Protection by scopolamine against the alterations of plasma lipoproteins, vascular morphology and vascular reactivity in hyperlipidaemic diabetic rabbit

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1 The in vivo pharmacological effects of scopolamine (6,7-dimethoxyxoumarin) in a hyperlipidaemic diabetic rabbit model were investigated.
2 Three groups of rabbits were studied: (1) normal, (2) hyperlipidaemic and diabetic-untreated and (3) hyperlipidaemic and diabetic-scopolamine treated. The hyperlipidaemic diabetic rabbits were fed with 1% cholesterol and treated with alloxan, a diabetogenic agent. The plasma levels of total cholesterol, total triglyceride, very low-density lipoprotein (VLDL) cholesterol, low density lipoprotein (LDL) cholesterol and high-density lipoprotein (HDL) cholesterol were markedly increased as soon as the rabbit became diabetic at the second week. Scopolamine-treatment (5 mg kg\(^{-1}\) day\(^{-1}\), s.c.) significantly reduced the plasma lipid and lipoprotein cholesterol levels of the hyperlipidaemic diabetic rabbit to 73.3% of total cholesterol, 48.3% of total triglyceride, 66.0% of VLDL cholesterol, 55.7% of LDL cholesterol and 79.5% of HDL cholesterol.
3 Six weeks after cholesterol-feeding, the aortic and thoracic aorta were dissected for morphological and functional studies. In vascular rings from the untreated hyperlipidaemic diabetic rabbit, there was intimal thickening with accumulation of fatty streaks, foam cells and migration of smooth muscle cells to the intima. In the rabbits treated with scopolamine, there were fewer pathological morphology changes found in vascular segments than in the untreated hyperlipidaemic diabetic rabbits.
4 In the vascular reactivity experiments, the phenylephrine-induced contraction and nitroprusside-induced dilatation did not differ significantly among the three rabbit groups, except that the contraction was enhanced in the thoracic aorta of hyperlipidaemic diabetic rabbits either untreated or treated with scopolamine, as compared to the normal group, and the sensitivity to nitroprusside was increased in the thoracic aorta of the scopolamine-treated group as compared to the untreated group.
5 The endothelium-dependent dilatation induced by acetylcholine was significantly attenuated in both the aortic and thoracic aorta from the hyperlipidaemic diabetic rabbits as compared to the normal rabbits. This attenuation was partially prevented, when scopolamine (5 mg kg\(^{-1}\)) was administered daily.
6 These results suggest that scopolamine protects against some alterations of plasma lipoproteins, vascular morphology and vascular reactivity in the hyperlipidaemic diabetic rabbit. These protective effects of scopolamine may be partly related to its free radical scavenging property.

Keywords: Scopolamine; coumarin derivative; hyperlipidaemic diabetic rabbit; hypolipidaemic effect; antitherogenic effect; vascular reactivity

Introduction

Scopolamine (6,7-dimethoxyxoumarin), an active principle from the hypolipidaemic Chinese herb Artemisia scoparia, has been found to possess free-radical scavenging properties (Huang et al., 1992b) and to exhibit vasodilator and antiproliferative effects (Huang et al., 1991a; 1992a,b; 1993). In this study, the in vivo pharmacological effects of scopolamine in the hyperlipidaemic diabetic rabbit were investigated. Hyperlipidaemia is often associated with diabetes and the abnormal lipoprotein metabolism may be one of the reasons for this (Rosenko et al., 1980; Bierman, 1991). The development of drugs with a cholesterol-lowering effect on hyperlipidaemic diabetic subjects is important for preventing the vascular complications of atherosclerosis and diabetes. During the course of studying the pharmacological actions of hypolipidaemic Chinese herbs, we evaluated the hypolipidaemic effects of some crude extracts and active principles from Chinese herbs in a hyperlipidaemic diabetic rabbit model. In this model, the cholesterol-fed rabbit was treated with diabetogenic agent, alloxan, to elevate more markedly the plasma lipid and lipoprotein lipid levels at the earlier weeks as compared to the animal fed with cholesterol only (Huang et al., 1991b). The effects of scopolamine on plasma lipid and lipoprotein lipid levels were investigated in this rabbit model. Moreover, as hypercholesterolaemia is known to induce important morphological and functional changes in the arterial wall, we also examined the vascular morphology and reactivity of the thoracic aorta and aortic arch from untreated and scopolamine-treated hyperlipidaemic diabetic rabbits.

Methods

Animals

The effects of scopolamine were evaluated by using three rabbit groups, normal, hyperlipidaemic diabetic (cholesterol-fed alloxan-diabetic) and scopolamine-treated (scopolamine-treated cholesterol-fed alloxan-diabetic) rabbit groups. Each group contained six rabbits. The three groups of rabbits were age-matched and weight-matched. Hyperlipidaemic cholesterol-fed alloxan-diabetic rabbits were prepared in our laboratory (Huang et al., 1991b). Rabbits (2.0–2.5 kg) were fed with a

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specific diet containing 1% cholesterol and 20% corn oil. In the second week, diabetes was induced by intravenous administration of a 10% solution of alloxan monohydrate freshly prepared in saline (60 mg kg\(^{-1}\)). In the scoparone-treated rabbit group, cholesterol-fed alloxan-diabetic rabbits were treated by daily injection of scoparone (5 mg kg\(^{-1}\); s.c.) starting at the time of the administration of alloxan. Six weeks after cholesterol feeding, the aortic arch and thoracic aorta were dissected for morphological and functional studies.

**Plasma lipid levels, blood pressure and blood glucose**

The body weight, blood pressure, blood glucose concentration and plasma lipid, lipoprotein lipid concentrations of rabbits were measured every week. The arterial blood pressure was measured by the tail plethysmographic method (PE 300, Narco Biosystem, U.S.A.) (Huang, 1984). Before the start of experiments, rabbits (restrained, at room temperature, with 7/16 inch i.d. cuff) were trained to enable reproducible control values to be obtained. The blood glucose concentration was measured with a glucose analyser (YSI model 23A, Scientific Division, U.S.A.). Lipoprotein fractions were isolated by repeated ultracentrifugations according to the method of Buege & Aust (1978). Plasma was adjusted to the desired density by the addition of NaBr. Lipoprotein fractions including very low-density lipoprotein (VLDL; \(d < 1.019 \text{ g mL}^{-1}\)), low-density lipoprotein (LDL; \(d = 1.019 - 1.063 \text{ g mL}^{-1}\)) and high-density lipoprotein (HDL; \(d = 1.063 - 1.21 \text{ g mL}^{-1}\)) were obtained sequentially by differential ultracentrifugation (110,000 g at 10°C). The plasma total cholesterol, total triglyceride and lipoprotein cholesterol levels were measured by Merck assay kits (Darmstadt, Germany).

**Vascular morphology**

Vascular segments were fixed in 10% formalin. The fixed tissue samples were dehydrated and embedded in paraffin, cut into 5 μm sections and stained with Movat's pentachrome stain. Histological sections were projected, and the intima/media index (intimal/media area times 100) was determined by computerized planimetry.

**Vascular reactivity**

The aortic arch and thoracic aorta were excised. The vessel was dissected free from connective tissue and ring segments (3 to 5 mm) were prepared. The vascular ring was mounted between hooks and placed in a 5 ml organ bath containing Krebs solution at 37°C and bubbled with 5% CO\(_2\), 95% O\(_2\). Isometric tension was measured with a transducer (Harvard Bioscience, South Natick, MA, U.S.A.) attached to tissue bath computer (Buxco electronics, Sharon, CT, U.S.A.). Rings were stretched to the optimal length for isometric contraction (Huang & Lee, 1985). The preparations were then allowed to equilibrate for 120 min.

Vascular responses to vasocostructor (phenylephrine) and vasodilators (acetylcholine and nitroprusside) were studied. Concentration-response curves of the vasocostructor were obtained by cumulative additions of phenylephrine. In order to demonstrate the effect of the vasodilators, a dose of phenylephrine (3 × 10\(^{-6}\) to 10\(^{-5}\) M) producing a sustained contraction was used to precontract the vascular ring. After the addition of phenylephrine (when a stable plateau was reached) cumulative doses of vasodilator were added. The contractions elicited by phenylephrine was expressed as the gram tension increase. The dilatations elicited by acetylcholine and nitroprusside were expressed as percentages of the maximal tension increase produced by phenylephrine. The concentration evoking 50% of the maximal response (EC\(_{50}\) value) for each experiment was estimated graphically from the dose-response curve.

**Materials**

Scoparone was purchased from Aldrich Chemical Co. (Milwaukee, WI, U.S.A.). (-)-Phenylephrine HCl, acetylcholine chloride, sodium nitroprusside, cholesterol, and sodium bromide were purchased from Sigma Co. (St. Louis, MO, U.S.A.). New Zealand rabbits were supplied from the animals centre of National Taiwan University, Taipei, Taiwan.

**Statistics**

The data were expressed as means ± s.e.mean. For statistical analysis, Student's t test for unpaired observation was used. P values less than 0.05 were considered to be significant.

![Figure 1](image-url) Effects of scoparone on plasma (a) total cholesterol and (b) total triglyceride concentrations in hyperlipidaemic diabetic rabbits. The plasma levels of total cholesterol and total triglyceride in hyperlipidaemic diabetic (●) and scoparone-treated (○) groups were measured. Hyperlipidaemic diabetic rabbits were fed with a specific diet containing 1% cholesterol and 20% corn oil and diabetes was then induced by 10% alloxan solution (60 mg kg\(^{-1}\)) at the second week. The scoparone-treated hyperlipidaemic diabetic group was treated by daily injection of scoparone (5 mg kg\(^{-1}\), s.c.) after the administration of alloxan. Points represent the means ± s.e.mean (n = 6); *P < 0.05, compared to the hyperlipidaemic diabetic group.
Table 1 Effect of scoparone on plasma lipid and lipoprotein lipid concentrations in the hyperlipidaemic diabetic rabbit

<table>
<thead>
<tr>
<th></th>
<th>Total cholesterol (mg dl⁻¹)</th>
<th>Total triglyceride (mg dl⁻¹)</th>
<th>VLDL</th>
<th>LDL</th>
<th>HDL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal group</td>
<td>76.0 ± 2.2</td>
<td>80.0 ± 7.5</td>
<td>29.7 ± 2.0</td>
<td>21.8 ± 2.5</td>
<td>33.0 ± 5.2</td>
</tr>
<tr>
<td>Hyperlipidaemic</td>
<td>1492.7 ± 6.0q</td>
<td>752.8 ± 128.3q</td>
<td>1182.3 ± 24.6q</td>
<td>219.1 ± 30.6q</td>
<td>58.0 ± 1.3q</td>
</tr>
<tr>
<td>diabetic group</td>
<td>1093.8 ± 105.1q</td>
<td>363.3 ± 103.5q</td>
<td>778.8 ± 20.8q</td>
<td>122.1 ± 27.5q</td>
<td>46.1 ± 0.7q</td>
</tr>
<tr>
<td>Scoparone-treated</td>
<td>(73.3%)</td>
<td>(48.3%)</td>
<td>(66.0%)</td>
<td>(55.7%)</td>
<td>(79.5%)</td>
</tr>
</tbody>
</table>

The values are means ± s.e.mean of plasma lipid and lipoprotein lipid concentrations at the end of the second week. The values in parentheses express percentage of values in the hyperlipidaemic diabetic group. The hyperlipidaemic diabetic group was fed with a specific diet containing 1% cholesterol and 20% corn oil and diabetes was then induced by bolus intravenous injection of 10% alloxn solution (60 mg kg⁻¹) at the second week. The scoparone-treated group was fed with the specific diet, injected with alloxn and treated by daily injection of scoparone (5 mg kg⁻¹ day⁻¹, s.c.) starting at the time of the administration of alloxn.

*P < 0.05, compared to normal group; **P < 0.05, compared to hyperlipidaemic diabetic group.

Table 2 Responsiveness of vascular rings from normal, untreated and scoparone-treated hyperlipidaemic diabetic rabbits to vasoactive agents

<table>
<thead>
<tr>
<th>Phenylephrine</th>
<th>Acetylcholine</th>
<th>Nitroprusside</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel</td>
<td>EC₅₀ (10⁻⁷ M)</td>
<td>Tₙₐₓ (g)</td>
</tr>
<tr>
<td>Normal group</td>
<td>Aortic arch</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Thoracic aorta</td>
<td>12</td>
</tr>
<tr>
<td>Hyperlipidaemic diabetic group</td>
<td>Aortic arch</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Thoracic aorta</td>
<td>12</td>
</tr>
<tr>
<td>Scoparone-treated group</td>
<td>Aortic arch</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Thoracic aorta</td>
<td>12</td>
</tr>
</tbody>
</table>

The values are means ± s.e.mean. The hyperlipidaemic diabetic group was fed with a specific diet containing 1% cholesterol and 20% corn oil and diabetes was then induced by intravenous injection of 10% alloxn solution (60 mg kg⁻¹) at the second week. The scoparone-treated group was fed with the specific diet, injected with alloxn and treated by daily injection of scoparone (5 mg kg⁻¹ day⁻¹, s.c.) after the administration of alloxn. Six weeks after cholesterol-feeding vessels were dissected out from three rabbit groups for vascular reactivity experiments.

*P < 0.05, compared to normal group; **P < 0.05, compared to hyperlipidaemic diabetic group.

Figure 2 Light microscopical features of cross sections of the aortic arches obtained from (a) normal, (b) hyperlipidaemic diabetic and (c) scoparone-treated hyperlipidaemic diabetic rabbits groups. Movat's pentachrome stain, 150 X. Bar = 70 μm. Marked intimal thickening, significant fibrous plaque and foam cells were found in vessels from the hyperlipidaemic diabetic group. In vessels from the scoparone-treated group, less intimal thickening, no significant fibrous plaque and fewer foam cells were observed. L: lumen.

Figure 3 Light microscopical features of cross sections of the thoracic aortae obtained from (a) normal, (b) hyperlipidaemic diabetic and (c) scoparone-treated hyperlipidaemic diabetic rabbit groups. Movat's pentachrome stain, 150 X. Bar = 70 μm. Marked intimal thickening, significant fibrous plaque and foam cells were found in vessels from the untreated hyperlipidaemic diabetic group. In vessels from the scoparone-treated group, less intimal thickening, less fibrous plaque and fewer foam cells were observed. L: lumen.
Results

Baseline data

During treatment in rabbits, scoparone (5 mg kg\(^{-1}\) day\(^{-1}\)) was well tolerated and no serious side effect was observed. Although the body weight increased with time during the experimental period (2.3 ± 0.1 to 2.5 ± 0.1 kg), there was no significant difference in body weight between the scoparone-treated and the untreated hyperlipidaemic diabetic rabbits (2.3 ± 0.1 to 2.5 ± 0.1 vs. 2.3 ± 0.1 to 2.6 ± 0.1 kg). There was no significant difference in the blood pressure between scoparone-treated and untreated rabbits (107.6 ± 4.6 vs. 118.6 ± 7.2 mmHg at the 6th week). The mean values of arterial blood pressure of the scoparone-treated group were lower than those of the untreated hyperlipidaemic diabetic group after the 3rd week (105.2 ± 5.7 vs. 118.9 ± 5.9 mmHg at the 4th week). However, the differences in blood pressure between treated and untreated groups were inconsistent and did not achieve significance during the 6-week period. Upon administration of aloxan in cholesterol-fed rabbit at the second week, the blood glucose concentration was elevated to a level above 250 mg dl\(^{-1}\) within 48 h. The blood glucose concentration of untreated hyperlipidaemic diabetic rabbit was elevated from 141.2 ± 3.5 to 262.0 ± 46.6 mg dl\(^{-1}\). Scoparone-treatment reduced the blood glucose to 223.5 ± 28.0 mg dl\(^{-1}\). However, the differences in blood glucose concentrations between treated and untreated groups did not achieve significance.

In the normal group, the plasma total cholesterol, total triglyceride and lipoprotein cholesterol concentrations did not change significantly during the 6-week period. In the untreated cholesterol-fed aloxan-diabetic group, the total plasma cholesterol and triglyceride levels were markedly increased as soon as the rabbit became diabetic at the second week. The increases in the plasma cholesterol and triglyceride in cholesterol-fed aloxan-diabetic rabbit were more marked than those in rabbits fed with cholesterol only (Huang et al., 1991b). The plasma total cholesterol concentrations were greatly increased at the second week (1492.7 ± 6.0 mg dl\(^{-1}\)) (Figure 1a) and continued to rise throughout the study (2123.8 ± 266.8 mg dl\(^{-1}\) at the 6th week). The plasma total triglyceride had a peak value at the second week (752.8 ± 128.3 mg dl\(^{-1}\)) and decreased at the third week (Figure 1b), then remained stable (523.0 ± 19.1 mg dl\(^{-1}\) at the 6th week). Table 1 shows the lipid profiles of three rabbit groups at the end of the second week. Scoparone-treatment (5 mg kg\(^{-1}\) day\(^{-1}\)) significantly reduced the plasma lipid and lipoprotein cholesterol concentrations of hyperlipidaemic diabetic rabbits at the second week to 73.3% of total cholesterol, 48.3% of total triglyceride, 66.0% of VLDL cholesterol, 55.7% of LDL cholesterol and 79.5% of HDL cholesterol. At the 6th week, scoparone-treatment still significantly reduced the plasma total cholesterol to 80%, but did not affect the plasma total triglyceride.

Vascular morphology

Six weeks after cholesterol feeding, the aortic arches and thoracic aortae were dissected out from the three rabbit groups. Microscopic evaluations of segments of aortic arch and thoracic aorta are shown in Figures 2 and 3. No lesion was noted in the blood vessels from normal group (I/M index = 0, n = 6, for both aortic arch and thoracic aorta) (Figures 2a and 3a). In contrast, there was intimal thickening with accumulation of fatty streaks, foam cells and migration of smooth muscle cells to the intima in vascular segments from the untreated hyperlipidaemic diabetic group (I/M index = 50 ± 3, n = 5, and 41 ± 7, n = 6, for aortic arch and thoracic aorta, respectively) (Figures 2b and 3b). Of the arteries obtained from the hyperlipidaemic diabetic rabbits, the aortic arch was more affected by the lesion than the thoracic aorta. In the rabbits treated with scoparone, there was a significantly less fatty lesion found in both vessels (I/M index = 7 ± 1, n = 5, and 3 ± 0.2, n = 6, for aortic arch and thoracic aorta, respectively) as compared to the untreated hyperlipidaemic diabetic rabbits (Figures 2c and 3c). Less atherosclerotic effect of scoparone treatment was observed in the aortic arch than in the thoracic aorta.

Figure 4 Concentration-response curves to (a) phenylephrine, (b) acetylcholine and (c) nitroprusside in aortic arch rings obtained from normal, hyperlipidaemic diabetic and scoparone-treated hyperlipidaemic diabetic groups. Contractile or dilator responses were recorded in vascular rings from normal (O), untreated hyperlipidaemic diabetic (■) and scoparone-treated hyperlipidaemic diabetic (△) groups. Contractile response was expressed in grams (Tension, g). Dilator response was expressed as percentage of the maximum tension increase produced by phenylephrine (Tension, %). Points represent the means ± s.e.mean (n ≥ 5). *P < 0.05, compared to the normal group.
(T_{max}) values of responses to phenylephrine are listed in Table 2. The EC_{50} and T_{max} values in aortic arch were not significantly changed between the hyperlipidemic diabetic and the scoparone-treated rabbit groups. In the thoracic aorta, the contraction responses to phenylephrine were significantly enhanced in hyperlipidemic diabetic rabbits either untreated or treated with scoparone (Figure 5a and Table 2).

When acetylcholine was added to vascular rings precontracted with phenylephrine, concentration-dependent dilatations were obtained in the aortic arch and thoracic aorta at the concentration ranges of 10^{-6}–10^{-5}M and 10^{-10}–3 × 10^{-8}M, respectively (Figures 4b and 5b). In the aortic arch and thoracic aorta, the dilator responses to acetylcholine were significantly attenuated at almost all concentrations in the untreated hyperlipidemic diabetic group as compared to the normal group. The attenuations were partially prevented when scoparone was administered daily (Figures 4b and 5b). As shown in Table 2, the sensitivity and maximal dilatation in the aortic arch and thoracic aorta were significantly reduced in the hyperlipidemic diabetic group and scoparone-treatment significantly restored the sensitivity in both vessels, but restored only the maximal dilatation in the thoracic aorta. A dose-dependency for the scoparone-induced protective effect was observed at the dose range of 1–10 mg kg^{-1} day^{-1}. At 5 and 10 mg kg^{-1} day^{-1}, scoparone exhibited the maximum protective activity against impaired endothelium-dependent relaxation.

Nitroprusside induced a concentration-dependent dilatation in vascular rings of the aortic arch and thoracic aorta at the concentration range of 10^{-5}–3 × 10^{-7}M in three rabbit groups (Figures 4c and 5c). The EC_{50} and maximal response values of nitroprusside-induced dilatations did not differ significantly among the three rabbit groups (Table 2), except that the EC_{50} was decreased in the thoracic aorta of scoparone-treated group as compared to the untreated group.

Discussion

We have evaluated the in vivo effects of scoparone in a hyperlipidemic diabetic rabbit model. The results demonstrate that scoparone not only reduced the elevation of plasma lipid and lipoprotein lipid levels, but also protected against some pathological alterations of vascular morphology and reactivity in the aortic arch and thoracic aorta. The hyperlipidemic cholesterol-fed alloxan-diabetic rabbit, provides a useful model to examine the effects of compounds on lipid profile, atherogenic lesion and vascular reactivity in the hyperlipidemic diabetic animal. Upon alloxan administration in the cholesterol-fed rabbit, the concentrations of plasma total lipid and lipoprotein cholesterol were markedly increased as soon as the rabbit became diabetic in the second week. Therefore, the hyperlipidemic effect of drugs can be easily evaluated at the earlier weeks in this animal model as compared to the animal fed with cholesterol only. By using this model we have evaluated the hypolipidemic effects of some crude extracts and active principles from Chinese herbs. In this study, scoparone-treatment significantly reduced the elevated levels of total cholesterol, total triglyceride, very low-density lipoprotein (VLDL) cholesterol, low-density lipoprotein (LDL) cholesterol, and high-density lipoprotein (HDL) cholesterol in hyperlipidemic diabetic rabbits. The reduction in HDL cholesterol was less than the other fractions. Six weeks after cholesterol feeding, the significant morphological and functional alterations were observed in vascular tissues. These pathological vascular changes may be induced by hyperlipidemia or diabetes. Administration of scoparone to this rabbit model has been found to be associ-
more prominent in the thoracic aorta than in the aortic arch. Proabcol, an effective antioxidant, has been reported to lower LDL and HDL levels, enhance the fractional catabolic rate of LDL, and lower plasma LDL levels. In the porcine model, the oxidative and anti-inflammatory properties of the drug were investigated. However, it has been shown that the drug may increase the oxidative damage to the LDL and affect the atherosclerotic lesion in the aorta. In the aorta, the drug is more effective in the thoracic aorta than in the aortic arch. Proabcol may affect the lipoprotein levels and atherosclerotic changes as does probucol.

In our vascular activity experiments, the enhancement of phenylephrine-induced contraction was observed in the thoracic aorta from hyperlipidaemic diabetic rabbits and probucol treatment had no effect on responses to phenylephrine. It has been reported that the contractions caused by the selective α₁-adrenoceptor agonist phenylephrine are not altered in arteries obtained from hypercholesterolaemic rabbits (Henry & Yokoyama, 1980; Yokoyama et al., 1983), indicating that the oxidative stress of the animal may be the important factor for the enhancement of phenylephrine-induced contraction in the present study. Similarly, an increased vascular reactivity to α₁-adrenoceptor agonists has been reported in aorta and carotid artery from alloxan-diabetic rabbits (Cseuz et al., 1973; Agrawal et al., 1985). It has been demonstrated that there are α₁-adrenoceptors but not α₂, on endothelial cells that mediate the release of endothelium-derived relaxing factor (EDRF) (Angus et al., 1986). The enhancement of phenylephrine-induced contraction may be less related to endothelial dysfunction. It has been indicated that the difference between induced contractions of healthy and diabetic vessels became evident only after denudation of endothelium and injury of endothelial cells may also contribute to the hyper-reactivity of diabetic arteries (Gebremedhin et al., 1987). Several changes, such as impairment of adrenergic nerve fibres, change in calcium homeostasis and increased activity of calcium channels have also been proposed as responsible for the altered contractile responsiveness of diabetic vascular smooth muscle to α₁-adrenergic stimulation (Gebremedhin et al., 1987). Further studies are needed to elucidate the mechanisms of the enhancement of phenylephrine-induced contraction in our animal model. On the other hand, the endothelium-dependent dilatation to acetylcholine in rabbit aorta has been reported to be impaired by cholesterol feeding (Jayakody et al., 1985). In the present LDL study, the endothelium-dependent dilatations induced by acetylcholine were significantly attenuated in both aortic arch and thoracic aorta from the hyperlipidaemic diabetic rabbit. The impairment of the acetylcholine-induced dilatation was partially restored by daily treatment with scopolamine. Components related to atherogenesis, such as endothelial cells and inflammatory cells, can produce superoxide anion, and this anion modified LDL at the extracellular space (Morel et al., 1984; Parthasarathy et al., 1986) and inactivates the endothelium-derived relaxing factor (EDRF) (Tagawa et al., 1991). Oxidized LDL may lead to an acceleration of atherosclerotic lesion. The oxidative modification of EDRF has been reported to be a possible mechanism for the impairment of endothelium-dependent dilatation to acetylcholine in the cholesterol-fed rabbit (Mügge et al., 1991). Since scopolamine has been found by us to exhibit free radical scavenging activity in the vascular ring (Huang et al., 1992b), it may protect against the atherosclerotic lesion and the impairment of vascular dilatation through reducing the oxidative modification of LDL and EDRF in the hyperlipidaemic diabetic rabbit. There was a decrease in the ECA of nitroprusside-induced dilatation in the thoracic aorta of the scopolamine-treated group as compared to the untreated group, suggesting that the endothelium-independent dilatation in the aorta may also be affected. This effect may be partly mediated through the direct activation of guanylate cyclase by scopolamine (Huang et al., 1992b).

In summary, scopolamine-treatment reduced the elevation of plasma lipid and lipoprotein cholesterol concentrations and protected against some in vivo vascular morphological and functional alterations in hyperlipidaemic cholesterol-fed alloxan-diabetic rabbit. These protective effects of scopolamine may be partly related to its free radical scavenging property.

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References


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