Original Paper

Progression of Chronic Kidney Disease Affects HDL Impact on Lipoprotein Lipase (LPL)-Mediated VLDL Lipolysis Efficiency

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Key Words

Chronic kidney disease • Lipoprotein lipase • Triglycerides • Lipolysis • Lipoproteins • Very low density lipoprotein • High density lipoprotein

Abstract

Background/Aims: Hypertriglyceridaemia (HTG) and reduction and dysfunction of high density lipoprotein (HDL) are common lipid disturbances in chronic kidney disease (CKD). HTG in CKD is caused mainly by the decreased efficiency of lipoprotein lipase (LPL)-mediated very low density lipoprotein triglyceride (VLDL-TG) lipolysis. It has not been clarified whether HDL dysfunction in CKD contributes directly to HTG development; thus, the aim of this study was to assess the impact of CKD progression on the ability of HDL to enhance LPL-mediated VLDL-TG lipolysis efficiency. **Methods:** VLDL was isolated from non-dialysis patients in CKD stages 3 and 4 and from non-CKD patients. The VLDL was incubated with LPL at the constant LPL:VLDL-TG ratio, in the absence or presence of HDL. After incubation, the VLDL was separated and the percentage (%) of hydrolyzed TG was calculated. **Results:** HDL presence increased the lipolysis efficiency of VLDL isolated from CKD and non-CKD patients, for the VLDL-TG > 50 mg/dl. Its effect was dependent on the VLDL-TG and HDL-cholesterol concentrations in the reaction mixtures: the higher the concentrations of VLDL-TG and HDL-cholesterol, the greater the effect. The positive impact of HDL on VLDL lipolysis was modified by CKD progression: the percentage of lipolyzed VLDL-TG in the presence of HDL decreased with a reduction in eGFR ($r=0.43$, $p=0.009$), and for patients with stage 4 CKD, no positive impact of HDL on lipolysis was observed. The percentage of lipolyzed TG correlated negatively with apoE and apoCs content in VLDL, and positively with HDL-apoCII, as well as with VLDL and HDL apoCII/apoCIII ratios. The progression of CKD was associated with unfavourable changes in VLDL

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and HDL composition; apoE and apoCs levels increased in VLDL with a decrease in eGFR whereas the HDL-cholesterol level decreased. **Conclusion:** The progression of CKD affects lipoprotein composition and properties, and modulates the positive impact of HDL on VLDL lipolysis efficiency. In CKD patients, HDL deficiency and dysfunction can directly affect hypertriglyceridaemia development.

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Introduction

HTG is a major lipid abnormality in chronic kidney disease (CKD) and an important contributor to a marked increase of cardiovascular mortality in this group of patients [1-3]. HTG reflects an increased quantity of triglyceride-rich lipoproteins (TRL) in plasma, i.e. chylomicrons (CM) carrying dietary lipids, liver-derived very low density lipoproteins (VLDL), and/or their remnant particles. The main mechanisms of HTG development include the enhanced liver secretion and impaired plasma TRL clearance, among which the clearance pathway is considered to be the most important [4, 5].

Intravascular lipolysis mediated by lipoprotein lipase (LPL) is a key process in plasma TRL clearance. LPL hydrolyzes triglycerides (TG) into glycerol and free fatty acid (FFA). Due to TG hydrolysis, CM is converted to smaller CM remnants and VLDL – to intermediate density lipoprotein (IDL), which can be taken up by the liver via LDL receptors or it can be further lipolyzed, producing low density lipoprotein (LDL). TG hydrolysis is accompanied by the release from TRL the surface material containing phospholipids (PL), free cholesterol (FC), and exchangeable apolipoproteins (apo): apoE, apoCII and apoCIII, which are transferred to high density lipoprotein (HDL), affecting its maturation and plasma concentration [4, 6].

Reduced HDL concentration and disturbances of its composition are known atherosclerosis risk factors. However, the mechanisms by which HDL affects atherosclerosis development still remain a matter of debate [7]. Taking into consideration the close link between plasma metabolism of TRL and HDL, it raises the question if unfavorable changes of HDL do not affect TRL clearance and HTG development in CKD patients.

HTG in CKD is accompanied by a significant reduction in plasma HDL, disturbed HDL composition, and HDL dysfunction [8, 9]. HDL in CKD have reduced ability to promote cholesterol efflux from macrophages as well as HDL anti-oxidative, anti-inflammatory and vasoprotective properties are impaired [8, 10]. Lipid and lipoprotein disturbances develop in the early stages of the disease and exaggerate with the progression of renal failure. Thus, patients with different stages of CKD display different severity of HTG and other lipid-related disturbances [11-13].

The aim of this study was to assess the impact of CKD progression on the ability of HDL to enhance LPL-mediated VLDL-TG lipolysis efficiency. We found that HDL enhanced lipolysis efficiency in a VLDL-TG and HDL concentration-dependent manner, but its positive effect was reduced with the progression of CKD.

Materials and Methods

Study group

Adult non-dialysis patients in CKD stages 3 and 4, being under the care of the Outpatient Clinic of the Nephrology Department of the Medical University of Gdansk, and non-CKD patients were recruited into the study (Table 1). The study exclusion criteria were: acute diseases within 3 months before the study, liver diseases, malignancy, diabetes, treatment with immunosuppressive agents, fibrates or heparin. 55% of CKD patients and none of non-CKD patients received statins.

The serum lipid and apolipoprotein concentrations for CKD and non-CKD patients are presented in Table 1. 29% of CKD patients were normolipidemic (TC<190 mg/dl, TG<150 mg/dl). 50% had hypercholesterolemia, 5% – hypertriglyceridemia, and 16% – mixed hyperlipidemia. 13 non-CKD patients

were normolipidemic, whereas 4 patients had TC values above 190 mg/dl (up to 206 mg/dl).

All subjects gave a written informed consent for participation in the study. The study was approved by the Independent Bioethics Commission for Research of the Medical University of Gdansk (Poland).

VLDL and HDL isolation

Blood was drawn from the vein after overnight fasting into commercially available test tubes to obtain the serum. VLDL was isolated by ultracentrifugation [14]. HDL was isolated from infranant after VLDL separation by combined precipitation-ultracentrifugation procedure [15]. Next, the VLDL and HDL were dialyzed (18 h, 4 °C) against 0.01 M Tris-HCl buffer, pH 7.4, containing 0.195 M NaCl and 0.01% NaN₃.

VLDL lipolysis

VLDL was incubated with LPL isolated from bovine milk (Sigma Aldrich, St Louis, MI, USA) for 1 h, 37 °C at the constant LPL:VLDL-TG 4.8 µg/ml:90 mg/dl ratio, in the absence or presence of HDL. The basic VLDL-cholesterol:HDL-cholesterol (VLDL-C:HDL-C) weight ratio was 1:1. In some experiments the different amount of HDL, i.e. VLDL-C:HDL-C ratios 1:0.1, 1:0.25, 1:0.5, 1:0.75, 1:1 were used. Albumin (Sigma Aldrich) was added to the reaction mixtures as an FFA acceptor (final concentration 2%, w/w). A respective volume of 0.01 M Tris-HCl buffer, pH 7.4, containing 0.195 M NaCl and 0.01% NaN₃, corresponding to the volume of HDL and/or LPL, was added to align the differences in volumes between the reaction mixtures. After incubation, the VLDL was separated by immunoprecipitation with anti-apoB antibodies [16], and the concentration and the percentage of TG released from the VLDL during lipolysis was calculated.

Biochemical analysis and electrophoresis

The concentrations of lipids (total cholesterol (TC), HDL-C, TG, phospholipids (PL)) were measured using commercially available enzymatic kits obtained from Pointe Scientific and Wako Diagnostics. LDL-C was calculated using the Friedewald formula. Apolipoproteins B, E, CII and CIII were measured by immunonephelometry using kits obtained from Siemens Healthcare and Randox. Pre-β1-HDL was determined using enzyme-linked immunoassay kit obtained from Sekisui Diagnostics. Serum creatinine was measured using the enzymatic method (Abbott Diagnostics). Agarose electrophoresis was performed using Hydragel 15 Lipoprotein(E) kit obtained from Sebia. Densitometric analysis of electropherograms was performed with GelScan V. 1.45 (K. Kucharczyk Electrophoretic Techniques, Poland).

Statistical analysis

Statistical analysis was performed using GraphPad Prism 4.03. Normality was assessed with the Kolmogorov-Smirnov test. Data was expressed as mean±standard deviation (mean±SD) or median and 25th–75th percentiles. Statistical significance between the two groups was determined by non-paired or paired *t* test, between more than two groups – by ANOVA with Tukey post-hoc test. Values of *p*<0.05 were considered statistically significant.

Table 1. Characteristics of study groups. Data are expressed as: mean±SD or median (25th–75th percentiles)

Parameter	Value
CKD patients	
Number	36
Age (years)	68 (61 – 74)
Gender (patients number)	Female (16), Male (20)
CKD stage (patients number)	3a (11), 3b (15), 4
eGFR-MDRD [ml/min/1.73m ²]	37 ± 12
Serum creatinine [mg/dl]	1.56 (1.37 – 2.12)
Lipids:	
TC [mg/dl]	211 ± 46
LDL-C [mg/dl]	135 ± 44
HDL-C [mg/dl]	51 ± 14
TG [mg/dl]	119 ± 51
PL [mg/dl]	215 ± 32
Apolipoproteins:	
apoB [mg/dl]	99 ± 25
apoE [mg/dl]	4.23 (3.44 – 5.07)
apoCII [mg/dl]	3.35 ± 0.86
apoCIII [mg/dl]	11.4 ± 3.11
Non-CKD patients	
Number	17
Age (years)	24 (23 – 26)
Gender (patients number)	Female (11), Male (6)
eGFR-MDRD	≥ 60
Serum creatinine [mg/dl]	0.76 ± 0.12
Lipids:	
TC [mg/dl]	171 ± 23
LDL-C [mg/dl]	94 ± 18
HDL-C [mg/dl]	63 ± 15
TG [mg/dl]	74 ± 30
PL [mg/dl]	208 ± 27
Apolipoproteins:	
apoB [mg/dl]	76 ± 14
apoE [mg/dl]	4.2 ± 1.0
apoCII [mg/dl]	2.73 ± 0.74
apoCIII [mg/dl]	8.36 ± 2.42

Results

For CKD patients, LPL-mediated lipolysis of VLDL-TG occurred in a VLDL-TG concentration and HDL presence dependent manners (Fig. 1). In the absence of HDL, for the VLDL-TG concentration below ~50 mg/dl, the concentration of lipolyzed TG increased proportionally with the concentration of VLDL-TG. For the VLDL-TG above ~50 mg/dl, the concentration of lipolyzed TG did not increase and reached a plateau on average of 53.2 ± 5.2 mg/dl. Conversely, in the HDL presence the concentration of lipolyzed TG increased with the VLDL-TG, in the whole range of the examined VLDL-TG concentrations (Fig. 1A).

In the absence of HDL there was a strong negative correlation between the percentage of lipolyzed TG and the concentration of VLDL-TG in the reaction mixtures (Fig. 1B). For VLDL-TG concentration above ~50 mg/dl, HDL presence significantly increased the percentage of hydrolyzed TG on average by 9.3% ($p < 0.0001$), in comparison to mixtures without HDL. The higher the VLDL-TG concentration, the greater effect of the HDL on lipolysis efficiency was observed. For the VLDL-TG concentration ~90 mg/dl, HDL increased the percentage of lipolyzed VLDL-TG by 15% (Fig. 1B).

A similar relationship between VLDL-TG concentration, HDL presence, and VLDL-TG lipolysis efficiency has been observed for non-CKD patients (Fig. 1, insert graphs).

The effect of HDL on VLDL-TG lipolysis efficiency was HDL concentration-dependent. For the reaction mixtures with an increasing amount of HDL, the percentage of lipolyzed VLDL-TG gradually increased – the means were 67.2%, 71.5%, 74.0%, 78.3%, 83.3%, and 85.1% for VLDL-C:HDL-C 1:0, 1:0.1, 1:0.25, 1:0.5, 1:0.75, 1:1 ratios, respectively (Fig. 2A).

The presence and concentration of HDL had influence on the electrophoretic mobility of VLDL remnants produced during lipolysis (Fig. 2B). The remnants displayed lower electrophoretic mobility than the VLDL-control. The remnants produced in the absence of HDL had the mobility between beta and pre-beta. The remnants produced in the presence of HDL had lower mobility than the remnants produced in the absence of HDL, and for the

Fig. 1. Impact of HDL presence on VLDL-TG lipolysis efficiency for CKD patients (main graphs), and non-CKD patients (insert graphs). A. The relationship between VLDL-TG concentration in the reaction mixture [mg/dl] and the concentration [mg/dl] of lipolyzed TG, in the absence and presence of HDL (VLDL-C:HDL-C 1:1 weight ratio). B. The correlation between the VLDL-TG concentration in the reaction mixture [mg/dl] and the percentage [%] of lipolyzed VLDL-TG, in the absence and presence of HDL (VLDL-C:HDL-C 1:1 weight ratio). Open circle/square – lipolysis in the absence of HDL, filled circle/square – lipolysis in the presence of HDL; $n = 36$ (CKD), $n = 17$ (non-CKD) patients. VLDL isolated from CKD and non-CKD patients was incubated with LPL (LPL:VLDL-TG 4.8 μ g/ml:90 mg/dl, 1 hour, 37°C), in the absence and presence of HDL. After incubation the VLDL was separated by immunoprecipitation, the TG was measured and the amount of lipolyzed TG was calculated.

remnants produced in the presence of the highest amount of HDL (VLDL-C:HDL-C 1:1 weight ratio), the electrophoretic mobility was the lowest (Fig. 2B).

The effect of HDL on VLDL-TG lipolysis efficiency was modified by CKD (Fig. 3). The percentage of lipolyzed VLDL-TG in the presence of HDL was the highest for non-CKD patients, reaching, on average, 95%. For CKD patients, the lipolysis efficiency was lower than for non-CKD patients (mean 89%, $p < 0.0001$) and decreased with a decrease of eGFR (Fig. 3). In comparison to non-CKD patients and CKD patients with stage 3a, for patients with stage 4 CKD the % of lipolyzed VLDL-TG in the presence of HDL was significantly lower, on average of 9% and 6%, respectively (Fig. 3B). Moreover, for patients with stage 4, HDL did not increase significantly the % of lipolyzed VLDL-TG, as it was observed for non-CKD patients and CKD patients with stage 3a and 3b (Fig. 3B). In the absence of HDL, the lipolysis efficiency for non-CKD patients was slightly higher than for CKD patients, but there was not statistically significant difference between the groups (Fig. 3B, $p = 0.2$).

The effect of HDL presence on VLDL-TG lipolysis efficiency was not affected by statin treatment. The mean percentages of lipolyzed VLDL-TG in the absence and presence of HDL was 83.3 ± 11 and 89.1 ± 3.8 ($p < 0.05$, HDL(-) vs HDL(+)) for patients not receiving statins, and 83.4 ± 9.0 and 89.3 ± 5.4 ($p < 0.01$, HDL(-) vs HDL(+)) for patients receiving statins, respectively.

The percentage of lipolyzed VLDL-TG correlated negatively with VLDL-apoE ($r = -0.493$, $p = 0.002$), VLDL-apoCII ($r = -0.424$, $p = 0.01$), and VLDL-apoCIII ($r = -0.441$, $p = 0.007$). Positive correlations were observed for HDL-apoCII ($r = 0.362$, $p = 0.03$) and VLDL and HDL apoCII/apoCIII ratios ($r = 0.310$, $p = 0.06$, and $r = 0.426$, $p = 0.01$, respectively).

The eGFR level was associated with the changes in lipid and lipoprotein profile in CKD patients (Table 2). The concentration of serum TG and apoCIII as well as the concentration of VLDL compounds such as TG, PL, cholesterol, apoE and apoCs increased with a decrease of eGFR. Conversely, the level of HDL-C decreased, but the concentration of pre β_1 -HDL increased with a decrease of eGFR (Table 2).

Fig. 2. Impact of HDL concentration on VLDL-TG lipolysis efficiency for CKD patients. A. The impact of different amount of HDL (VLDL-C:HDL-C 1:0, 1:0.1, 1:0.25, 1:0.5, 1:0.75, 1:1 weight ratios) on the percentage [%] of lipolyzed VLDL-TG. Data are presented as mean $\pm$ SD. *vs 1:0, #vs 1:0.1, ^vs 1:0.25, $p < 0.05$; $n = 5$. B. Exemplary electropherogram of VLDL control and VLDL remnants obtained after LPL-mediated lipolysis in the absence or presence of a different amount of HDL. VLDL isolated from non-dialysis CKD patients was incubated with LPL (LPL:VLDL-TG 4.8 μ g/ml:90 mg/dl, 1 hour, 37 °C), in the absence and presence of HDL. After incubation the VLDL was separated by immunoprecipitation, the TG was measured and the amount of lipolyzed TG was calculated. The reaction mixtures were separated by agarose gel electrophoresis and stained with Sudan black B.

Fig. 3. Impact of CKD progression on VLDL-TG lipolysis efficiency. A. The correlation between the eGFR-MDRD [ml/min/1.73m²] and the percentage [%] of lipolyzed VLDL-TG, in the absence and presence of HDL. Open circle – lipolysis in the absence of HDL, filled circle – lipolysis in the presence of HDL; n=36. B. The percentage [%] of lipolyzed VLDL-TG for non-CKD (n=17) and CKD patients with stage 3a (n=11), 3b (n=15) and 4 (n=10) CKD, in the absence and presence of HDL. Data are presented as mean±SD; ***vs CKD stages 3b and 4, p<0.001, *vs CKD stage 4, p<0.05, #vs HDL (-), p<0.05. VLDL isolated from non-CKD and CKD patients was incubated with LPL (LPL:VLDL-TG 4.8 µg/ml:90 mg/dl, 1 hour, 37 °C) in the absence and presence of HDL (VLDL-C:HDL-C 1:1 weight ratio). After incubation the VLDL was separated by immunoprecipitation, the TG was measured and the amount of lipolyzed TG was calculated.

Discussion

In this study we show that the HDL presence and concentration significantly affects the VLDL lipolysis efficiency, and its positive effect is modified by the progression of CKD.

For both CKD and non-CKD patients, in the absence of HDL the percentage of lipolyzed VLDL-TG ranged from 65% to 98% and was dependent on VLDL-TG concentration. HDL presence increased the VLDL-TG lipolysis efficiency in a VLDL-TG and HDL-concentration-dependent manners, and influenced the features of the generated remnants. The remnants produced in the presence of HDL had electrophoretic mobility corresponding to LDL (β), whereas the remnants produced in the absence of HDL displayed higher mobility (between pre β and β) corresponding to IDL, which can confirm delayed VLDL catabolism in the absence of HDL.

The high VLDL-TG concentration as a main reason of impaired lipolysis has been shown by others. Von Barlingen et al. found that VLDL isolated from HTG and normolipidemic subjects had the same K_m and V_{max} for LPL-mediated lipolysis reaction, despite the significant differences in VLDL lipid and protein composition, and they concluded that the delayed VLDL catabolism in HTG could be related to excessive VLDL-TG concentration [17]. The impact of basal TG concentration on lipolysis efficiency has also been confirmed in postprandial lipemia studies where the strong positive correlation between the magnitude of triglyceridemia in postprandial state and the fasting plasma TG concentration was observed [18, 19].

Table 2. Correlation coefficients for the relationship between the eGFR-MDRD [ml/min/1.73 m²] and lipid and apolipoprotein concentrations in CKD patients (n=36). * Pearson's correlation coefficient, # Spearman's correlation coefficient

Variable	Correlation coefficient r	p value
TC in serum	-0.165*	0.34
LDL-C	-0.181*	0.29
VLDL-C	-0.387#	0.02
HDL-C	0.304*	0.07
TG in serum	-0.324*	0.05
VLDL-TG	-0.300*	0.07
HDL-TG	-0.085*	0.62
PL in serum	-0.067*	0.70
VLDL-PL	-0.310*	0.07
HDL-PL	0.282*	0.09
ApoB in serum	-0.182*	0.29
VLDL-apoB	-0.246#	0.15
ApoE in serum	0.271#	0.11
VLDL-apoE	-0.430#	0.009
HDL-apoE	0.367*	0.03
ApoCII in serum	-0.081*	0.64
VLDL-apoCII	-0.307*	0.07
HDL-apoCII	0.081*	0.64
ApoCIII in serum	-0.419*	0.01
VLDL-apoCIII	-0.323#	0.05
HDL-apoCIII	0.014*	0.9
pre- β_1 -HDL	-0.502*	0.006

Postprandial lipemia studies also confirm the observed by us the impact of HDL on VLDL lipolysis efficiency and TG serum level, since the magnitude of triglyceridemic response after fat meal intake correlated negatively with the HDL-C [18, 20].

The previous *in vitro* LPL-mediated VLDL lipolysis studies did not reveal the effect of HDL presence on lipolysis efficiency, but the beneficial effects of HDL on VLDL remnant features were shown. However, the impact of HDL on lipolysis efficiency has been observed for VLDL lipolysis mediated by other enzyme participating in the plasma VLDL lipolysis and its conversion to LDL, i.e. hepatic lipase (HL) [21, 22]. HDL directly affected the rate of HL-mediated VLDL lipolysis in an HDL concentration and composition-dependent manner. It was also shown that reconstituted HDL (rHDL) composed of apoAI and PL stimulated HL-mediated VLDL lipolysis in a PL:apoAI ratio-dependent manner [22]. In our previous study, we showed that phosphatidylcholine liposomes increased the amount of surface material released from VLDL during LPL-mediated lipolysis and enhanced VLDL-TG lipolysis efficiency [23]. It can confirm that particles rich in PL, such as HDL, rHDL or liposomes, which are able to accept the surface material released from VLDL during lipolysis, are able to enhance VLDL lipolysis efficiency.

CKD patients display disturbances in lipoproteins composition [24], which could have an impact on TG LPL-mediated lipolysis susceptibility. However, the data concerning the influence of CKD on lipolysis efficiency is scarce and inconclusive. Lee et al. showed that the (VLDL+IDL) isolated from non-dialysis and dialysis CKD patients had a lower initial rate and total extent of lipolysis in comparison to lipoproteins isolated from the control subjects [25]. Arnadottir et al. observed that VLDL isolated from hemodialysis patients had the same initial reaction velocity, but it was lipolyzed to a lesser extent compared to VLDL isolated from healthy subjects [26]. In the postprandial lipemia studies performed by Weintraub et al. the postprandial triglyceride response in normolipidemic dialysis patients were similar to those in the normolipidemic nonrenal patients, whereas for hypertiglyceridemic subjects the triglyceridemic response were exaggerated and prolonged, independently of renal impairment [27]. On the other hand, Charlesworth et al. showed, that patients with renal diseases had a greater incremental rise in postprandial TG compared to control patients [28]. Saland et al. also found that the lipemic response was impaired in CKD children and the lower eGFR the greater postprandial lipemia occurred [29].

In our study, we observed that, for non-CKD patients, VLDL lipolysis efficiency in the presence of HDL was significantly higher than in CKD patients. Moreover, lipolysis efficiency decreased with a reduction in eGFR. For the patients with CKD stage 4, the presence of HDL did not increase the percentage of lipolyzed VLDL-TG. In the absence of HDL, lipolysis efficiency for non-CKD patients was slightly higher than for CKD patients, but the difference did not attain statistical significance. Thus it can be concluded that HDL disturbances in CKD play a very important role in delayed VLDL catabolism and HTG development.

The impact of HDL disturbances on VLDL lipolysis efficiency may be due to the increased amount of HDL subpopulation known as LPL inhibitor: pre β -HDL [30] or due to changes in the interaction between VLDL and HDL caused by the modifications of their composition and properties in CKD [24]. Indeed, we observed that the lipolysis efficiency correlated negatively with apoE and apoCs content in VLDL, and positively with HDL-apoCII and VLDL and HDL apoCII/apoCIII ratios. Moreover, eGFR-MDRD correlated with the unfavourable changes in the lipid and apolipoprotein composition of VLDL and HDL. VLDL became richer in cholesterol and PL, as well as in apoE and apoCs. HDL-C was reduced, but the concentration of pre- β_1 -HDL increased with the progression of CKD. These results can confirm that CKD plays a crucial role in the VLDL catabolism, since pre- β_1 -HDL as well as apoE and apoCIII are LPL inhibitors, and the reduction of HDL means the reduction of the number of acceptors of VLDL surface material that can also impair the lipolysis efficiency [23, 30, 31]. Thus it can be assumed that CKD affects HTG development through changes in lipoproteins concentration and composition, which has an impact on reducing the susceptibility of VLDL to lipolysis and/or HDL ability to interact with VLDL.

Conclusion

Our results prove that HDL directly increases the VLDL lipolysis efficiency in a VLDL-TG and HDL-C concentration-dependent manner, and its effect is modified by the progression of CKD. It can be concluded that a decrease of concentration and impairment of HDL function combined with an increase of TRL levels in CKD patients form a 'vicious circle' that can substantially impact one another, as well as the intensification of lipid disturbances and atherosclerosis development in this group of patients.

Abbreviations

apo (apolipoprotein); CKD (chronic kidney disease); CM (chylomicron); FC (free cholesterol); FFA (free fatty acid); HDL (high density lipoprotein); HL (hepatic lipase); HTG (hypertriglyceridaemia); LDL (low density lipoprotein); LPL (lipoprotein lipase); PL (phospholipid); TC (total cholesterol); TG (triglyceride); TRL (triglyceride-rich lipoprotein); VLDL (very low density lipoprotein)

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Disclosure Statement

We declare no conflict of interest.

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