Original Article

Arterial compliance in patients on long-treatment-time dialysis


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Abstract. Arterial compliance is found to be reduced in haemodialysis patients. It is not clear whether decreased arterial compliance in uraemic patients is a consequence of long-standing increased mean arterial blood pressure or a consequence of the uraemic state. An adequate blood pressure can be achieved by long-treatment-time dialysis of 8 h three times a week. We studied femoral and carotid artery wall properties in 24 normotensive patients on long-treatment-time dialysis and normal controls matched for mean arterial pressure, age, sex, and body mass index. Arterial distensibility coefficient and compliance coefficient were determined with a vessel wall movement detector system, 24 h after dialysis in the supine position.

The patients were 5.9 ± 6.6 years on long-treatment-time dialysis at a Kt/V of 1.8 ± 0.4. We found no significant differences in mean arterial pressure or pulse pressure between patients (85 ± 13, 55 ± 17 mmHg) and controls (84 ± 6, 50 ± 13 mmHg). Femoral distensibility coefficient and compliance coefficient were lower in patients (6.0 ± 2.4 10^-3/kPa; P < 0.05, 0.52 ± 0.28 mm^2/kPa; n.s.) compared to the controls (8.8 ± 4.0 10^-3/kPa, 0.67 ± 0.38 mm^2/kPa). No differences in carotid distensibility coefficient and compliance coefficient were found between patients (12.8 ± 4.6 10^-3/kPa, 0.72 ± 0.30 mm^2/kPa) and controls (14.1 ± 4.4 10^-3/kPa, 0.70 ± 0.23 mm^2/kPa).

We conclude that patients on long-treatment-time dialysis have an increased stiffening of the muscular femoral artery but not of the more elastic carotid artery. Results suggest that the uraemic state itself has a deleterious effect on the elastic properties of the muscular femoral artery.

Key words: arterial compliance; fluid status; haemodialysis; haemodynamics; hypertension; long dialysis

Introduction

In haemodialysis patients, cardiovascular complications are the main cause of morbidity and mortality [1]. Hypertension is a major risk factor for cardiovascular disease [2]. Cardiac disease usually results from ischaemic heart disease, systolic failure and left ventricular hypertrophy (LVH) with diastolic dysfunction [3]. Left ventricular hypertrophy is an independent risk factor in dialysis patients [4]. Furthermore in haemodialysis patients peripheral vascular changes have also been found, e.g. a reduced venous and arterial compliance [5,6]. The consequence of a decreased arterial compliance, i.e. a decreased cushioning function, is an increase in arterial pulse pressure resulting in a decrease of diastolic pressure and an increased systolic pressure [7]. Furthermore arterial compliance affects pulse pressure amplitude also by an increased velocity of the pressure wave through the stiffened arterial system, resulting in a change on the timing and incidence of reflected waves. By these effects a decreased arterial compliance contributes to the development of LVH [8]. It is not clear whether the decreased arterial compliance in uraemic patients is a passive consequence of an increased mean blood pressure or the consequence of altered arterial composition, i.e. smooth-muscle hypertrophy and increased or changed collagen content of the media [9].

In most dialysis centres the incidence of hypertension is high. An adequate blood pressure control with less than 5% of the patients having hypertension is achieved with long-treatment-time dialysis of 8 h three times weekly [10]. In the present study we investigated whether uraemic patients on long-treatment-time dialysis with an adequate blood pressure control had different arterial wall properties, as compared to normal controls matched for age, sex, body mass index (BMI), and mean arterial pressure (MAP).

Methods

Vessel wall properties of the elastic common carotid artery and the common femoral artery were studied in 24 normotensive patients on long-treatment-time dialysis (8 h, three times a week) and 24 normal controls matched for age, sex, BMI, and MAP. None of the dialysis patients were using antihypertensive drugs. Diabetic patients were excluded from the study.

Dialysis patients were measured on the day after dialysis, after full equilibration of the intra- and extracellular fluid...
compartments. All subjects were evaluated in supine position after 15 min of rest. Blood pressure and heart rate were measured every 3 min with a semi-automated device (Dinamap). The mean of at least 10 recordings was calculated. Pulse pressure (ΔP) was calculated as the difference between the systolic and diastolic blood pressure.

The vessel wall properties of the carotid and femoral arteries were assessed with a vessel wall movement detector system, consisting of an echo-imaging system and a data acquisition system, connected to a personal computer [11,12]. Arterial diastolic diameter (D) and change in diameter during the heart cycle (ΔD), were recorded over 5–6 s. The means of three consecutive measurements were taken as the patient’s reading. Vessel wall properties were calculated using the following equations:

Distensibility coefficient: \( DC = \frac{2 \Delta D}{D} \)

Compliance coefficient: \( CC = \frac{\pi D \times \Delta D}{2 \Delta P} \)

Data were analysed, using a non-parametric Mann–Whitney U test. A \( P < 0.05 \) value was considered statistically significant. Data are presented as mean ± SD.

Results

Dialysis patients had been 5.9 ± 6.6 years on long-treatment-time dialysis. Mean \( Kt/V \) was 1.8 ± 0.4. 23 Patients were anuric, and one patient had a diuresis of 250 ml/day. Patients and controls characteristics are shown in Table 1. No differences were apparent between patients and controls in respect to sex distribution, age, length, weight, BMI, \( MAP \), and \( ΔP \). Systolic/diastolic blood pressure in dialysis patients was 118 ± 24 mmHg/69 ± 6 mmHg compared to 118 ± 24 mmHg/69 ± 6 mmHg in controls. Heart rate was significantly higher in dialysis patients compared to healthy controls.

In all dialysis patients and healthy controls it was possible to measure carotid vessel wall dimensions. Femoral artery properties could be measured in 19 of 24 dialysis patients and in all healthy controls. Five patients had severe atheromatous changes, making it technically impossible to measure a reliable femoral diameter and distensibility.

Vessel wall properties are shown in Table 2. Carotid artery diameter was significantly greater in dialysis patients compared to controls. No differences were found between dialysis patients and controls in respect to carotid distension, DC, and CC. No significant differences were found in femoral artery diameter and distension between dialysis patients and controls. Femoral DC was significantly lower in dialysis patients compared to controls. Also femoral CC tended to be lower in dialysis patients, but these differences did not reach the level of significance.

Discussion

In the present study we investigated elastic properties of two different arteries using a vessel wall movement detector system [11] in normotensive uraemic patients on long-treatment-time dialysis matched for blood pressure, age, BMI, and sex. Femoral artery distensibility was decreased compared to healthy controls. Also femoral artery compliance tended to be lower in dialysis patients compared to controls, although these differences were not significant. No differences in carotid artery distensibility or compliance were found. Brachial \( ΔP \) was used for calculating femoral and carotid DC and CC. Although there are no significant differences between mean and diastolic pressure at the carotid, femoral, and brachial artery, \( ΔP \) is significantly amplified between central and peripheral arteries. This amplification depends on progradive properties of the arterial tree, which are influenced by body length [7,13]. In normal controls the central \( ΔP \) is lower than the peripheral \( ΔP \). Femoral \( ΔP \) is very closely to brachial \( ΔP \). However, for the carotid compliance one should keep some reserve because of the differences between brachial and central (carotid) \( ΔP \).

Using the same vessel wall movement detector

<table>
<thead>
<tr>
<th>Patients (n = 24)</th>
<th>Controls (n = 24)</th>
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</thead>
<tbody>
<tr>
<td>Diameter (mm)</td>
<td>10.3 ± 2.2</td>
</tr>
<tr>
<td>Distension (μm)</td>
<td>217 ± 124</td>
</tr>
<tr>
<td>DC [10⁻⁵ kPa]</td>
<td>6.0 ± 2.4*</td>
</tr>
<tr>
<td>CC [mm²/kPa]</td>
<td>0.52 ± 0.28</td>
</tr>
</tbody>
</table>

DC, distensibility coefficient; CC, compliance coefficient; \* \( P < 0.05 \).
system Barenbrock reported a decreased carotid artery distensibility in young dialysis patients as compared to age-matched controls [14]. In older haemodialysis patients no difference could be found. Although the older patients group in the Barenbrock study were 6 years younger and their MAP was 6 mmHg lower when compared to our long-treatment-time dialysis patients, DC of the carotid artery was similar to DC in long-dialysis patients measured in our study (11.7 ± 1.1 10–3 kPa and 12.8 ± 4.6 10–3 kPa). Barenbrock did not report how many years the patients had been on dialysis, and no data were given concerning the muscular femoral artery.

London also found a decreased large artery compliance in haemodialysis patients compared to controls matched for age and MAP, by measuring pulse wave velocity in the aorta, leg, and arm [6]. He found pulse wave velocity to be more increased, so elastic properties more decreased, in the aorta as compared to the smaller femoral and brachial arteries. In our study we found muscular femoral artery elastic properties to be more affected in uraemic patients than carotid artery elastic properties. While in all 24 dialysis patients elastic properties of the carotid artery could be measured, it was not possible to measure femoral artery properties in five of the 24 patients because of atherosomatic plaques. This is compatible with the clinical observation that complications due to vascular disease of muscular arteries e.g. coronary and iliac arteries, are more common than complications due to vascular disease of elastic arteries, e.g. carotid artery [1].

In non-uraemic subjects, alterations of arterial elastic properties are especially found to be influenced by blood pressure control and ageing [15,16]. Stiffening of the arterial vessels is most probably caused by structural changes of the vascular wall as atherosclerosis, medial and intimal thickening, accumulation of collagen fibres, deposition of calcium, and degeneration of elastic laminae [17]. Whether the uraemic state itself has a deleterious effect on arterial elastic properties is still a subject of study. Arterial compliance is found to be decreased in haemodialysis patients [6]. Many haemodialysis patients are hypertensive, which will have a negative influence on the arterial compliance. On the other hand, other factors than an elevated blood pressure such as hyperpulaemia, anaemia, lipid disorders, hyperparathyroidism, and perhaps uraemic toxins cause (cardio)vascular changes in haemodialysis patients [18,19]. Intimal thickening and medial calcification are frequently seen in dialysis patients. There is, however, no strong correlation between pulse wave velocity and arterial calcification [6].

In the present study we have investigated patients who had been more than 5 years on long-treatment-time dialysis. Blood pressure control was adequate for many years. Patients on long-treatment-time dialysis have a better survival and less cardiovascular complications as compared to patients on a more usual short treatment time dialysis regime [10]. Nevertheless femoral artery distensibility was decreased in patients on long-treatment-time dialysis as compared to age and blood pressure matched controls. This suggests deleterious effects of other factors than blood pressure on arterial elastic properties. Another explanation for the decreased arterial elasticity could be the fact that irreversible vascular changes were already present before the patients were treated with renal replacement therapy.

Why the muscular femoral artery in dialysis patients is more affected than the elastic carotid artery is not clear. In several pathophysiological conditions such as hypercholesterolaemia [20] and in uncomplicated insulin-dependent diabetes mellitus [21], the femoral artery was more suspect than carotid arteries for wall stiffening.

In the present study heart rate was higher in patients on haemodialysis than in controls. Could this higher heart rate account for the lower distensibility in these uraemic patients? Recently it has been shown in rats that increases in heart rate are accompanied with a decrease in arterial distensibility and compliance [22]. This decrease in arterial distensibility and compliance was more pronounced in elastic than in muscular arteries. Heart rates are about five times higher in rats than in men. It is not clear whether these findings with high heart rates in rats also apply to the much lower heart rates in men. In addition, in the present study, a clear difference was seen at the muscular femoral artery and only a trend at the more elastic common carotid artery, which is opposite to the results obtained in rats. It therefore is very unlikely that the smaller distensibility and compliance in these patients on haemodialysis would only be due to their increase in heart rate.

From these data we conclude that haemodialysis patients on long-treatment-time dialysis notwithstanding a good blood pressure control for many years and a decreased cardiovascular morbidity, have an increased stiffening of the femoral arteries but not of the carotid arteries as compared to controls. Whether the uraemic state itself can have a deleterious effect on the elastic properties of the muscular femoral artery, or whether the decreased distensibility is related to pre-existent irreversible vascular changes, requires further study.

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References
5. Kooman JP, Wijnen JAG, Draaijer P et al. Compliance and


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