Hypercholesterolaemia in anorexia nervosa: Frequency and changes during refeeding

D. Rigaud\textsuperscript{a,b,*}, I. Tallonneau\textsuperscript{b}, B. Vergès\textsuperscript{b}

\textsuperscript{a}CESG-CNRS UMR 5170, 21000 Dijon, France
\textsuperscript{b}Service d'endocrinologie et nutrition, CHU Le Bocage, 1, boulevard Mal-de-Lattre-de-Tassigny, 21000 Dijon, France

Received 27 February 2008; received in revised form 12 August 2008; accepted 18 August 2008
Available online 19 December 2008

Abstract

High total cholesterol (TC) is common in patients with anorexia nervosa (AN), but its mechanisms remain unclear.

Patients and methods. – We prospectively studied plasma lipoprotein (LP), haptoglobin, free (f) T3, fT4, TSH, transthyretin and albumin in 120 malnourished adult AN patients (BMI: 13.5 $\pm$ 1.5 kg/m\textsuperscript{2}), 116 non-AN malnourished patients and 119 healthy subjects, matched for age and gender.

Results. – In 18\% of our AN patients, TC was higher than 270 mg/100 mL (in non-AN: 5\%; $P<0.01$). TC, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C) and HDL2 levels were higher in AN patients than in non-AN patients ($P<0.001$). Low TC (<150 mg/100 mL) and LP levels were observed in 8\% of AN patients, but only when BMI was less than 13 kg/m\textsuperscript{2}. Cholesterol ester transfer protein (CETP) activity was higher in AN patients than in healthy subjects. LP was positively correlated with BMI, albumin, fT3 and haptoglobin levels. In AN patients, there was a biphasic LP profile (low values when BMI was very low, normal values in an intermediate state, and high values when BMI was highest and where bulimia was also present).

Conclusion. – In AN, both high and low cholesterol-rich LP levels were observed. Low T3 and low catabolism allow LP to be maintained, while CETP activity increases cholesterol turnover as an adaptation to its low intake. In severely malnourished AN patients, this fails and LP drops. On the other hand, LP values were higher in the bingeing–purging type of AN than in the restrictive type. Recovery from AN results in the normalization of the LP profile.

© 2008 Elsevier Masson SAS. All rights reserved.

**Résumé**

Lipoprotéines plasmatiques et anorexie mentale : fréquence et évolution des anomalies durant la renutrition.

Une hypercholestérolémie (HCT) est décrite en cas d’anorexie mentale (AM), mais sa fréquence et les facteurs qui l’expliquent sont mal connus.

Patients et méthodes. – Nous avons étudié prospectivement les lipoprotéines plasmatiques (LP), l’haptoglobine, la fT3, la fT4 et la TSH, la transthyrétine et l’albumine chez 120 malades AM dénutris (IMC : 13.5 $\pm$ 1.5 kg/m\textsuperscript{2}), 120 malades dénutris « non-AM » et 120 témoins appariés âge et sexe.

Résultats. – Dix-huit pour cent des malades AM avaient un CT supérieur à 270 mg/100 mL (non-Am : 5 % ; $P<0.01$). CT, LDL-C, HDL-C et HDL2 étaient plus élevés chez les AM que chez les dénutris non-AM ($P<0.001$). Un CT bas (<150 mg/100 mL) et des LP effondrées furent notés chez 8 % des AM, mais seulement si l’IMC était <13 kg/m\textsuperscript{2}. L’activité CETP était plus haute dans l’AM que chez les témoins. Il y avait une corrélation positive entre les LP et l’IMC, l’albumine, la fT3 et l’haptoglobine. En cas d’AM, le profil LP était biphasique ; bas en cas d’IMC inférieur à 12 kg/m\textsuperscript{2} et normal, voire haut au-dessus de cette valeur. La forme boulimique s’associait à des LP plus hautes que la forme restrictive de l’AM.

Conclusion. – En cas d’AM, on peut observer des valeurs de CT et de LP très basses ou élevées. Cela est fonction de l’IMC. L’absence de baisse du CT et des LP en cas d’AM, par rapport aux autres dénutritions, pourrait s’expliquer par l’absence de nécessité, dans l’AM, de synthèse des protéines inflammatoires : baisse des LP et de l’albumine en cas de dénutrition... et haptoglobine élevée, non baisse des LP.
et de l’albumine dans l’AM. Il est possible que la baisse de la fT3 et la catabolisme des LP bas soit une adaptation aux apports effondrée en lipides, comme la valeur de CETP le suggère. Si la dénutrition est trop sévère (IMC < 12), le CT et les LP s’effondrent. La récupération d’un IMC normal restaure des valeurs de lipoprotéines normales, sauf en cas d’antécédent de dyslipoprotéinémie familiale.

1. Introduction

High serum total-cholesterol (TC) levels have been reported in anorexia nervosa (AN) patients since 1965 [1–4], and such high TC levels could have important clinical implications: it may lead some physicians to prescribe a low-fat diet to young girls who have AN and in those patients who do not recover by middle age, the high TC may become a risk factor for cardiovascular disease [5–7]. In our cohort of 482 patients, two patients (aged 37 and 41 years) with high TC developed a myocardial infarction. This high TC is paradoxical in AN, as malnutrition is classically associated with low TC, and every AN patient is strictly committed to a low-fat, low-cholesterol diet.

The published frequency of high TC in small groups of AN patients varies from 37 to 76% [1–4,8–17]. The largest reported groups were the 65 patients in the Klinefelter’s study [1], the 74 patients in the Favaro’s et al. study [8] and the 101 patients in the Boland’s et al. study [9]. No comparison was made with non-AN malnourished patients. Moreover, the profile of the high TC remains a subject of debate: Arden et al. [14] observed a high content of high-density lipoprotein cholesterol (HDL-C), and Mordasini et al. [15] a high content of low-density lipoprotein cholesterol (LDL-C). Smorawinska et al. found high TC, LDL-C and HDL-C in 63, 69 and 71% of their 36 AN patients, respectively [16]. For Boland et al. [9], only LDL-C was high. A few authors have reported on the evolution of TC with refeeding and show mixed results [2,3,14–18]. In 14 AN girls, Feillet et al. [17] found that TC and apoprotein (apo) B returned to normal values, while Haluzik et al. [18] observed no change. The mechanism behind these high TC and lipoprotein (LP) levels has been discussed: Misra et al. [19] found that, in their 23 AN girls, free (f) T3 predicted apoB and LDL-C. Recently, Ohwada et al. [20] found that the mean LDL-C, HDL-C, and apoA1 and B values were related to a significantly higher activity of cholesterol ester transfer protein (CETP) than in controls.

These contradictory results suggest that there might be a bimodal repartition of TC and LP in AN. The objective of this study was to clarify this point and to propose a mechanism to explain the high TC levels seen in AN patients. Thus, we prospectively studied plasma LP before, during and after refeeding in a large cohort of adult malnourished AN patients, and compared them with age- and gender-matched non-AN malnourished patients and healthy women.

2. Patients and methods

2.1. Patients

Over a five-year period, 126 AN patients admitted to the hospital nutrition department for renutrition were considered for the study. Six patients were excluded because of infectious diseases. All patients fulfilled the DSM-IV criteria for AN, and were adults (26±9 years old; 96% women) with a long disease duration (median: 7 years; range: 2–25 years) and malnutrition (BMI: 13.5±1.5 kg/m²). All women, but one, complained of amenorrhoea; 83 had the restrictive form of AN (AN-R; 69%) and 37 had the bingeing–purging form (AN-BP; 31%). One patient had a family history of hypercholesterolaemia. On recovery, 59 patients achieved a normal and stable BMI (range: 17.9–19.1 kg/m²) and normal energy intake. The non-AN patients consisted of 120 malnourished patients admitted for renutrition (age: 29.9±9.8 years; women: 95%; BMI: 22.4±1.6 kg/m²). Four were excluded because of known dyslipoproteinemia. All suffered from digestive diseases (inflammatory: 55%; small bowel malabsorption or resection: 23%; others: 22%), and all had lost at least 10% of their body weight within the last few months. They were matched for gender and age with the AN patients. The normal-weight control group comprised of 120 healthy subjects, matched for gender and age (age: 26.9±7.0 years; women: 95%; BMI: 15.8±1.8 kg/m²), who had consulted during the same time period for dietary counselling and had neither an eating disorder nor a LP disease. One was excluded for technical reasons.

2.2. Methods

The patients had blood samples drawn before refeeding, after fluid correction and then every month during refeeding for LP, determined from 20 mL of blood drawn after a 12-hour overnight fast. Agarose gel electrophoresis was performed (for chylomicrons). Total serum and very-low-density lipoprotein cholesterol (VLDL-C), LDL-C and HDL-C and triglycerides (TG) were assayed twice (Biotrol, Paris, France). VLDL was prepared by ultracentrifugation: 2 mL of serum were mixed with 1 mL solution containing 0.9% NaCl and centrifuged (3 h at 45,000 rpm); LDL in infranatant was precipitated by MgCl₂ and the supernatant was considered HDL. Reliability was checked by reference standards supplied by the French institution ARCOL [21]. Serum apoA1 and B
were determined in duplicate by double-antibody immunosorbent assay (ELISA), using monoclonal antibodies for apo A1 and a polyclonal antibody for apo B (interassay coefficient of variation: 2.8–5.6%). The HDL2 and HDL3 fractions were assayed by discontinuous-gradient gel electrophoresis as described elsewhere [22], with an interassay variation <6%. In 52 AN patients and 49 matching healthy subjects, CETP mass and activity were measured [23].

Fat mass, determined by skinfold thickness (four sites), serum albumin, thyroxin-binding prealbumin (transthyretin), transferrin, haptoglobin by laser-nephelometry, and fT3, fT4 and TSH by immunoassay.

Three-day dietary recall, where the same dietitian (V.R.) calculated nutrient intake—specifically, fat, cholesterol, and saturated and unsaturated fatty acids—using a computerized programme (Bilnut 1999, Tours, France).

3. Statistical analyses

Results are expressed as means ± standard deviations (S.D.). The patients were divided into five classes by BMI (kg/m²): >18; 16–18; 14–16; 12–14; <12. The significance of differences between groups and BMI classes was determined by a two-way analysis of variance (ANOVA), using the disease as the variate and the BMI as covariate. Percentages of patients in each LP or disease groups were compared using the chi² test. Factors associated with LP levels were tested in a multiple-regression analysis, with BMI, binges, amenorrhoea, total body fat, albumin, fT3, fT4 and TSH as independent variables. The changes with refeeding were analyzed by Student’s paired t test. Correlations between LP and nutritional variables were performed by linear-regression analysis, and detailed by ANOVA (three variables and their interactions). All analyses were performed using the MGLH module of Systat (Systat Inc., IL, USA).

4. Results

4.1. Before refeeding

4.1.1. Total cholesterol

Using ANOVA, the TC level was related to disease (AN, non-AN, healthy: F > 12; P < 0.001). Integrating the BMI into the model did not change the results. Twenty-two AN patients (18%) had TC values higher than 270 mg/100 mL versus none of the non-AN malnourished patients and only 7% of the healthy controls (Fig. 1; chi²: α = 5.4; P < 0.02). In contrast, 42 AN patients (35%) had TC levels less than 180 mg/100 mL versus only 11% of the healthy controls. For each BMI class, TC levels were higher in AN than in non-AN patients (Fig. 2; chi²: α = 6.7; P < 0.01). All AN patients with TC levels less than 150 mg/100 mL had a BMI less than 14 kg/m², whereas none of the AN patients with a BMI higher than 14 kg/m² had TC levels less than 150 mg/100 mL; TC values increased with BMI (F = 7.3; P < 0.01; Table 1). The bingeing–purging AN patients had higher TC levels than the restrictive ones (P < 0.01 with ANOVA using BMI as covariate; data not shown).
non-AN patients (P < 0.01); in AN patients with the lowest BMI (kg/m²) classes, LP levels were similar to those of non-AN patients (Table 3). High TG levels (>150 mg/mL) were found in 21 AN patients (17%) versus 1% of the healthy controls (α = 4.6; P < 0.05). Chylomicrons were found in 11 AN patients (9%) and VLDL-TG higher than 70 mg/100 mL in 10% (versus 0.8% of the healthy controls; χ²; α = 3.9; P < 0.05). The frequency of each type of dyslipoproteinaemia was: IIa, 13.3%; IIb, 6.7%; IV, 14.2%; V, 9.2%; and chylomicrons alone, 1.7%.

Lipid intakes were very low in AN patients, which was reflected in serum LP levels: total fat: 29 ± 18 g per day in AN versus 62 ± 18 and 82 ± 21 g per day in non-AN and healthy controls, respectively (P < 0.0001). Cholesterol and saturated fatty acid (FA) intakes were also very low in AN patients (138 ± 46 mg/day; 32 ± 5%), and mono- and polyunsaturated FA intakes high (31 ± 6 mg/day; 37 ± 9%), compared with non-AN patients and healthy controls (637 ± 39 mg/day and 48 ± 12% for cholesterol and saturated FA, respectively; 22 ± 7% and 28 ± 9% for mono- and polyunsaturated FA, respectively; P < 0.001 versus AN for all).

4.2. CETP, fT3, nutritional and inflammatory markers, and lipid profiles

CETP mass was similar in AN patients and in healthy subjects (2.85 ± 0.75 mg/L versus 3.18 ± 0.19 mg/L; P = 0.16), whereas CETP activity was higher in AN than in healthy controls (35.4 ± 9.5 µg/mL per hour versus 23.1 ± 5.2 µg/mL per hour; P < 0.02).

4.2.1. Nutritional markers

In the multiple-regression analysis using BMI, binges, amenorrhoea, total body fat (%), albumin, fT3, fT4 and TSH as independent variables, the variability of LDL-C and HDL-C was predicted by BMI (or total body fat), albumin and haptoglobin (except TG and VLDL-TG), were low in AN patients with a BMI <12 kg/m².

### Table 2

<table>
<thead>
<tr>
<th>Patients (n)</th>
<th>AN patients</th>
<th>Malnourished non-AN patients</th>
<th>Healthy subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cholesterol</td>
<td>190 ± 41</td>
<td>159 ± 37**</td>
<td>202 ± 25*</td>
</tr>
<tr>
<td>LDL-C</td>
<td>128 ± 22</td>
<td>104 ± 25**</td>
<td>124 ± 21</td>
</tr>
<tr>
<td>HDL-C</td>
<td>50 ± 12</td>
<td>37 ± 18*</td>
<td>56 ± 13</td>
</tr>
<tr>
<td>Total TG</td>
<td>104 ± 75</td>
<td>121 ± 57*</td>
<td>75 ± 31**</td>
</tr>
<tr>
<td>VLDL-TG</td>
<td>59 ± 58</td>
<td>83 ± 35**</td>
<td>35 ± 23*</td>
</tr>
<tr>
<td>Apo B (g/L)</td>
<td>0.87 ± 0.36</td>
<td>0.71 ± 0.09*</td>
<td>0.80 ± 0.16</td>
</tr>
<tr>
<td>Apo A1 (g/L)</td>
<td>1.47 ± 0.21</td>
<td>1.24 ± 0.17*</td>
<td>1.64 ± 0.28*</td>
</tr>
<tr>
<td>HDL2 (%)</td>
<td>59.6 ± 8.6</td>
<td>–</td>
<td>40.7 ± 10.3**</td>
</tr>
<tr>
<td>HDL3 (%)</td>
<td>40.4 ± 7.5</td>
<td>–</td>
<td>59.3 ± 10.6**</td>
</tr>
<tr>
<td>LDL-C/HDL-C</td>
<td>2.58 ± 1.33</td>
<td>3.13 ± 1.23</td>
<td>2.19 ± 1.21</td>
</tr>
</tbody>
</table>

Data are expressed as means ± S.D.; for AN and non-AN malnourished patients, the above profile was prior to refeeding; cholesterol (C) and triglyceride (TG) values are expressed as mg/100 mL; –: not done; HDL2 and HDL3 are expressed as percentages of total particle numbers.

*: P < 0.05 versus AN patients; **: P < 0.01 versus AN patients (ANOVA, then Student’s t test).
Table 3  
Nutritional markers and serum lipoprotein values for AN and non-AN patients in relation to BMI.

<table>
<thead>
<tr>
<th></th>
<th>AN patients (BMI &lt;14)</th>
<th>AN patients (BMI 14–18)</th>
<th>Malnourished non-AN patients (BMI 14–18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients (n)</td>
<td>28/120</td>
<td>92/120</td>
<td>112/116</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>11.8 ± 0.74</td>
<td>15.8 ± 0.95***</td>
<td>16.1 ± 1.1**</td>
</tr>
<tr>
<td>Albumin (g/L)</td>
<td>33.5 ± 4.8</td>
<td>43.4 ± 3.7***</td>
<td>33.5 ± 6.7***</td>
</tr>
<tr>
<td>Haptoglobin (g/L)</td>
<td>0.52 ± 0.09</td>
<td>0.72 ± 0.10*</td>
<td>1.47 ± 0.09***</td>
</tr>
<tr>
<td>fT3 (pmol/L)</td>
<td>2.8 ± 0.3</td>
<td>3.4 ± 0.4**</td>
<td>3.9 ± 0.7**</td>
</tr>
<tr>
<td>fT4 (pmol/L)</td>
<td>7.6 ± 1.9</td>
<td>10.2 ± 1.8*</td>
<td>10.9 ± 3.2*</td>
</tr>
<tr>
<td>TSH (mIU/L)</td>
<td>0.47 ± 0.52</td>
<td>1.91 ± 0.73**</td>
<td>1.33 ± 0.56</td>
</tr>
<tr>
<td>Total cholesterol (C)</td>
<td>158 ± 23</td>
<td>198 ± 29**</td>
<td>163 ± 47***</td>
</tr>
<tr>
<td>LDL-C</td>
<td>83 ± 15</td>
<td>127 ± 27***</td>
<td>105 ± 55**</td>
</tr>
<tr>
<td>HDL-C</td>
<td>39 ± 16</td>
<td>60 ± 13**</td>
<td>37 ± 18***</td>
</tr>
<tr>
<td>Total TG</td>
<td>111 ± 42</td>
<td>86 ± 37**</td>
<td>121 ± 47**</td>
</tr>
<tr>
<td>VLDL-TG</td>
<td>1.01 ± 72</td>
<td>38 ± 17**</td>
<td>83 ± 25**</td>
</tr>
<tr>
<td>Apo B (g/L)</td>
<td>0.56 ± 0.18</td>
<td>0.88 ± 0.21**</td>
<td>0.72 ± 0.13*</td>
</tr>
<tr>
<td>Apo A1 (g/L)</td>
<td>1.28 ± 0.26</td>
<td>1.59 ± 0.24**</td>
<td>1.34 ± 0.19</td>
</tr>
</tbody>
</table>

In AN patients with BMI <13 kg/m²: *: P < 0.05; **: P < 0.01 and ***: P < 0.001 versus AN patients (Student’s t test); apo B from 13–18 BMI AN subgroup was higher than that of non-AN malnourished controls (P < 0.05); normal values for fT3, fT4 and TSH are 4.0–7.5, 8.5–18 and 0.25–3.5, respectively.

4.2.2. Inflammatory markers and thyroid hormones

In AN patients (with multiple-regression analysis using haptoglobin as covariate), TC, LDL-C and apo B, HDL-C and apo A1 levels were explained by haptoglobin (P < 0.002): the lower the haptoglobin, the lower the TC. This relationship persisted even when BMI or albumin was included in the model (P < 0.01). In contrast, in non-AN patients, the correlation between haptoglobin and TC, LDL-C or HDL-C was negative (r > −0.40; P < 0.001). In AN patients, fT3 was negatively correlated with TC, LDL-C and HDL-C (r > −0.34; P < 0.01).

4.3. During refeeding

At this time, the mean TC levels remained unchanged (from 190 ± 51 to 197 ± 29 mg/100 mL at week 12), although there was a shift in both the lowest and the highest quintiles of TC to normal values. In the 22 AN patients with TC higher than 270 mg/100 mL, levels of TC, LDL-C, apo B and VLDL-C progressively decreased (P < 0.02) during the six weeks of refeeding: TC from 297 ± 32 to 187 ± 21 mg/100 mL; LDL-C from 189 ± 15 to 111 ± 11 mg/100 mL; and HDL-C from 76 ± 9 to 64 ± 7 mg/100 mL. These values all reached normal in 17 patients (77%), but only several weeks before recovery. Indeed, in these 22 patients, while LP levels decreased, energy and fat intake increased. At week 12, energy intake had increased from 865 ± 357 to 2252 ± 405 kcal per day, fat intake from 29 ± 18 to 74 ± 9 g per day, cholesterol intake from 138 ± 46 to 453 ± 59 mg per day and saturated FA from 9.3 ± 1.2 to 25.9 ± 1.4 g per day.

4.4. After recovery

In 56 (95%) of the 59 AN patients who achieved a normal BMI (>18.5 kg/m²), all LP levels were within the normal range for age and gender. However, LDL-C remained higher than 150 mg/100 mL in one patient who had a family history of high TC and in two others who had bulimia nervosa.

5. Discussion

In our AN patients, TC, LDL-C, HDL-C, apo B and apo A1 levels were all markedly higher than those observed in non-AN malnourished patients. The percentage of high TC and LDL-C values was higher in AN: 18% of our young AN women had TC higher than 270 mg/100 mL plus LDL-C higher than 150 mg/100 mL compared with 8% of our age- and gender-matched healthy controls.

Contrary to Arden et al. [14] and Mordasini et al. [15], we found high LDL-C in 75% and high HDL-C in 79% of the AN patients with high TC levels. The mean high LDL-C and HDL-C levels in our AN patients are surprising, considering their malnutrition [24,25]: lower-than-normal values would be expected in AN patients, who had lower BMIs than the non-AN patients. These higher LP levels in AN patients could be explained by a higher rate of synthesis of cholesterol-rich LP in such patients. Indeed, other levels of circulating proteins (albumin and transthyretin) were also higher in our AN than non-AN patients. In addition, in severely malnourished AN patients (BMI <14 kg/m²), the levels of LP, albumin and transthyretin were all lower. Furthermore, a positive correlation was found in both groups between TC or LDL-C and albumin or transthyretin. Nevertheless, the higher rate of synthesis in AN patients compared with non-AN patients is surprising, as the...
AN patients had very low protein, cholesterol and saturated FA intakes.

The low catabolism of cholesterol-rich LP could theoretically explain the absence of low levels in 92% of our AN patients. Such a low catabolism was also described in hypothyroidism [26]. One argument for a relative hypocatabolism in AN patients is that, when high, LP levels decrease with refeeding while protein catabolism increases. Also, we observed lower haptoglobin levels (an acute-phase inflammatory protein) in AN patients versus non-AN patients, which suggests lower catabolism related to the absence of an inflammatory process. In non-AN patients with an inflammatory process, the higher their haptoglobin levels, the lower their TC, LDL-C and HDL-C levels. Others [25,27,28] have also described such a relationship. Moreover, an infectious disease developed in five AN patients (data not shown): in four, TC, LDL-C and HDL-C decreased within two weeks. Thus, it may be concluded that, in AN patients, malnutrition, and low nitrogen and low amino-acid intakes lead to lowered protein synthesis which, in turn, is responsible for a decrease in protein catabolism. This ‘near-to-zero balance’ between low synthesis and the subsequent low catabolism allows normal serum levels of albumin, transthyretin and LP to be maintained [25,28]. A possible mechanism for these unexpectedly normal LP levels in AN could be hypothyroidism [12,16,26]. In the present study, high TC and LDL-C levels were associated with high HDL-C, as seen in hypothyroidism [14,26].

In our cohort, we also observed inhibition of TG-rich LP catabolism in the 20% of AN patients with high TC levels: in these cases, high TC was associated with high VLDL-C and VLDL-TG levels, and all LP levels reverted to normal with refeeding. This suggests a transfer of cholesterol from VLDL to LDL by CETP, which is known to increase cholesterol turnover and, thus, TC and LDL-C levels. The reason for this could be to scavenge cholesterol from dead cells. The increase in CETP activity in the face of the low fat and cholesterol intakes in AN patients might also allow the increased transfer of cholesterol esters, thereby saving endogenous cholesterol [15,17].

One piece of unexplained data from the present study was the higher TC and LDL-C levels in the binging–purging AN patients compared with the restrictive ones. Although high TC levels have been described in bulimia nervosa by Monteleone et al. [29], Weinbrenner et al. made no such observation [10]. Could these mixed results be related to differences in alimentary intakes. Another explanation is that the liver is relatively deficient in the activity of albumin, transthyretin and LP to be maintained [25,28]. A possible mechanism for these unexpectedly normal LP levels in AN could be hypothyroidism [12,16,26]. In the present study, high TC and LDL-C levels were associated with high HDL-C, as seen in hypothyroidism [14,26].

In conclusion, in malnourished AN patients, the distributions of TC, LDL-C and HDL-C are bimodal, with greater percentages of patients in both the lowest and highest classes of LP levels. The curve is different from that observed in non-AN malnourished patients (a gaussian curve with a shift toward lower values) and in the healthy population (another gaussian curve). High LP levels were noted in one-sixth of our AN patients, and low LP levels in one-tenth. A lower rate of catabolism of cholesterol-rich LP could explain both the normal and high levels of TC and LDL-C. This could also be related to the decreased thyroxin activity and increased cholesterol turnover due to the increased CETP activity. In addition, it is possible that cholesterol released from cells is incorporated during the turnover cycles by CETP to maintain cholesterol in the body when cholesterol from food is lacking. However, when malnutrition is too severe and too long-lasting, the above adaptive changes cannot be maintained, and so LP synthesis drops [27]. Future studies using stable isotopes for determination of apo B synthesis and catabolism as well as cholesterol synthesis will confirm (or not) these hypotheses.

Conflicts of Interest

Authors declare no conflict of interest in this subject.

References


