±0.012*	0.011±0.005
Campesterol/TC	0.033±0.009	0.038±0.018
Sitosterol/TC	0.019±0.006	0.024±0.013
Cholesterol/TC	0.020±0.004	0.022±0.006
Campesterol/Lathosterol ratio	3.0±1.4*	4.2±2.8
HbA _{1c} , %	5.7±1.0	5.3±0.9
Log [hsCRP], mg/dl	3.12±0.76	2.96±0.72
Albumin, mg/dl	3.5±0.3	3.5±0.3
Medication, n (%)		
ARB/ACE-I	15 (58)	40 (48)
CCB	15 (58)	40 (58)
α -blocker	3 (12)	6 (9)
β -blocker	3 (12)	6 (9)
Diuretics	8 (31)	18 (26)
Insulin	7 (27)	8 (12)
Ethyl icosapentate	10 (38)*	13 (19)

Continuous variables are expressed as mean±SD.

Abbreviations as in Table 1.

*P<0.05 vs. non-CAD group.

cal software package (Stat View 5; SAS Institute INC, Cary, NC, USA) at Fukuoka University (Fukuoka Japan). Data are expressed as the mean±standard deviation (SD). The significance of differences was evaluated using the t-test for continuous variables and the χ^2 test for non-continuous variables. Multivariate analysis was performed using a logistic regression analysis for independent variables that were related to the presence or absence of CAD. A value of P<0.05 was considered significant.

Results

Characteristics of HD vs. Non-HD Patients

The patient characteristics in the HD and non-HD groups are shown in Table 1. In the HD group, the duration of HD and HD time were 105±84 months and 239±21 min, respectively. The incidences of CAD in the HD and non-HD groups were 27% and 35%, respectively. There were no differences in the prevalence of CAD, PAD, HT, DM, DL, and HU between the HD and non-HD groups. In the lipid profile, TC, TG, HDL-C, LDL-C, non-HDL-C, and L/H in the HD group were signifi-

Table 3. Patient Characteristics in the Non-HD Group

	CAD group (n=20)	Non-CAD group (n=38)
Age, years	70±9*	65±7
Male, n (%)	11 (55)	37 (45)
BMI, kg/m ²	23.6±3.1	23.3±3.3
HT, n (%)	18 (90)*	20 (53)
DM, n (%)	10 (50)	16 (42)
DL, n (%)	11 (55)	17 (45)
HU, n (%)	4 (20)	4 (11)
TC, mg/dl	132±96	138±86
HDL-C, mg/dl	52±14	53±12
LDL-C, mg/dl	132±40	121±31
TG, mg/dl	132±96	138±86
Non-HDL, mg/dl	158±46	149±29
L/H	2.6±0.8	2.4±0.8
Lathosterol/TC	0.011±0.01	0.012±0.01
Campesterol/TC	0.022±0.009	0.023±0.009
Sitosterol/TC	0.011±0.01	0.012±0.01
Cholesterol/TC	0.013±0.004	0.015±0.004
Campesterol/Lathosterol ratio	2.8±1.8	2.8±2.2
HbA _{1c} , %	6.3±1.1	6.5±1.9
Medication, n (%)		
ARB/ACE-I	6 (30)	5 (13)
CCB	10 (50)*	8 (21)
β -blocker	1 (5)	3 (8)
Diuretics	2 (10)	1 (3)

Continuous variables are expressed as mean±SD.

Abbreviations as in Table 1.

*P<0.05 vs. non-CAD group.

cantly lower than those in the non-HD group. All markers of cholesterol absorption (campesterol/TC, sitosterol/TC, and cholesterol/TC) and campesterol/lathosterol in the HD group were significantly higher than those in the non-HD group, whereas there was no difference in lathosterol/TC between the groups. The HD group showed significantly a lower concentration of hemoglobin A_{1c} and a higher concentration of UA than the non-HD group. Medications such as angiotensin receptor blocker/angiotensin converting enzyme inhibitor, calcium channel blocker (CCB), α -blocker, β -blocker, diuretics, insulin, and ethyl icosapentate were used more frequently in the HD group than in the non-HD group.

Characteristics of CAD vs. Non-CAD Patients in the HD and Non-HD Groups

The characteristics of CAD and non-CAD patients in the HD and non-HD groups are summarized in Tables 2 and 3. There were no differences in age, sex, presence of diseases, or medications between CAD and non-CAD patients in the HD group. HD time in CAD patients was significantly longer than that in non-CAD patients. In addition, in the HD group, CAD patients showed significantly a higher concentration of lathosterol/TC and a lower concentration of campesterol/lathosterol than non-CAD patients, whereas there were no differences in markers of cholesterol absorption or the lipid profile between CAD and non-CAD patients. Ethyl icosapentate were used more frequently in the CAD group than in the non-CAD group.

In the non-HD group, CAD patients were significantly older than non-CAD patients, whereas there were no differences in lipid profile or cholesterol metabolism. In addition, the inci-

Figure 1. Association between lipid profile and cholesterol metabolism in the hemodialysis (HD) group. L/H (a ratio of low-density lipoprotein cholesterol to high-density lipoprotein cholesterol) was negatively correlated with lathosterol/total cholesterol (TC) (A), campesterol/TC (B), sitosterol/TC (C), and cholestanol/TC (D).

dence of HT in CAD patients was significantly greater than that in non-CAD patients, and CCB was used more frequently in CAD patients than in non-CAD patients.

Association Between the Lipid Profile and Cholesterol Metabolism in the HD and Non-HD Groups

Figure 1 shows the association between the lipid profile and cholesterol metabolism. In the HD group, L/H was negatively correlated with lathosterol/TC ($r=-0.207$, $P=0.044$), campesterol/TC ($r=-0.243$, $P=0.018$), sitosterol/TC ($r=-0.225$, $P=0.029$), and cholestanol/TC ($r=-0.218$, $P=0.039$), whereas there was no association between L/H and campesterol/lathosterol (data not shown).

In the HD group, LDL-C was negatively correlated with lathosterol/TC ($r=-0.234$, $P=0.022$), and TC and HDL-C were positively correlated with campesterol/lathosterol ($r=0.208$, $P=0.043$) and campesterol/TC ($r=0.218$, $P=0.033$), respectively. Moreover, these associations between the lipid profile and cholesterol metabolism were not seen in the non-HD group.

Association Between the Lipid Profile and Highly Sensitive C-Reactive Protein (hs-CRP) or Albumin in the HD Group

Figure 2 shows the association between the lipid profile and log [hs-CRP] or albumin concentrations in the HD group. In the HD group, albumin was negatively correlated with log [hs-CRP] ($r=-0.457$, $P<0.0001$) and positively correlated with HDL-C ($r=0.326$, $P=0.0012$), and albumin tended to be associated with TC ($r=0.185$, $P=0.073$). In addition, log [hs-CRP] was negatively correlated with HDL-C ($r=-0.239$, $P=0.020$).

Predictors of the Presence of CAD in the HD and Non-HD Groups

Next, we examined the associations between the presence of CAD and possible predictors of CAD in the HD and non-HD groups (**Table 4**). In the HD group, CAD was associated with BMI, lathosterol/TC, and campesterol/lathosterol, as shown in **Table 2**. BMI was positively correlated with lathosterol/TC ($r=0.380$, $P=0.0001$) and negatively correlated with campesterol/lathosterol ($r=-0.217$, $P=0.035$). In addition, campesterol/lathosterol was negatively correlated with lathosterol/TC

Figure 2. Association between the lipid profile and log [hs-CRP] or albumin in the hemodialysis (HD) group. Albumin was negatively correlated with log [hs-CRP] (A) and positively correlated with high-density lipoprotein cholesterol (HDL-C) (B), and albumin tended to be associated with total cholesterol (TC) (C). Log [hs-CRP] was negatively correlated with HDL-C (D). hs-CRP, highly sensitive C-reactive protein.

Table 4. Factors That Contribute to the CAD in the HD and Non-HD Groups				
Factors	HD group		Non-HD group	
	OR (95% CI)	P value	OR (95% CI)	P value
Age	1.01 (0.97–1.06)	0.628	1.05 (0.97–1.14)	0.242
Gender	1.03 (0.40–2.67)	0.945	0.87 (0.25–3.05)	0.833
Lathosterol/TC	2.07 (1.08–3.98)	0.028	0.88 (0.30–2.56)	0.819
Campesterol/TC	0.80 (0.54–1.19)	0.276	0.75 (0.37–1.52)	0.425
HT			7.21 (1.36–38.2)	0.020

OR, odds ratio; CI, confidence interval; HD, hemodialysis. Other abbreviations as in Table 1.

($r=-0.544$, $P<0.0001$). These factors were associated with each other. Therefore, we excluded these factors (BMI and campesterol/lathosterol) from the logistic regression analysis and performed the analysis using independent variables (lathosterol/TC in addition to age, gender, and campesterol/TC as a marker of absorption) that were related to the presence of CAD. CAD was significantly associated only with lathosterol/

TC ($P=0.028$).

In the non-HD group, CAD was associated with age, HT, and use of CCB, as shown in Table 2. As CCB was associated with the presence of HT ($P<0.0001$), we excluded this factor from the logistic regression analysis and performed the analysis using independent variables (age and HT in addition to gender, lathosterol/TC, and campesterol/TC) that were related

to the presence of CAD. CAD was significantly associated only with HT ($P=0.020$).

Discussion

In the present study, HD patients showed lower cholesterol concentrations and higher cholesterol absorption than non-HD patients. In addition, CAD was significantly associated with cholesterol synthesis, which was positively associated with BMI in the HD group, whereas CAD was significantly associated only with HT in the non-HD group.

In the HD group, higher cholesterol synthesis was an independent predictor of the presence of CAD. Although there was no difference in cholesterol absorption between the presence and absence of CAD in the HD group, CAD patients in the HD group showed higher cholesterol absorption compared to CAD patients in the non-HD group. Inflammation and malnutrition are often seen in HD patients¹⁸ and have been recognized as important contributors to an adverse prognosis in dialysis patients.¹⁹ Thus, HD patients have generally a characteristic of higher cholesterol absorption probably as a result of inflammation and malnutrition, subsequently CAD patients in the HD group show higher cholesterol synthesis. In addition, L/H was negatively associated with both cholesterol absorption and synthesis. As there was no difference in L/H between the presence and absence of CAD in the HD group, the presence of CAD was not associated with the concentrations of L/H in HD patients.

In this study, HD patients had lower cholesterol concentrations and lower BMI, as well as higher cholesterol absorption, compared to non-HD patients. As the lower BMI and lower cholesterol concentrations might be a result of inflammation and malnutrition in HD patients, as compensation, their cholesterol absorption might be accelerated. In addition, albumin was negatively correlated with log [hs-CRP] and tended to be associated with TC in HD patients. Although TC was surprisingly not associated with hs-CRP, higher concentrations of hs-CRP (greater inflammatory state) induce lower levels of albumin (greater malnutrition). As HDL-C was negatively correlated with hs-CRP, and because HDL has many pleiotropic effects, HDL-C might suppress inflammation in HD. Interestingly, in this study, cholesterol absorption probably increased when the HDL-C concentration increased, whereas cholesterol synthesis increased when the LDL-C level decreased. In the case of HD patients, LDL-C in HD patients was significantly lower than that in non-HD patients. Because inflammation and malnutrition in HD patients might associate with the significant reduction of LDL-C level, it is possible that cholesterol synthesis increased as an adaptation system when the LDL-C level decreased. In addition, in the HD group, L/H was negatively correlated with the markers of cholesterol synthesis and absorption. Although LDL-C did not correlate with hs-CRP, HDL-C was negatively associated with hs-CRP and positively associated with albumin. If the patients show higher HDL-C with lower L/H, the patients might have lower inflammation and better nutritional status, and then they might show higher cholesterol absorption and synthesis than the patients with lower HDL-C with higher L/H.

Several studies in the dialysis patients demonstrated an unexpected higher mortality rate associated with low cholesterol concentrations.^{8,20,21} Deaths under low cholesterol concentrations are thought to be mainly as a result of non-cardiovascular causes, such as cancer, stroke, liver disease, and alcohol dependence syndrome.²² Atorvastatin had no statistically significant effect on the composite primary endpoint of cardio-

vascular death, non-fatal myocardial infarction, and stroke in patients with diabetes receiving HD.²³ In this study, HD patients showed lower LDL-C and normal HDL-C concentrations (LDL-C and HDL-C concentrations averaged 86 and 47 mg/dl, respectively). Although L/H in the HD group was significantly lower than that in the non-HD group, the ratio was approximately 2.0 without lipid-lowering therapy. Nicholls et al indicated that statin therapy is associated with the regression of coronary plaque when LDL-C is substantially reduced and HDL-C is increased by more than 7.5% ($L/H < 1.5$).²⁴ The regression of coronary plaque might have prevented cardiovascular events in atherosclerotic left main coronary arteries of 56 patients with established atherosclerosis.²⁵ As statin therapy reduced the volume of lipid cores and lipid-rich coronary plaques,^{26–28} we might be able to prevent the progression of coronary plaque and subsequent cardiovascular events if L/H is < 1.5 . Although the association between cholesterol concentrations or statin treatment and the risk of CAD morbidity and mortality in the endo-stage renal disease is controversial, we might need to perform intensive lipid-lowering therapy by inhibition of cholesterol synthesis using statin in HD patients because CAD was significantly associated only with lathosterol/TC in this study. Moreover, reduced cholesterol absorption has been associated with fewer recurrent cardiovascular events and with better survival in elderly patients, although the participants were not HD patients.²⁹ The inhibition of cholesterol absorption by ezetimibe reduced not only serum LDL-C but also hs-CRP in patients with end-stage renal failure who were undergoing HD.³⁰ It might be important to reduce cholesterol absorption in addition to inhibition of cholesterol synthesis even if HD patients show lower LDL-C concentrations. Thus, lipid-lowering therapy might be needed to prevent cardiovascular events even in patients who are undergoing HD. In fact, a reduction of LDL-C with statin plus ezetimibe reduced the incidence of major atherosclerotic events in a wide range of patients with advanced chronic kidney disease.³¹

The remarkable abnormality in lipid profile is generally an increased in TG concentration in HD patients, but not in this study group. There are some reasons why HD patients show the higher concentrations of TG. For example, metabolizing enzymes of TG are inhibited by uremic substances as a result of renal dysfunction. In addition, higher concentrations of TG are a result of kinds of dialysate and types of dialysis membrane or secondary parathyroidism. We did not have more information for these aspects.

This study has several limitations. First, the study was cross-sectional. Second, the measurements were performed after various treatments. It can generally be assumed that HD patients were taking more medications than non-HD patients. Although many of the patients were taking anti-hypertensive and/or anti-diabetic medications that might modify the measurements, we excluded patients who were being treated with statin and/or ezetimibe. Third, the non-HD group described in this study was a special group and was not considered as a usual control group because it had very high incidence of CAD with at least 1 risk. Fourth, prospective studies are needed to clarify the associations we identified.

In conclusion, our data demonstrated that HD patients have lower cholesterol concentrations than non-HD patients, and, as compensation, their cholesterol absorption might be accelerated. However, a higher BMI, which was correlated with higher cholesterol synthesis, might be an independent predictor for the presence of CAD in HD patients.

Disclosures

K.S. is a Chief Director and S.M. is a Director of NPO Clinical and Applied Science, Fukuoka, Japan.

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