Effects of vitamin E-coated membrane dialyser on markers of oxidative stress and inflammation in patients on chronic haemodialysis

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Abstract

Background. In the present prospective, controlled, observational cohort study, we investigated the effects of the use of a vitamin E-coated membrane dialyser (VEM) on markers of chronic inflammation, oxidative stress and endothelial cell apoptosis in end-stage renal disease (ESRD) patients on chronic haemodialysis (HD), as long as evidence of their effects on these pathogenetic routes are inconclusive as yet, despite their use for the last several years.

Methods. Thirty-five stable ESRD patients underwent HD with the use of VEM for 6 months. Another 25 age- and sex-matched ESRD patients, being dialysed with conventional dialysers, served as controls. In both patient groups, beyond complete haematology and biochemistry work-up, serum CRP, apolipoproteins A1 and B, lipoprotein (a) (Lp(a)), hsIL-6, MCP-1, sICAM-1, sVCAM-1, sE-selectin, sFas and sFasL, as well as plasma oxLDL, TBARS and TAS levels were determined at baseline and at 6 months of the study.

Results. In the VEM group at 6 months, a significant reduction in CRP (P = 0.004), IL-6 (P = 0.004) and sICAM-1 (P = 0.04) levels was observed compared with baseline, along with a remarkable change in all markers of oxidative stress, i.e. increase in TAS (P = 0.005) and decrease in TBARS (P = 0.04) and oxLDL (P < 0.001). No significant changes were noted in the other parameters studied in the VEM group or in any parameter studied in the controls. Between the groups, significant differences were found in the change of CRP (P = 0.001), sICAM-1 (P = 0.03) and oxLDL (P = 0.04) compared with baseline.

Conclusions. HD with the use of VEM resulted in a significant reduction in inflammation and oxidative stress markers. Larger prospective randomized studies will need to confirm the findings of the present observational study.

Keywords: haemodialysis; inflammation; oxidative stress; vitamin E dialysers

Introduction

Oxidative stress is the common denominator of some common haemodialysis (HD) side effects such as anaemia, immunologic dysfunction, coagulopathy, accelerated atherosclerosis and ageing, secondary amyloidosis and carcinogenesis. Inadequate dialyser biocompatibility is considered to be the most important cause of the yet unresolved problem of oxygen-free radical production during HD. The use of vitamin E-coated membrane dialysers (VEM) has been proposed in recent years for the amelioration of oxidative stress, a strategy based on the fact that vitamin E acts as a powerful hydrophilic scavenger which provides protection of plasma lipids and cell membranes against peroxidation [1]. So far, small-scale studies have suggested that biocompatible VEM can exert a site-specific and timely scavenging effect against oxygen-free radicals as well as a suppression of the polymorphonuclear respiratory burst [2–7]. We conducted the present observational cohort study to assess the effect of a 6-month use of VEM on sensitive markers of oxidative stress, namely oxidized low-density lipoproteins (oxLDL), total antioxidant status (TAS) and malondialdehyde (MDA) concentrations, determined by measuring thiobarbituric acid reactive substances (TBARS). We studied in parallel the effects of the use of VEM on markers of inflammation and endothelial cell apoptosis in patients on HD. The hypothesis was that the 6-month use of VEM would have significant anti-inflammatory and anti-oxidative effects in patients on HD.

Materials and methods

Patients

In the present single centre, prospective, controlled, observational cohort study, 62 end-stage renal disease (ESRD) Caucasian patients were enrolled. All patients were stabilized on standard chronic HD therapy for at least 6 months (mean duration: 43±34 months). Primary renal disease was glomerulonephritis in 21 patients (38%), diabetes mellitus in 10 patients (18%), tubulointerstitial nephritis in 8 patients (14%), adult dominant polycystic kidney disease in 4 patients (7%), vascular renal disease in 4 patients...
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(7%) and unknown in 8 patients (14%). Twenty-two patients (40%) were active smokers, a state defined as the regular use of smoke products over the last 5 years. Criteria for patient inclusion in the study were age 18–85 years, chronic maintenance HD for at least 6 months and clinically stable health condition. Exclusion criteria were use of anti-oxidants or hypolipidaemic drugs, non-steroid anti-inflammatory drugs or corticosteroids prescribed during the last 3 months, malignancy, cachexia, liver disease, alcohol abuse, hypothyroidism, active inflammation, considerable iron overload and rheumatological disorders. Thirty-seven patients were enrolled in the VEM group and 25 age- and sex-matched patients in the control group. Of them, two patients died and, eventually, 35 patients in the VEM group and all of the controls completed the study. From the VEM group, for the previous 3 months minimum, 17 (48%) patients were dialysed with a cellulose, 8 (23%) patients with a haemophane and 10 (29%) patients with a polysulfone 1.2 to 1.5 m² hollow fibre dialyser. HD using a vitamin E-coated regenerated cellulose 1.2 to 1.5 m² hollow fibre dialyser (exclusively low- or medium-flux), Clirans® E (CL-E; Terumo ≥lant. Dialysis prescription was guided by a goal of achieving a value of a central supply system and low molecular weight heparin as anticoagulant. Mean pre-dialysis BP was calculated as diastolic BP + [(systolic BP obtained during the month preceding the study. The mean value for BP was calculated as the average value of all recordings (13 measurements per month) plotted from clotted blood by immediate centrifugation (1500 ×g for 10 min), Aliquots and stored immediately at -70°C until assayed.

Blood sampling

Blood samples were taken from a peripheral vein under fasting conditions, immediately before the morning of a midweek routine dialysis day, at baseline and after 6 months in both groups. Moreover, in the VEM group, an intermediate sample was taken at 3 months, to enable us to study the time sequence of the potential changes. Serum and plasma samples were separated from clotted blood by immediate centrifugation (1500 g for 10 min), aliquoted and stored immediately at -70°C until assayed.

Laboratory methods

Biochemistry. Serum albumin, urate, total cholesterol, triglycerides and HDL cholesterol were determined by routine techniques and serum apolipoproteins A1 (ApoA1), B (ApoB) and lipoprotein (a) (Lp(a)) by immunoturbidimetric method, with the use of an automated analyser (Olympus AU560, Hamburg, Germany). Normal range for ApoA1 was 105–175 (males) and 105–205 mg/dL (females), for ApoB 60–140 (males) and 60–130 mg/dL (females), and for Lp(a) 0–30 mg/dL (both sexes). LDL cholesterol was calculated with the use of the Friedewald formula [LDL = TC-triglycerides / 5-HDL].

Soluble markers of inflammation, oxidative stress and endothelial cell apoptosis. Serum CRP levels were measured by nephelometry (normal values ≤ 5 mg/L). Serum levels of high-sensitivity interleukin-6 (IL-6), monocyte chemotactant protein-1 (MCP-1), soluble cellular adhesion molecule-1 (sICAM-1), soluble vascular cell adhesion molecule-1 (sVCAM-1), soluble E-selectin (sE-selectin), soluble Fas (sFas), soluble Fas ligand (sFasL) and plasma levels of oxidized LDL (oxLDL) were determined by enzyme-linked immunosorbent assay (ELISA), with the use of commercially available standard kits (Quantikine human hIL-6, MCP-1, sICAM-1, sVCAM-1, sE-selectin, sFas, sFasL; Research & Diagnostic Systems Europe Ltd, Abingdon, UK; and Medcia, Upsala, Sweden). Sera were diluted 1/3, 1/2, 1/3, 1/30, 1/20, 1/10 and 1/1 for the quantitation of MCP-1, hIL-6, sICAM-1, sVCAM-1, sE-selectin, sFas, sFasL. Measurements of the concentrations were done with the use of spectrophotometer Universal Microplate Reader EL800 (Bio-Tek Instruments Inc., VT, USA), at absorption wave length 490 nm for hIL-6 and 450 nm for all other molecules measured, with correction at 540 nm. The concentrations of these molecules were calculated by reference to standard curves performed with the corresponding recombinant molecule. TAS in serum samples was measured with the use of Ramod assay. MDA concentrations in serum samples were determined by measuring TBARS with the use of a commercially available TBARS assay kit (Cayman Chemical Company, Ann Arbor, MI, USA). All samples were tested in duplicate. The sensitivity of the ELISA system for MCP-1, hIL-6, sICAM-1, sVCAM-1, sE-selectin, sFas and sFasL was 0.039 pg/mL, 5.0 pg/mL, 1 ng/mL, 2 ng/mL, 0.1 ng/mL, 20 pg/mL and 2.66 pg/mL, respectively. OxlDL was measured in U/L and method sensitivity was < 1 u/mL.

Statistical analysis

Results are expressed as mean ± standard deviation (SD) or median and range, depending on the normality of the distributions of each parameter. Sample size was defined for an arbitrarily anticipated difference in parameters change of 30% between the two groups, which could be considered a clinically significant effect of a 6-month VEM use. The SD was assumed to be twice the difference (0.6). Therefore, it was estimated that the study required 25 subjects minimum per group for alpha to equal 0.05 (one-tailed test) and a power (1-β) of 0.80. We finally managed to recruit 62 subjects in the study (VEM:controls ratio = 3:2). Student’s t-test and Mann–Whitney test were used for the evaluation of the differences between patient groups for parametric and non-parametric parameters, respectively. Differences in proportions were tested with the use of χ² statistic and the single-tail Fisher test. Repeated measures ANOVA analysis was used for the evaluation of the change from baseline in the VEM. The between groups difference in the change in the parameters during the study was evaluated with the use of Student’s t-test. Statistical analysis was performed with the use of SPSS v. 18.0 statistical software (SPSS Inc., Chicago, IL, USA).

Results

Baseline epidemiological, clinical and laboratory parameters of both study groups are shown in Tables 1 and 2. Patients in the VEM group had slightly higher BMI, bigger percentage of smokers and smaller percentage of history of cardiovascular disease compared with the controls. No other significant differences in the anthropometric parameters were observed between the VEM group and the controls. During the use of VEM, all patients tolerated treatment well and no meaningful adverse effects were documented that could have justified termination of therapy. During the study, three patients were hospitalized: two patients from the VEM group (one for pneumonia and one for transient ischaemic cerebral attack) and one patient from the controls (for acute cholecystitis). However, all hospitalizations were far from the times of blood sampling and the events did not justify the exclusion of the patients from the study.

HD with the use of VEM resulted in a significant decrease in CRP (P = 0.02) and IL-6 (P = 0.02) at 3 months compared with baseline. At 6 months of the study, the use
of VEM resulted in a significant reduction in CRP (P = 0.004), IL-6 (P = 0.004) and sICAM-1 (P = 0.04) levels compared with baseline. At this point in time, a remarkable change in all markers of oxidative stress was noted, i.e. increase in TAS (P = 0.005) and decrease in TBARS (P = 0.04) and oxLDL (P < 0.001) (Table 3). On the contrary, no significant changes were found in the controls (Table 4). The analysis of the between groups differences in the change in the parameters during the 6-month study revealed significant differences in the change of CRP (P = 0.001), sICAM-1 (P = 0.03) and oxLDL (P = 0.04) between the groups (Table 5). In the VEM group, there was a 388% higher mean decline rate of CRP, a 744% higher mean decline rate of sICAM-1 and a 500% higher mean decline rate of oxLDL compared with the controls. The respective differences in the change of TAS and IL-6 barely failed to reach statistical significance (P = 0.06 and P = 0.07, respectively); however, a clinical significance of these tendencies cannot be ruled out. On the contrary, no significant changes were noted in lipids, Lp(a), uric acid, apolipoproteins, MCP-1, sICAM-1, E-selectin or the markers of apoptosis during the study. The wide confidence intervals found in most variables apparently reflect the rather small sample size of each group.

**Discussion**

The present study is, to the best of our knowledge, the largest study investigating the anti-oxidative and anti-inflammatory effects of VEM with regard to the number of enrolled patients to date, and yields important results with potentially significant clinical implications. Patients in the VEM group had slightly higher BMIs, a bigger percentage of smokers and a smaller percentage of patients with a history of cardiovascular disease compared with the controls, a finding attributed to the rather small number of patients included in each group. Most importantly, however, we consider clinically the fact that both groups had comparable baseline levels of inflammatory and oxidative markers, a finding which we believe diminishes the possibility that the groups had clinically meaningful differences.

**Controls**

In the control group, no spontaneous changes in the parameters studied were noticed during the 6-month follow-up period. This finding signifies that these molecules remain at steadily high levels in stabilized ESRD patients, with no significant fluctuations during any periods of time over the 6-month order. The analysis of the between groups differences in the change in the parameters during the 6-month study revealed the changes caused genuinely by the use of VEM and disclosed any confounding spontaneous effects.

**Anti-inflammatory effects**

In the present study, the levels of IL-6 as well as CRP dropped significantly from as early as the third month of treatment with the use of VEM. At the 6th month of the treatment, this effect appeared to be stabilized, with no further reductions in their levels. Furthermore, an apparent decrease in sICAM-1 levels was found during the first 3 months, which reached levels of statistical significance at 6 months of the treatment. In addition, the analysis between the groups revealed that the 6-month decrease in CRP and sICAM-1 levels was significantly higher in the VEM group compared with the controls. MCP-1, E-selectin and sVCAM-1 levels remained unaltered in both groups.
\[ \begin{array}{l}
\text{Parameter} & \text{Baseline} & \text{At 3 months} & \text{At 6 months} \\
\text{Total cholesterol, mg/dL} & 179 \pm 38 & 186 \pm 34 & 198 \pm 42 \\
\text{HDL cholesterol, mg/dL} & 38 \pm 9 & 38 \pm 5 & 41 \pm 6* \\
\text{LDL cholesterol, mg/dL} & 117 \pm 35 & 120 \pm 37 & 124 \pm 35 \\
\text{Triglycerides, mg/dL} & 171 \pm 86 & 170 \pm 69 & 171 \pm 69 \\
\text{ApoA1, g/L} & 129 \pm 22 & 132 \pm 25 & 133 \pm 25 \\
\text{ApoB, g/L} & 121 \pm 43 & 126 \pm 43 & 126 \pm 43 \\
\text{Plg(a), μmol/L} & 1.0 \pm 0.6 & 0.98 \pm 0.4 & 0.97 \pm 0.4 \\
\text{Albumin, g/L} & 12.5 \pm 13.8 & 14.1 \pm 14.3 & 14.2 \pm 14.3 \\
\text{Urate, mg/dL} & 1.63 \pm 0.1 & 1.69 \pm 0.1 & 1.74 \pm 0.2* \\
\text{White blood cell, × 10^9/L} & 6822 \pm 1583 & 6676 \pm 1630 & 7209 \pm 2041 \\
\text{CRP, mg/L} & 4.2 (3.5–18.3) & 3.2 (3.2–10.0)* & 3.0 (3.0–12.4)* \\
\text{hsIL-6, pg/mL} & 6.2 \pm 4.8 & 3.7 \pm 3.6* & 3.2 \pm 2.8* \\
\text{sICAM-1, ng/mL} & 2792 \pm 1605 & 2305 \pm 404 & 2107 \pm 404 \\
\text{E-selectin, ng/mL} & 90 \pm 32 & 80 \pm 33 & 79 \pm 34 \\
\text{sVCAM-1, ng/mL} & 483 \pm 96 & 487 \pm 121 & 486 \pm 99 \\
\text{oxLDL, U/L} & 45 \pm 13 & 40 \pm 9 & 6.0 \pm 0.7 \\
\text{TBARS, nmol/L} & 13.3 \pm 2.8 & 13.0 \pm 2.8 & 11.2 \pm 2.7* \\
\text{TAS, mmol/L} & 1.66 \pm 0.1 & 1.64 \pm 0.1 & 1.74 \pm 0.2* \\
\text{Fas, mg/L} & 97 \pm 25 & 106 \pm 25 & 96 \pm 29 \\
\end{array} \]

Results are expressed as mean ± SD or median and range, as appropriate.

From the existing literature, it seems that the effects of vitamin E on the markers of inflammation depend, among others, on the form and the route of treatment [8]. Although several groups have shown that α-tocopherol supplementation in humans has various anti-inflammatory effects both in vivo and in vitro, such as a decrease in CRP, plasminogen activator inhibitor-1, inflammatory cytokines, etc., the existing data regarding the effects of VEM on markers of inflammation in HD patients are rather limited and inconclusive and refer mainly in the production of inflammatory cytokines by peripheral blood cells [9–11]. It is interesting that Takouli et al. in their recent study [12] on the effects of VEM on inflammation and oxidative stress in nine patients have found significant anti-oxidative and anti-inflammatory effects. The present larger study confirms these earlier results and, to the best of our knowledge, this is the first report in the literature of the long-term effects of VEM on certain inflammatory markers, such as soluble adhesion molecules in HD patients. The effects of VEM are exerted through in situ action of the membrane-bound vitamin E on blood cells and not through the release of vitamin E molecules in the systemic circulation. Therefore, the results found in the present study apparently take place through the better bio-compatibility of VEM, which leads to the amelioration of the stimulation of circulating leukocyte and, hence, prevents these cells from producing inflammatory cytokines and further activating endothelial cells. It is interesting that what was found to decrease principally in our study was IL-6 and sICAM-1, both of which are molecules produced by endothelium as much as by circulating leukocytes. sVCAM-1 on the other hand, a molecule which is known to be produced exclusively by endothelial cells, remained unaffected by the use of VEM, indicating that there is no direct effect of VEM on endothelial cells. In this context, the predominant effect of VEM seems to be the decrease in IL-6 induced production of CRP by the liver rather than the direct result of VEM on endothelial cells, although it would be sensible to assume a probable secondary beneficial effect of VEM on the endothelium in the long-term as a result of their anti-inflammatory action.
ApoB, g/L 5 ± 37

Triglycerides, mg/dL 10 ± 33

LDL cholesterol, mg/dL 10 ± 21

Apo B/A1 0.9 ± 0.3

HDL cholesterol, mg/dL 5 ± 10

Albumin, g/L 0.1 ± 0.4

CRP, mg/L 0.9 ± 3.5

hsIL-6, pg/mL 3.3 ± 4.1

sICAM-1, ng/mL 67 ± 4.6

sVCAM-1, ng/mL 58 ± 3.4

E-selectin, ng/mL 3 ± 1.3

MCP-1, ng/mL 19 ± 5

oxLDL, U/L 12 ± 1.0

TAS, mmol/L 0.26 ± 0.07

Fas, pg/mL 12 ± 10

FasL, pg/mL 21 ± 10

Table 5. Comparison of 6-month changes in the parameters studied between VEM group and controls

Parameter Controls VEM Δ Comparison 95% CI P-value

Total cholesterol, mg/dL 4 ± 6 21 ± 38 17 −13 to 47 0.27

HDL cholesterol, mg/dL 4 ± 6 5 ± 4 1 −2 to 5 0.26

LDL cholesterol, mg/dL 2 ± 52 10 ± 29 8 −19 to 36 0.54

Triglycerides, mg/dL −1 ± 81 20 ± 86 21 −33 to 74 0.44

ApoA1, g/L 3 ± 31 6 ± 24 3 −14 to 20 0.75

ApoB, g/L 5 ± 37 −2 ± 32 −7 −29 to 14 0.50

Apo B/A1 −0.04 ± 0.5 −0.03 ± 0.3 −0.07 −0.23 to 0.24 0.95

Lp(a), μmol/L 1.6 ± 3.4 0.3 ± 3.5 −1.3 −3.5 to 0.9 0.24

Albumin, g/L 0.1 ± 0.4 0.1 ± 0.5 0 −35 to 13 0.17

Urate, mg/dL −0.3 ± 0.8 0.04 ± 1.0 −0.26 −0.2 to 1.0 0.24

White blood count, × 10⁶/L 400 ± 1300 −30 ± 1300 −430 −1300 to 390 0.29

CRP, mg/L 0.9 ± 3.5 −2.6 ± 3.2 −3.5 −5.4 to −1.6 0.001

hsIL-6, pg/mL −0.7 ± 3.4 −2.6 ± 4.6 −3.3 −4.1 to 0.3 0.07

sICAM-1, ng/mL 9 ± 132 −58 ± 73 −67 −129 to −5 0.03

sVCAM-1, ng/mL 85 ± 382 −166 ± 1626 −251 −864 to 362 0.41

E-selectin, ng/mL −2 ± 48 −12 ± 34 −10 −31 to 12 0.38

MCP-1, ng/mL −6 ± 38 3 ± 58 9 −30 to 49 0.63

oxLDL, U/L −2 ± 19 −12 ± 10 −10 −19 to −1 0.04

TAS, mmol/L −0.01 ± 0.1 0.1 ± 0.2 0.11 −0.01 to 0.2 0.06

TBARS, nmol/L −0.7 ± 1.9 −1.3 ± 2.9 −0.6 −2.5 to 1.3 0.53

Fas, pg/mL −236 ± 41 129 −1171 ± 6146 −935 −4271 to 2400 0.57

FasL, pg/mL 10 ± 25 4 ± 27 −6 −21 to 10 0.46

Results are expressed as mean ± SD. Comparison of mean differences (with 95% confidence intervals of the difference) for each variable was estimated using Student’s t-test: positive numbers for TAS and negative numbers for all other variables favour VEM.

Anti-oxidative effects

In the present study, a significant decrease in oxLDL and TBARS as well as a significant increase in TAS was found at 6 months compared with their baseline levels. In addition, the analysis between the groups revealed that the 6-month decrease in oxLDL levels was significantly higher in the VEM group compared with the controls. Our findings are in line with the findings from earlier studies showing the anti-oxidative effects of VEM [2,4,7,12], with or without a concomitant increase in plasma vitamin E levels. The anti-oxidative effects of VEM are exerted locally through the action of the vitamin E molecules on circulating leukocytes and the systemic release of vitamin E seems to take place [13]. This in situ scavenging of free oxygen radicals by vitamin E coating might lead secondarily to an excess of vitamin E in the systemic circulation and, hence, to an increase in its plasma levels which has been reported in several studies.

Anti-apoptotic effects

Several in vitro and ex vivo studies have shown that vitamin E suppresses endothelial cell apoptosis, either through the decrease of oxLDL [14–16] or through direct inhibition of the action of caspase-3 [17]. However, there is no conclusive clinical evidence as yet regarding the effects of vitamin E supplementation or VEM on markers of endothelial cell apoptosis. It is interesting that, in the present study, the 6-month use of VEM did not seem to affect significantly the levels of endothelial cell apoptosis markers sFas and sFasL. The above findings taken together with the rest of the findings of our study reflect a rather in situ effect of VEM on circulating leukocytes rather than a systemic effect on endothelium, although a secondary long-term beneficial effect on endothelial cells, as a result of the anti-inflammatory and anti-oxidative effects of VEM, would not be surprising.

Limitations and clinical implications of the study

This prospective study has some inherent limitations. First of all, the present study, being an observational one, is prone to patient selection bias. Moreover, the rather small sample groups renders the study rather underpowered. Hence, the results should be interpreted with caution, until future larger randomized studies and meta-analyses confirm these findings in the ESRD population and reach more definite conclusions regarding the effects of VEM. However, the parallel study of the effects of VEM on different aspects of the atherogenetic procedure strengthen the credibility of the results. As long as inflammation and oxidative stress are pathways known to contribute to the atherogenetic process from the early stages of chronic kidney disease, the observed anti-inflammatory and anti-oxidative effects of VEM provide evidence of potential cardiovascular prevention by VEM in HD patients. It is a fact that over the last years, there has been an unexpected discrepancy between the anticipated cardiovascular benefits from the dietary supplementation with α-tocopherol and the results of major prospective primary and secondary prevention clinical trials. Hence, large-scale studies [18–22] failed to show any beneficial effects of vitamin E supplementation in the general population. Similar studies in ESRD patients have yielded conflicting and inconclusive results.
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[23,24]. Surprisingly, however, in most of the intervention studies, no measurement was made of oxidative stress and, thus, it was impossible to conclude whether these interventions actually modified oxidative stress in the patients. Furthermore, the form and the route of treatment seem to be of major importance, and a better understanding of the dosing, duration and timing of therapy as well as the mechanisms of action of vitamin E itself is a sine qua non for the comprehensive and rationalized study of the actual cardiovascular benefits from the dietary α-tocopherol supplementation. In addition, it is rather paradoxical that chronic inflammation has been studied vaguely, if at all, in all the major intervention studies, although it is now known to play a pivotal role in the atherogenetic process, in interplay with oxidative stress, and α-tocopherol has been shown to exert anti-inflammatory effects in in vitro and in vivo studies. As long as there is solid evidence that chronic inflammation is a pivotal player in the atherogenetic process in interplay with oxidative stress, the benefits from the treatment could be observed in special patient populations, such as diabetics or ESRD patients, i.e. patients with high degrees of both oxidative stress and chronic inflammation. Furthermore, the beneficial effects of VEM on inflammation and oxidative stress in these patients are also evident by the improvement in haemoglobin levels and the lower erythropoietin requirements associated with these HD membranes that were found recently [25]. These concerns have not been taken into account in any of the major studies of α-tocopherol benefits up to now and may be a crucial obstacle for the documentation of the real cardiovascular benefits which vitamin E probably confers in particular patients.

Conclusions

In ESRD patients on chronic HD, the 6-month use of VEM resulted in a significant decrease in the levels of IL-6, CRP, sICAM-1, oxLDL and TBARS as well as a significant increase in TAS. During the study period, no significant effects on endothelial cell apoptosis were found. These results might signify potential beneficial effects from the long-term use of VEM.

Conflict of interest statement. None declared.

References


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