Use of EPA and DHA in Secondary Prevention of Neurological Events, Particularly Strokes

The present invention relates to the use of the n-3 PUFA eicosapentaenoic acid (EPA) and/or docosahexaenoic acid (DHA) in the prevention of secondary neurological events, particularly strokes, in patients with symptoms of atherosclerosis of arteries supplying the brain.

There is a substantial epidemiological evidence that consumption of fish or of long-chain n-3 polyunsaturated fatty acids (PUFA), especially EPA and DHA, found in oily fish and fish oils, protects against cardiovascular disease in Western populations. Long chain n-3 PUFA lower fasting plasma triacylglycerol (TAG) concentrations and reduce the post-prandial lipaemic response. Dietary fish oil has been demonstrated to decrease atherosclerosis in animal models, which might be due to lipid lowering, decreased growth factor production, decreased inflammation, or a combination of these effects. Secondary prevention studies, providing long chain n-3 PUFA to patients who had already suffered a myocardial infarction (MI), demonstrate significant benefit, as described and claimed in EP-B- 1 152 755. N-3 PUFA are especially potent in reducing sudden death, (EP-B- 1 152 755), an effect that occurs in the absence of significant lipid lowering. It has been surmised that this effect might be due to anti-thrombotic and anti-arrhythmic actions of n-3 PUFA. In contrast, we have thought it possible that n-3 PUFA might contribute to the stabilisation of atherosclerotic plaques through their anti-inflammatory actions. Conversely, there are indications that n-6 PUFA linoleic acid, which is found in vegetable oil such as sunflower oil, can promote inflammation, in which case an increased intake of linoleic acid might contribute to plaque instability.

To our knowledge there are no studies reporting effects of n-6 or n-3 PUFA on plaque stability. Rapp *et al* (Arterioscler.Thromb. 1991, II, 903-911) carried out a study in which patients destined to undergo endarterectomy consumed very high doses of fish oil (48-64g/day) for a period prior to surgery and they found that the levels of the n-3 PUFA, eicosapentaenoic acid (EPA; 20:5n-3) and docosahexaenoic acid (DHA;22:6n-3) in the

plaques removed at surgery were significantly higher than in plaques removed from control patients. However, Rapp *et al* provided no structural details of the plaques.

We have now found, in accordance with the present invention, that the administration of relatively modest doses of fish oil to patients with symptoms of atherosclerosis of arteries supplying the brain not only results in incorporation of EPA and DHA into low density lipoprotein (LDL) and atherosclerotic plaque lipids but, significantly, also leads to improved atherosclerotic plaque stability.

More particularly, we have discovered that such patients who are given fish oil orally tend to have more plaques with a well-formed fibrous cap, rather than a thin inflamed cap, and further the plaques are less heavily infiltrated with macrophages. As is well known the characteristics of an atherosclerotic plaque that make it vulnerable to rapture include a thin fibrous cap and increased numbers of inflammatory cells such as macrophages The presence of macrophages in carotid plaques is also known to be associated with an increased incidence of neurological events i.e. strokes and transient ischaemic attacks. Consequently, the oral administration of fish oil provides an effective, and safe, method for helping to prevent neurological events, particularly strokes, in patients with symptoms of atherosclerosis of arteries supplying the brain.

Thus, the present invention is directed to the use of EPA and/or DHA in the preparation of an oral medicament for preventing cerebral damage in patients having symptoms of atherosclerosis of arteries supplying the brain.

In a first aspect the invention provides the use of eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), or a mixture of EPA and DHA, or of a pharmaceutically acceptable salt or derivative thereof, in the preparation of an oral medicament for preventing cerebral damage in patients having symptoms of atherosclerosis of arteries supplying the brain, wherein the dosage will range from 0.5 to 5.0 g of EPA and/or DHA daily.

In a second aspect the invention provides the use of eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), or a mixture of EPA and DHA, or of a pharmaceutically

acceptable salt or derivative thereof, for the preparation of an oral medicament for preventing a stroke in a patient with a symptom of cerebrovascular accident, amaurosis fugax and/or transient ischaemic attack, wherein the dosage will range from 0.5 to 5.0 g of EPA and/or DHA daily.

In a third aspect the invention provides the use of a mixture of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), or of a pharmaceutically acceptable salt or derivative thereof, for the preparation of an oral medicament for preventing a stroke in a patient with a symptom of transient ischaemic attack and/or amaurosis fugax, wherein the dosage will range from 0.5 to 5.0 g of EPA and DHA daily

We will now describe in detail the experimental study which has led to the present invention.

Patients and Methods

Study design

Patients destined to undergo carotid endarterectomy ie exhibiting symptoms of advanced atherosclerosis of arteries supplying the brain, and who agreed to participate were randomised, in

a double-blind manner, to receive one of three types of oil provided in capsules. The control oil was an 80:20 blend of palm and soybean oils; the fatty acid composition of this blend closely matches that of the average adult UK diet. The other oils were sunflower oil and an EPA/DHA-containing fish oil. The fatty acid composition of the oils is shown in Table 1. Each capsule contained 1 g of oil and 1 mg α-tocopherol. Patients consumed 6 capsules/day until surgery; patients were recommended to consume two capsules with a meal three times each day. Thus, the amount of long chain n-3 PUFA provided was 1.4 g/day. The amount of linoleic acid provided was 3.6 g/day, which represented a 40% increase in intake of this fatty acid.

Table 1. **Fatty acid composition of the capsules used in study**

	Fatty acid (g/100 g total fatty acids)		
Fatty acid	Control	Sunflower oil	Fish oil
Lauric (12:0)	0.9	-	-
Myristic (14:0)	2.1	1.5	6.2
Palmitic (16:0)	34.9	8.6	20.4
Palmitoleic (16:1n-7)	2.0	1.0	12.3
Stearic (18:0)	3.7	3.5	5.7
Oleic (18:1n-9)	33.8	18.6	10.1
Linoleic (18:2n-6)	18.9	62.8	2.3
α-Linolenic (18:3n-3)	1.8	1.4	4.6
Arachidonic (20:4n-6)	-	1.2	1.1
EPA (20:5n-3)	-	-	14.3
Docosapentaenoic (22:5n-3)	-	-	1.5

Sample size was calculated based on the fatty acid composition of plaque phospholipids (PL) described by Rapp et al., (Arteriscler. Thromb. 1991 11, 903-11) taking into account the 10- to 15-fold lower dose of EPA + DHA employed in the present study. On this basis it was calculated that a sample size of 50 would be required to detect a 1-fold increase in EPA in plaque PL at $P < 0.05$. To allow for a drop-out rate of 20%, 188 patients were recruited into the study.

At entry to the study a fasting venous blood sample was taken into EDTA. Patients then commenced consumption of capsules as described above, and completed a 7-day weighed food diary. Patients continued with medications throughout the study period and were advised not to change their diet. Compliance was promoted by regular contact with patients and was assessed by counting returned capsules and by measuring the fatty acid composition of LDL lipid fractions. Patients who reported an inability to comply (n = 5) were withdrawn from the study. Returned capsule counts suggested compliance > 85% in each treatment group. Furthermore, the proportion of EPA in each plasma LDL lipid fraction increased by more than 0.5 g/100 g total fatty acids in > 90% of patients in the fish oil group. These observations indicate that compliance was at least 85 to 90% in each treatment group.

Surgical removal of carotid plaques was performed generally between 7 and 190 days after patients' entry into the study. Patients who went to surgery within 7 days were excluded from the study. On the morning prior to surgery a second fasting venous blood sample was taken. At surgery the carotid plaque was collected and rinsed. It was then cut into cross-sections 2 mm in width starting at the common carotid artery. Sections for biochemical analysis were frozen in liquid nitrogen. Sections for histology were fixed in formaldehyde and then embedded in paraffin wax. Sections for immunohistochemistry were frozen in optimal cutting temperature embedding medium (Agar Scientific, Stansted, UK), and stored at -70°C.

Analysis of habitual nutrient intakes

Food diaries were analysed for habitual nutrient intakes using a modification of FOODBASE (Institute of Brain Chemistry, London, UK), which has been validated for determination of fatty acid intakes.

Plasma lipids and lipoproteins

Plasma total cholesterol and triacylglycerol (TAG) concentrations were determined using commercially available colorimetric assays (Sigma Chemical Co., Poole, UK). Low density lipoproteins (LDL) were prepared from plasma on a two-step density gradient formed by layering 1.7 mL of plasma (adjusted to a density of 1.24 g/mL by addition of solid potassium bromide) under 3.3 mL of phosphate-buffered saline and centrifuging in sealed tubes at a speed of 100,000 rpm for 2 h at 15°C in a Beckman TLA-100.4 rotor in a Beckman Optima ultracentifuge. Purified LDL were frozen at -70°C for fatty acid composition analysis.

Fatty acid composition analyses

The fatty acid compositions of the PL, cholesteryl ester (CE) and TAG fractions of LDL and of the frozen section closest to the bifurcation of the carotid plaques were determined. Total lipid was extracted, lipid fractions separated by thin layer chromatography and the fatty acid composition of each fraction determined by gas chromatography as described by Thies et al. (Am. J. Clin. Nutr. 2001, 73, 539-48).

Morphology of carotid plaques

Paraffin embedded sections were stained with haematoxylin and eosin. The section closest to the bifurcation was classified using both the guidelines published by the American Heart Association

(Stary et al., Circulation, 1995, 92, 1355-74) and also using a modification of this system proposed by Virmani et al. (Arterioscler. Thromb. Vasc. Biol. 2000 20, 1262-75). Sections were examined by a cardiovascular pathologist (PJG) in random order and without access to any patient information. The American Heart Association (AHA) classification involves six grades, or types, as follows: Type I (initial lesion); Type II (early lesion or fatty streak); Type III (intermediate lesion or pre-atheroma); Type IV (atheroma or atheromatous plaque); Type V (fibroatheroma or fibrotic lesion); Type VI (lesion with surface defect and/or haemorrhage and/or thrombotic deposit). The modification of this classification proposed by Virmani et al. involves a series of descriptive grades of increasing severity as follows: pathological intimal thickening (smooth muscle cells in the matrix with areas of extracellular lipid accumulation but no necrosis or thrombus); fibrous cap atheroma (a well formed necrotic core with an overlying fibrous cap; no thrombus); thin fibrous cap atheroma (a thin fibrous cap infiltrated by macrophages and lymphocytes with rare smooth muscle cells and an underlying necrotic core; no thrombus); erosion (luminal thrombosis); plaque rupture (fibroatheroma with disruption; luminal thrombus communicating with necrotic core); calcified nodule and fibrocalcific plaque (eruptive calcification).

Immunohistochemistry of carotid plaques

The plaque section second from the bifurcation was used for immunohistochemistry. Sections were stained for the presence of macrophages (distinguished by the presence of CD68 on their surface) and T lymphocytes (distinguished by the presence of CD3 on their surface) and for two adhesion molecules, vascular cell adhesion molecule-1 (VCAM-1) and intercellular adhesion molecule-1 (ICAM-1), involved in movement of immune cells into the plaque. Cryostat sections of frozen plaque were mounted on organosilan-coated microscope slides. Endogenous peroxidase activity was blocked and then the sections were successively incubated with optimal dilutions of

the different anti-human antibodies, biotinylated goat anti-mouse (swine anti-goat for staining of VCAM-1) immunologobulin G (DAKO, Ely, UK), and streptavidin-horseradish peroxidase (DAKO, Ely, UK). Finally, peroxidase activity was visualised using hyrogen peroxide as substrate and 3-amino-9-ethyl carbazole (Sigma Chemical Co., Poole, UK) as chromogen. Stained sections were fixed using formalin, counterstained with Harris hematoxylin, and viewed using a microscope under 10 x power of magnification. Primary antibodies used were mouse anti-human CD3 (Leu 4; Becton Dickinson, Oxford, UK), mouse anti-human CD68 (KP1; DAKO, Ely, UK); mouse anti-human ICAM-1 (R & D Systems, Oxford, UK), and goat anti-human VCAM-1 (R & D Systems, Oxford, UK). Staining was ranked 0 (no staining), 1 (moderate staining) or 2 (heavy staining).

Statistical analysis

Data are shown only for patients who completed the study (n = 57 in the control group; n = 52 in the sunflower oil group; n = 53 in the fish oil group). Age, body mass index (BMI), blood lipid concentrations at study entry, clinical history, medication use and habitual nutrient intakes among the different treatment groups were compared using one-factor ANOVA. The effects of treatment on blood lipid concentrations and on the fatty acid compositions of LDL lipid fractions were determined as change from baseline value. Changes from baseline among the different treatment groups were compared by one-factor ANCOVA using baseline value and duration of treatment as co-variates; where there was a significant effect of treatment Student's t-test was used to identify differences between groups. In some cases post-treatment values were compared with baseline values within the same treatment group by the paired Student's t-test and post-treatment values were compared among treatment groups by one-factor ANOVA with *post-hoc* Student's t-test. The fatty acid compositions of carotid plaque lipid fractions among the different treatment groups were compared using one-factor ANCOVA, using duration of oil treatment as covariate;

where there was a significant effect of treatment Student's t-test was used to identify differences between groups. The distributions of staining intensity (immunohistochemistry) and of plaque morphology were compared among treatment groups using the Chi-squared test. The mean rank of each distribution in each treatment group was determined and these were compared using the Jonckheere-Terpstra test. Correlations were determined as Spearman's correlation coefficients (ρ). All analyses were performed using SPSS version 11 (SPSS, Chicago, IL, USA) and in all cases a value for $P < 0.05$ was taken to indicate a statistically significant difference.

Results

Patient characteristics

Eighteen patients withdrew from the study, 13 for clinical reasons and 5 because they could not comply with the study protocol. A further 8 patients were excluded from the study because they went to surgery within 7 days of entry to the study.

The characteristics of the patients who completed the study are shown in Table 2. There were no significant differences among the treatment groups at study entry with respect to gender mix, age, BMI, fasting plasma TAG and cholesterol concentrations, intake of energy and of individual macro- and micronutrients including individual fatty acids, number of smokers/ex-smokers, degree of stenosis of the affected carotid artery, clinical history and use of medications (all $P > 0.1438$ at least; one-factor ANOVA) (Table 2). Each group received the supplemented oils for similar durations (Table 2). Patients in the sunflower oil group received an extra 3.6 g linoleic acid/day, increasing daily consumption of this fatty acid by about 40%. Patients in the fish oil group received an extra 1.4 g long chain n-3 PUFA/day, increasing EPA intake approximately 10-fold and DHA intake approximately 4-fold.

Table 2. **Patient characteristics at study entry**

	Control	Sunflower oil	Fish oil
Male (n)	36	32	33
Female (n)	21	20	20
Age (years)	70 ± 8 (38 - 85)	69 ± 9 (44 - 83)	69 ± 9(52 - 84)
BMI (kg/m^2)	26.4 ± 4.1 (19.1 - 37.1)	25.9 ± 3.5 (20.1 - 34.1)	25.9 ± 4.2 (17.1 - 42.4)
Plasma TAG (mmol/L)	1.7 ± 0.8	1.8 ± 1.1	1.7 ± 1.3
Plasma cholesterol (mmol/L)	4.8 ± 1.2	4.7 ± 0.9	4.8 ± 1.0
Energy intake (kcal/day)	1833 ± 377	1911 ± 496	2004 ± 437
Habitual fatty acid intakes (g/day)†			
Linoleic acid	8.5 ± 3.2	9.2 ± 4.9	8.1 ± 4.1
Arachidonic acid	0.06 ± 0.06	0.05 ± 0.06	0.05 ± 0.06
α-Linolenic acid	0.91 ± 0.51	0.82 ± 0.31	0.98 ± 0.47
EPA	0.11 ± 0.12	0.11 ± 0.06	0.08 ± 0.06
DHA	0.15 ± 0.19	0.13 ± 0.13	0.10 ± 0.12
Current smokers (n)	7	9	5
Ex-Smokers (n)*	42	39	40
Clinical history (n)			
Symptoms in the 6 months prior to study entry	39	31	35
Cerebrovascular accident¶	6	9	11
Amaurosis Fugax‡	14	13	20
Transient ischaemic attack	22	20	14
Symptoms more than 6 months prior to study entry	22	21	22
Cerebrovascular accident¶	8	9	11
Amaurosis Fugax	7	7	6
Transient ischaemic attack	12	14	10
Angina	21	17	18
Myocardial infarction	11	9	11
Aortic aneurysim	4	3	1
Previous coronary artery bypass graft	12	4	4
Hypertension	44	33	35
Diabetes	10	10	11
Stenosis (%)	95 (80, 95)	90 (80, 95)	90 (80, 95)
Medication use (n)			
Aspirin	57	52	53
β-Blockers	13	14	12
ACE inhibitors	16	9	9
Nitrates	9	10	11
Calcium channel blockers	23	15	20
Fibrates	1	1	3
Statins	19	18	17
Insulin	1	1	5
Oral antidiabetics	9	6	6
Duration of oil treatment (days)	34 (14, 95)	43 (17, 101)	46 (15, 100)

Data for age, BMI, blood lipids and nutrient intakes are mean ± SD (age and BMI ranges are shown in parentheses).

Data for stenosis are median with 25th and 75th centiles shown in parentheses.

Data for duration of oil treatment are median with 10th and 90th centiles shown in parentheses.

†data are calculated from 7-day weighed food diaries.

*most ex-smokers had given up smoking more than 3 years before entry into the study.

¶i.e. stroke.

‡temporary partial or complete loss of sight.

Plasma lipid concentrations

There was no significant effect of treatment on plasma cholesterol concentration (data not shown). However, there was a significant effect of treatment on plasma TAG concentration (P = 0.0184; one-factor ANCOVA). Fish oil resulted in a significant decrease (-0.48 ± 1.06 mmol/L) in plasma TAG concentration, which was not significantly changed in the other groups. Thus, plasma TAG concentration was significantly lower after fish oil treatment (1.2 ± 0.8 mmol/L) compared with at baseline (P = 0.0032; paired Student's t-test). Furthermore, plasma TAG concentration in the fish oil group at the end of treatment was significantly lower than that in the other two groups (P = 0.0294 vs. control and P = 0.0347 vs. sunflower oil; one-factor ANOVA). There was a significant linear correlation between duration of treatment with fish oil and change in plasma TAG concentration (ρ = -0.44; P = 0.0118).

Fatty acid composition of LDL lipid fractions

There was a significant effect of treatment on the proportions of several fatty acids in LDL PL, CE and TAG. The proportions of EPA and DHA increased in all three LDL lipid fractions after

fish oil treatment (Table 3). These proportions were significantly different from baseline ($P < 0.0001$ for EPA in each fraction, $P = 0.0031$ for DHA in CE, $P < 0.0001$ for DHA in PL and TAG; paired Student's t-test) and from those in the other two groups after treatment ($P \leq 0.0003$ at least; one-factor ANOVA). Increases in the proportions of the long chain n-3 PUFA in LDL PL in the fish oil group were accompanied by significant decreases in the proportions of linoleic, di-homo-γ-linolenic (20:3n-6) and arachidonic (20:4n-6) acids. Increases in the proportions of the long chain n-3 PUFA in LDL CE and TAG in the fish oil group were accompanied by significant decreases in the proportions of linoleic and oleic (18:1n-9) acids, respectively. Sunflower oil treatment resulted in an increased proportion of linoleic acid in LDL CE, largely at the expense of oleic acid. These observations are summerized in Table 3.

Table 3. **Effects of dietary oil treatment on the fatty acid composition of LDL lipid fractions**

		Fatty acid (g/100 g total fatty acids)						One-factor ANCOVA
		Control		Sunflower oil		Fish oil		effect of treatment
		Baseline	Change	Baseline	Change	Baseline	Change	*P*
PL	18:1n-9	11.4 ± 1.9	-0.1 ± 1.2[a]	11.6 ± 1.8	-0.7 ± 1.2	11.7 ± 2.2	-1.1 ± 1.4[b]	< 0.0001
	18:2n-6	19.5 ± 3.2	0.1 ± 1.4[a]	19.9 ± 2.5	0.3 ± 1.6[a]	20.4 ± 2.8	-2.7 ± 1.7[b]	< 0.0001
	20:3n-6	3.4 ± 0.8	-0.1 ± 0.6[a]	3.2 ± 0.7	0.1 ± 0.6[a]	3.4 ± 0.6	-1.0 ± 0.6[b]	< 0.0001
	20:4n-6	8.8 ± 1.8	0.1 ± 1.3[a]	8.3 ± 1.8	0.3 ± 1.3	8.7 ± 1.6	-1.0 ± 1.4[b]	< 0.0001
	20:5n-3	1.0 ± 0.4	0.0 ± 0.4[a]	1.3 ± 0.6	-0.1 ± 0.4[a]	1.3 ± 0.9	2.4 ± 1.3[b]	< 0.0001
	22:5n-3	1.8 ± 0.9	-0.1 ± 0.9[a]	2.0 ± 1.0	-0.3 ± 0.9[a]	1.9 ± 0.9	0.2 ± 0.8[b]	< 0.0001
	22:6n-3	3.3 ± 1.1	0.3 ± 1.1[a]	3.7 ± 1.4	0.1 ± 0.9[a]	3.4 ± 1.4	2.5 ± 1.7[b]	< 0.0001
CE	18:1n-9	19.4 ± 2.2	-0.7 ± 1.8[a]	19.4 ± 2.8	-1.7 ± 2.2[b]	19.2 ± 2.6	-0.2 ± 2.1[a]	0.0013
	18:2n-6	49.2 ± 4.5	-1.0 ± 3.6	48.3 ± 5.4	3.0 ± 3.7[a]	49.4 ± 4.6	-1.9 ± 3.5[b]	< 0.0001
	20:4n-6	6.1 ± 1.6	0.1 ± 0.9[a]	7.0 ± 1.7	-0.7 ± 1.9	6.7 ± 1.6	-1.0 ± 0.8[b]	0.0022
	20:5n-3	1.1 ± 0.8	-0.1 ± 1.0[a]	1.3 ± 0.8	-0.3 ± 0.8[a]	1.2 ± 0.8	3.1 ± 1.3[b]	< 0.0001
	22:6n-3	1.0 ± 0.9	0.1 ± 0.8[a]	1.0 ± 0.7	-0.1 ± 0.8[a]	1.0 ± 0.6	0.9 ± 1.3[b]	< 0.0001
TAG	18:1n-9	41.4 ± 3.5	-1.1 ± 2.6[a]	41.6 ± 3.9	-2.1 ± 3.3	41.4 ± 3.4	-4.2 ± 2.6[b]	0.0012
	18:2n-6	15.0 ± 3.3	1.9 ± 3.2	14.7 ± 3.1	1.1 ± 3.5	15.4 ± 3.9	0.2 ± 1.7	0.4613
	20:4n-6	1.6 ± 0.7	0.2 ± 0.4	1.6 ± 0.7	0.2 ± 0.5	1.7 ± 0.6	0.1 ± 0.6	0.6385
	20:5n-3	0.5 ± 0.4	0.0 ± 0.2[a]	0.5 ± 0.3	0.2 ± 0.7[a]	0.5 ± 0.2	1.4 ± 1.0[b]	0.0064
	22:5n-3	0.4 ± 0.3	0.1 ± 0.3[a]	0.5 ± 0.3	0.1 ± 0.5[a]	0.5 ± 0.3	1.2 ± 1.3[b]	0.0076
	22:6n-3	0.9 ± 0.6	0.2 ± 0.4[a]	1.0 ± 0.6	0.3 ± 0.5[a]	0.9 ± 0.6	1.5 ± 1.3[b]	< 0.0001

Data are mean ± SD.

Change values across a row indicated by different superscript letters are significantly different from one another (one-factor ANCOVA using baseline value and duration of treatment as co-variates).

Fatty acid composition of carotid plaques

There was a significant effect of treatment on the proportions of EPA and DHA in each of the plaque lipid fractions and on the proportion of linoleic acid in plaque PL. The proportion of EPA was higher in the PL, CE and TAG of carotid plaques from patients in the fish oil group than in those from patients in the control ($P < 0.0001$, 0.0053 and 0.0007 for PL, CE and TAG, respectively; one-factor ANCOVA) and sunflower oil ($P < 0.0001$, 0.0278 and 0.0024 for PL, CE and TAG, respectively; one-factor ANCOVA) groups. There was a significant positive linear relationship between the proportion of EPA in plaque PL and duration of fish oil treatment ($\rho = 0.41$, $P = 0.0051$). The proportion of DHA was higher in the CE and TAG of carotid plaques from patients in the fish oil group than in those from patients in the control group ($P = 0.0042$ and 0.0241 for CE and TAG, respectively; one-factor ANCOVA). Furthermore, the proportion of DHA was higher in the PL and CE of carotid plaques from patients in the fish oil group than in those from patients in the sunflower oil group ($P = 0.0100$ and 0.0278 for PL and CE, respectively; one-factor ANCOVA). There was a lower proportion of linoleic acid in PL of plaques from patients in the fish oil group compared with those in the other two groups ($P = 0.0118$ vs. control and $P = 0.0015$ vs. sunflower oil; one-factor ANCOVA). There were no significant differences in the fatty acid compositions of plaque lipid fractions between the control and sunflower oil groups. These observations are summarized in Table 4.

Table 4. **Fatty acid composition of carotid plaque lipid fractions in different oil treatment groups**

		Fatty acid (g/100 g total fatty acids)			One-factor ANCOVA effect of treatment
		Control	Sunflower oil	Fish oil	*P*
PL	16:0	39.1 ± 3.5	39.1 ± 4.0	39.8 ± 4.5	0.4453
	18:0	14.8 ± 1.8	14.9 ± 2.1	14.9 ± 1.5	0.9501
	18:1n-9	14.1 ± 1.6	13.7 ± 1.6	14.2 ± 2.1	0.3152
	18:2n-6	10.9 ± 2.0[a]	11.2 ± 1.9[a]	9.9 ± 1.6[b]	0.0099
	20:3n-6	2.1 ± 0.4	2.0 ± 0.5	1.9 ± 0.6	0.0356
	20:4n-6	10.1 ± 1.8	10.1 ± 2.2	9.9 ± 2.0	0.6412
	20:5n-3	0.6 ± 0.4[a]	0.6 ± 0.5[a]	1.1 ± 0.6[b]	< 0.0001
	22:6n-3	3.3 ± 1.2	2.9 ± 1.0[a]	3.6 ± 1.2[b]	0.0444
CE	16:0	14.5 ± 1.8	15.0 ± 1.9	14.5 ± 1.7	0.1128
	16:1n-7	3.9 ± 1.3	4.1 ± 1.3	3.8 ± 0.9	0.4017
	18:0	1.0 ± 0.6	0.7 ± 0.6	0.7 ± 0.6	0.2171
	18:1n-9	27.3 ± 4.2	25.7 ± 3.6	26.7 ± 3.2	0.1417
	18:2n-6	38.6 ± 6.0	40.4 ± 5.4	39.5 ± 5.5	0.4454
	20:3n-6	2.4 ± 1.1	2.1 ± 0.8	2.2 ± 1.1	0.1268
	20:4n-6	6.6 ± 1.4	6.6 ± 1.0	6.8 ± 1.1	0.8452
	20:5n-3	1.1 ± 0.5[a]	1.1 ± 0.9[a]	1.5 ± 0.5[b]	0.0314
	22:6n-3	1.5 ± 0.6[a]	1.6 ± 0.6[a]	2.0 ± 0.8[b]	0.0084
TAG	16:0	28.9 ± 4.9	28.8 ± 3.2	27.4 ± 4.5	0.3348
	16:1n-7	3.7 ± 1.7	3.4 ± 1.0	3.8 ± 2.4	0.3758
	18:0	5.9 ± 1.9	5.8 ± 1.4	5.7 ± 1.2	0.8954
	18:1n-9	37.8 ± 4.3	37.6 ± 2.9	38.8 ± 4.3	0.2126
	18:2n-6	15.9 ± 4.0	16.4 ± 3.3	15.1 ± 2.9	0.3666
	20:4n-6	2.1 ± 0.9	2.2 ± 0.8	1.9 ± 0.6	0.5016
	20:5n-3	0.2 ± 0.2[a]	0.2 ± 0.2[a]	0.4 ± 0.3[b]	0.0026
	22:6n-3	0.9 ± 0.6[a]	1.0 ± 0.7	1.2 ± 0.6[b]	0.0382

Data are mean ± SD.

Values across a row indicated by different superscript letters are significantly different from one another (one-factor ANCOVA using duration of treatment as co-variate).

Carotid plaque morphologic classification

The distribution of lesion types determined using the AHA classification was significantly different between patients taking fish oil and those taking the control or sunflower oils (P = 0.0234 vs. control and P = 0.0107 vs. sunflower oil; Chi-squared test). This appeared to be due to a greater proportion of Type IV lesions ("atheromas") and a lower proportion of Type V lesions ("fibroatheromas and fibrotic lesions") in the fish oil group. The distributions of lesion types from patients treated for shorter or for longer than the median duration in each group were compared. For plaques from patients treated for shorter than the median time, the distribution was not significantly different among the treatment groups. However, the lesion distribution in patients receiving fish oil for longer than the median duration was significantly different from those observed in both the control and sunflower oil groups (P = 0.0111 and 0.0432, respectively; Chi-squared test). Across all patients, the EPA and DHA content was highest for Type IV plaques and lowest for Type VI plaques.

The distribution of lesion types determined using the modified AHA classification was significantly different between patients taking fish oil and those taking the control or sunflower oils (P = 0.0344 vs. control and P = 0.0313 vs. sunflower oil; Chi-squared test). This difference appeared to be due to a greater proportion of lesions with a well-formed fibrous cap and absence of thrombus (fibrous cap atheromas) and a lower proportion of lesions with a thin, inflamed fibrous cap (thin fibrous cap atheromas) in the fish oil group.

There were no significant differences in the distribution of plaque lesion types between the control and sunflower oil groups. These observations are tabulated in Tables 5 and 6.

Table 5. **Carotid plaque morphology in different oil treatment groups**

		Control	Sunflower oil	Fish oil
AHA classification[†]	Type III (%)	1.8	0	0
	Type IV (%)	59.6	60.7	71.7
	Type V (%)	29.8	32.2	15.1
	Type VI (%)	8.8	7.1	13.2
Modified AHA classification[‡]	Pathological intimal thickening (%)	7.0	7.4	7.5
	Fibrous cap atheroma (%)	56.1	53.7	66.0
	Thin fibrous cap atheroma (%)	22.8	29.6	15.1
	Erosion (%)	0	1.9	1.9
	Plaque rupture (%)	3.5	5.6	3.8
	Calcified nodule and fibrocalcific plaque (%)	10.5	1.9	5.7

†distribution of lesion types significantly different between fish oil and control ($P = 0.0234$) and fish oil and sunflower oil ($P = 0.0107$) groups (Chi-squared test).

‡distribution of lesion types significantly different between fish oil and control ($P = 0.0344$) and fish oil and sunflower oil ($P = 0.0313$) groups (Chi-squared test).

Table 6. **N-3 polyunsaturated fatty acid content of carotid plaque lipids according to AHA classification and macrophage (anti-CD68) staining intensity**

	Fatty acid (g/100 g total fatty acids)					
	EPA			DHA		
	CE	PL	TAG	CE	PL	TAG
AHA Type IV	1.26 ± 0.08[a]	0.78 ± 0.06[a]	0.30 ± 0.03[a]	1.75 ± 0.08[a]	3.32 ± 0.13	1.01 ± 0.07
AHA Type V	1.14 ± 0.08	0.66 ± 0.08	0.28 ± 0.04	1.63 ± 0.11	3.28 ± 0.19	1.03 ± 0.10
AHA Type VI	1.04 ± 0.16[b]	0.62 ± 0.17[b]	0.22 ± 0.07[b]	1.47 ± 0.21[b]	2.75 ± 0.23	0.97 ± 0.15
Anti-CD68 staining intensity 1	1.33 ± 0.09	0.67 ± 0.11	0.28 ± 0.03	1.81 ± 0.09	3.18 ± 0.13	1.15 ± 0.08
Anti-CD68 staining intensity 2	1.19 ± 0.13*	0.65 ± 0.05	0.22 ± 0.05*	1.63 ± 0.17*	3.02 ± 0.29	0.98 ± 0.15

Values for AHA classification indicated by different superscript letters are significantly different from one another (one-factor ANOVA).

* indicates anti-CD68 staining intensity 2 is different from staining intensity 1 (unpaired Student's t-test).

Lymphocytes and macrophages in carotid plaques

There was no difference in the presence of ICAM-1 or VCAM-1 in plaques from patients in the different treatment groups (data not shown). Likewise, there was no effect of treatment on the presence of T lymphocytes in the plaques. In contrast, plaque sections from patients consuming fish oil were less heavily stained with anti-CD68, a macrophage marker, such that the distribution of staining scores was different for this group compared with the others ($P < 0.0001$ vs. control and $P = 0.0016$ vs. sunflower oil; Chi-squared test) and the mean rank of staining intensity was significantly lower ($P = 0.0246$). Duration of fish oil treatment was significantly negatively correlated with anti-CD68 staining intensity ($\rho = -0.352$; $P = 0.0301$). Plaques from patients taking fish oil for shorter than the median duration of treatment showed a higher intensity of anti-CD68 staining (25% staining intensity 1 and 75% staining intensity 2) than those from patients treated for longer than the median duration (47% staining intensity 1 and 53% staining intensity 2). However, these distributions of staining intensity were not significantly different ($P = 0.0827$; Chi-squared test). The distributions of anti-CD68 staining intensity of plaques from patients treated for shorter or for longer than the median duration in each group were compared. The distributions observed in the fish oil group were significantly different from those observed in both the control ($P < 0.0001$ and 0.0048 for patients treated for shorter or longer than median duration, respectively) and sunflower oil ($P = 0.0109$ and 0.0363 for patients treated for shorter or longer than median duration, respectively) groups (Chi-squared test).

Across all patients plaques with a high infiltration of macrophages (i.e. an anti-CD68 staining intensity of 2) contained significantly less EPA and DHA than plaques with a moderate infiltration (i.e. an anti-CD68 staining intensity of 1) (Table 6).

There were no significant differences in the distribution of anti-CD68 staining scores or in the mean ranks of staining intensity between the control and sunflower oil groups.

The T-lymphocyte and macrophage staining observations are summarized in Table 7.

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Table 7. **T lymphocyte and macrophage staining in carotid plaques from patients in different oil treatment groups**

		Control	Sunflower oil	Fish oil
Macrophages[‡]	Staining intensity 0 (%)	2.6	0	0
	Staining intensity 1 (%)	13.2	19.4	38.1
	Staining intensity 2 (%)	84.2	80.6	61.9
	Mean rank[†]	63.5[a]	61.8[a]	51.1[b]
T lymphocytes	Staining intensity 0 (%)	4.8	5.0	0
	Staining intensity 1 (%)	19.0	30.0	26.1
	Staining intensity 2 (%)	76.2	65.0	73.9
	Mean rank	33.7	30.2	33.4

‡distribution of staining scores significantly different between fish oil and control ($P < 0.0001$) and fish oil and sunflower oil ($P = 0.0016$) groups (Chi-squared test).

†Values across a row indicated by different superscript letters are significantly different from one another ($P = 0.0246$; Jonckheere-Terpstra test).

Discussion

Supplementation of the diet of patients in this study with sunflower oil, providing 3.6 g linoleic acid/day, had only a very limited influence on the outcomes measured. This is probably because these patients were already consuming a significant quantity of linoleic acid in their habitual diet; this intake is in accordance with that reported for adults in the UK. Our observations showed that increasing linoleic acid intake by up to 40% in subjects with advanced carotid atherosclerosis and consuming typical amounts of this fatty acid did not lead to increased linoleic acid incorporation into carotid plaques and did not lead to altered plaque stability, at least over the time period studied.

Supplementation of the diet with fish oil significantly lowered plasma TAG concentration. The degree of TAG lowering was consistent with that seen in other studies of fish oil supplementation, and was related to the duration of fish oil supplementation.

Long chain n-3 PUFA such as EPA and DHA are usually consumed in small quantities, and are therefore found in relatively low proportions in plasma and tissue lipids. However, increased consumption of these fatty acids is marked by an increase in their proportion in various blood and tissue lipid pools, as observed in the present work for LDL lipid fractions. A key observation from the present study is that when long chain n-3 PUFA are consumed at a modest dose they are readily incorporated into atherosclerotic plaque lipids. The incorporation of EPA into plaque lipids, especially PL, was linear with respect to time. The only previous study to examine the effect of fish oil supplementation on the fatty acid composition of atherosclerotic plaques of

which we are aware was that of Rapp et al. supra, which showed substantial incorporation of EPA and DHA into plaque lipids following consumption of a very high dose of fish oil. However, Rapp et al. did not investigate the effect of EPA/DHA intake of plaque morphology. The present invention has demonstrated that administration of n-3 PUFA at levels that approximate those that have been used in landmark secondary prevention studies (see, e.g. EP-A-1,152,755) are incorporated into plaque lipid pools. Furthermore, even at the modest dosage levels we have used, the incorporation of n-3 PUFA occurs within a relatively short time frame. This suggests that atherosclerotic plaques are fairly dynamic, with some degree of lipid turnover, even at an advanced stage of atherosclerosis.

Immunohistochemical staining and measures of plaque morphology revealed a significant impact of n-3 PUFA. There were more plaques with a well-formed fibrous cap, rather than a thin inflamed cap, in the fish oil group than in either of the other groups. Furthermore, plaques from patients treated with fish oil were less heavily infiltrated with macrophages. The changes in plaque morphology observed as a result of fish oil supplementation in the present study therefore indicate a more stable plaque, which is less vulnerable to rupture. These differences (i.e. less heavy infiltration with macrophages and more plaques with a well-formed fibrous cap) were related to a higher content of EPA and DHA in the plaque lipids, indicating that it is these n-3 PUFA which determine plaque stability.

Preparation of Medicaments and Mode of Administration

In the present invention the active ingredient of the medicament is EPA, DHA or a mixture of EPA and DHA. These n-3 PUFA fatty acids may be present as the naturally occurring triglyceride form, or they may be in the form of pharmaceutically acceptable salts or derivatives, especially their ethyl esters or other alkyl ester.

Suitably, the active ingredient is derived from fish oil although other sources of EPA and DHA may become commercially available in future years. Methods for manufacturing

pharmaceutical grade fish oil from raw fish oil, and for varying the concentration of the EPA and/or DHA contents in the product, are well known to those skilled in the art. It is preferred from the viewpoints of obtaining a faster uptake of the n-3 PUFA and of ensuring patient compliance that the concentration of EPA and/or DHA in the fish oil should be high, so that an adequate dose can be given by means, for example, of one or two capsules each day. Preferably there is used as the active ingredient a composition containing from 20% to 100% by weight of a mixture of EPA and DHA, more preferably a composition containing more than 70% by weight of the mixture of EPA and DHA, most preferably a composition containing from 70% to 90% by weight of the EPA/DHA mixture. Whilst it is not believed that the ratio of EPA to DHA in the mixture is particularly critical it is usually preferred that the relative amounts of EPA: DHA should be for 1:2 to 2:1, more preferably about 3:2.

Although it is preferred that the active ingredient of the medicament should contain a mixture of EPA and DHA it is written in the scope of this invention to use either of these n-3 PUFA acids by itself. Methods for preparing essentially pure EPA or DHA are known and are described in the literature.

The medicament of the present invention is for oral administration. Suitably the oral form is a hard or soft shell capsule, although other oral forms eg powder obtained through microencapsulation can be used if desired.

The medicaments may comprise, in addition to the EPA and DHA active ingredients as defined, one or more pharmaceutically acceptable carrier as well known in the art. The compositions can also include fillers, stabilizers, extenders, binders, humidifiers, surfactants, lubricants and the like, as shown in the art of formulating pharmaceutical compositions.

In addition antioxidants, for example hydroxytoluene, butyrate, quinone, tocopherol, ascorbic acid etc., preservatives, colouring agents, perfumes, flavourings and other pharmaceutical agents may be used. An antioxidant is a particularly preferred optional component of the medicaments.

EXAMPLE OF ORAL MEDICAMENT PREPARATION

Soft gelatine capsules containing 1 g/per capsule

Composition:

EPA ethyl ester	525	mg/capsule
DHA ethyl ester	315	mg/capsule
d-alpha Tocopherol	4	IU/capsule
Gelatine	246	mg/capsule
Glycerol	118	mg/capsule

The active ingredients and the excipients are weighted and homogenized on a high speed stirrer. The mixture is then colloid milled and deareated in a stainless steel vessel ready for encapsulation. The mixture is filled in soft gelatine capsules of size 20 oblong, (average weight 1.4 g) using a standard encapsulation machine.

The medicament of the present invention may be administered to patients with symptoms of atherosclerosis of arteries supplying the brain at any suitable dose, the n-3 PUFA being essentially non-toxic even at quite high dosage levels. In the trial described above the dosage regimen was such as to provide about 1.4g of EPA and DHA total per day, and this was shown to be effective to increase plaque stability. Generally, the dosage will range from 0.5 to 5.0g of EPA and/or DHA daily, with the preferred dosage being from 1.0 to 3.0g/daily.

The medicament of the invention is suitably administered to patients with symptoms of atherosclerosis of arteries supplying the brain, for instance a stroke or a transient ischaemic attack, in order to reduce the risk of a further, possibly fatal, attack. To this end the medicament may also be utilized in conjunction with other therapeutic agents, for example

aspirin and warfarin, known to reduce the risk of secondary neurological events in such patients.

CLAIMS

1) The use of eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), or a mixture of EPA and DHA, or of a pharmaceutically acceptable salt or derivative thereof, in the preparation of an oral medicament for preventing cerebral damage in patients having symptoms of atherosclerosis of arteries supplying the brain, wherein the dosage will range from 0.5 to 5.0 g of EPA and/or DHA daily.

2) The use according to claim 1, wherein a mixture of EPA and DHA is used.

3) The use according to claim 2, wherein the ratio of EPA to DHA in said mixture is from 1:2 to 2:1.

4) The use according to claim 3, wherein said ratio is approximately 3:2.

5) The use according to any preceding claim, wherein said EPA and/or DHA are present as ethyl esters.

6) The use according to any one of claims 2 to 5, wherein said medicament contains as active ingredient from 20% to 100% of said mixture.

7) The use according to claim 6, wherein said medicament contains as active ingredient more than 70% by weight of said mixture.

8) The use according to claim 7, wherein said medicament contains as active ingredient from 70% to 90% by weight of said mixture.

9) The use according to any preceding claim, wherein said medicament also contains an antioxidant for said EPA and/or DHA.

10) The use of eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), or a mixture of EPA and DHA, or of a pharmaceutically acceptable salt or derivative thereof, for the preparation of an oral medicament for preventing a stroke in a patient with a symptom of cerebrovascular accident, amaurosis fugax and/or transient ischaemic attack, wherein the dosage will range from 0.5 to 5.0 g of EPA and/or DHA daily.

11) The use of a mixture of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), or of a pharmaceutically acceptable salt or derivative thereof, for the preparation of an oral medicament for preventing a stroke in a patient with a symptom of transient ischaemic attack and/or amaurosis fugax, wherein the dosage will range from 0.5 to 5.0 g of EPA and DHA daily.

12) The use according to any preceding claim, wherein said medicament is for administration at a dosage of from 1.0 to 3.0 g/day of EPA and/or DHA.

13) The use according to any preceding claim, wherein the oral medicament is in capsule form.