Increased basal myocardial perfusion in patients with chronic kidney disease without symptomatic coronary artery disease

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Abstract

Background. Even minor renal dysfunction is a powerful cardiovascular risk factor. The abnormalities in coronary and peripheral artery function in different stages of chronic kidney disease (CKD) remain poorly understood. Our aim was to test by a positron emission tomography (PET)-based method whether microvascular dysfunction, an early marker of coronary dysfunction, exists already in early stages of CKD.

Methods. Myocardial blood flow was measured at baseline and during dipyridamole-induced hyperaemia by PET. Peripheral artery endothelial function was examined by measuring flow-mediated dilatation (FMD) of the brachial artery at rest and during reactive hyperaemia. Twenty-two patients with moderate to severe kidney failure and 10 healthy controls were investigated. Diabetic patients were excluded. Baseline characteristics were similar between the groups with the exception of antihypertensive medication in all CKD patients.

Results. The basal myocardial perfusion was statistically significantly higher in CKD patients than observed values in similarly aged controls. There was a statistically significant negative correlation between the baseline myocardial perfusion and the estimated glomerular filtration rate. Coronary flow reserve was comparable to healthy controls in all patients. FMD was significantly reduced in all patients with CKD regardless of the stage of kidney failure.

Conclusions. Coronary flow reserve was normal although baseline myocardial blood flow was increased in all CKD patients as compared to healthy controls. Peripheral endothelial dysfunction was detected in all patients. Our findings suggest that coronary perfusion and peripheral vascular function are disturbed by different mechanisms in patients with CKD.

Keywords: CKD; imaging; myocardial perfusion

Introduction

Cardiovascular (CV) mortality is 15–30 times higher in patients with chronic kidney disease (CKD) than the age-adjusted CV mortality in the general population [1]. It is well established that even minor renal dysfunction predicts CV events and CV death in the general population [2–5]. Both autopsy [6] and clinical studies have documented a high prevalence of coronary artery plaque in patients with end-stage renal disease (ESRD) [7]. However, there seems to be a disconnection between coronary anatomy and CV disease events, since the myocardial infarction is only the third most common cause of CV death in this patient population, sudden death and heart failure being more frequent causes [8].

Although the CV risk factors in CKD are far from well defined, the increased risk of CV disease may be due to both traditional and non-traditional risk factors associated with kidney dysfunction, including hypertension, diabetes and inflammation [9,10]. One of the principal pathophysiological mechanisms involved may be endothelial dysfunction (ED), which has been documented in CKD patients by measuring direct indices such as flow-mediated vasodilatation (FMD) [11,12].

Myocardial blood flow dynamically adapts to the metabolic demand of the myocardium and is controlled by coronary microvascular resistance. There are different mechanisms at the level of microvasculature that influence smooth muscle tone. These include metabolic regulation, shear-sensitive control and myogenic (pressure-sensitive) control in the normal heart [13]. The role of the endothelium, by providing vasoactive factors such as nitric oxide, is critical for regulation of vasodilatation and smooth muscle tone. The functional capacity of the myocardial microcirculation may be assessed by measuring myocardial perfusion at baseline and during pharmacological hyperaemia. This enables calculation of coronary flow reserve (CFR), which is an integrating measure of endothelial function, vascular
smooth muscle relaxation and epicardial stenoses [14–16].

Positron emission tomography (PET) is a well-established method for noninvasive quantification of myocardial perfusion. Brachial artery flow-mediated dilatation (FMD) is a commonly used measure of peripheral endothelial function.

Our aim was to test by a PET-based method whether microvascular dysfunction exists already in early stages of CKD as an early marker of coronary dysfunction. Brachial artery FMD was used as a measure of peripheral endothelial function.

**Subjects and methods**

**Subjects**

A total of 22 patients with moderate to severe ESRD kidney failure (CKD stage 3, GFR 37 ± 7 ml/min; CKD stage 4, GFR 21 ± 5 ml/min; CKD stage 5, GFR 12 ± 5 ml/min) and 10 healthy controls (GFR 76 ± 5 ml/min) were included in the study. The patients were recruited from a nephrology outpatient clinic of Turku University Hospital. The aetiology of CKD was polycystic kidney disease in 7 of 22 patients, chronic glomerulonephritis in 8 (3 IgA nephropathy, 1 FSGS, 2 vasculitis, 2 undetermined), chronic interstitial nephritis in 4, postrenal obstruction caused by benign prostate hyperplasia in 1, secondary amyloidosis related to juvenile rheumatoid arthritis in 1 and hypertensive nephrosclerosis in 1.

Patients with any signs or symptoms of CV disease and patients with diabetes were excluded, since our purpose was to investigate, as selectively as possible, the effect of CKD on microvascular function. Healthy, similarly aged volunteers served as controls. None of the healthy controls were on any medication or had a history of kidney or heart disease. The demographics of the patients and controls are shown in the Table 1.

All patients and controls gave written informed consent. The study was approved by the Ethical Committee of the Turku University Central Hospital, and it was conducted in accordance with the Declaration of Helsinki as revised in 1996.

**Methods**

**Assessment of renal function**

The assessment of renal function was based on the estimated glomerular filtration rate (eGFR) equation from the modification of diet in renal disease (MDRD) study [17]. CKD was referred according to the KDOQI definition.

**Study design**

The imaging studies were performed after a 10-h overnight fast. Alcohol, smoking and caffeine were prohibited for 3 days before assessment. None of the subjects had symptoms of acute infections within a week prior to or during the study. Brachial artery FMD was measured before the PET study. A venous catheter was inserted in an antecubital vein for injection or during the study. Brachial artery FMD was measured before the PET study.

**Image acquisition, processing and correction**

The subjects were positioned supine in PET tomograph (ECAT 931/08-12, Siemens/CTI Inc., Knoxville, TN, USA, or GE Advance, General Electric, Milwaukee, WI, USA). Correct positioning of the study objects was ascertained on a rectilinear transmission scan followed by a transmission scan for photon attenuation correction. For each PET study, 900–1400 MBq of $^{15}$O water was injected over 20 s. $^{15}$O water was injected intravenously over 2 min, and dynamic scanning was started. Myocardial perfusion was measured at baseline and 2 min after the end of intravenous administration of dipyridamole (0.56 mg/kg body weight over period of 4 min). All PET data were corrected for dead time, decay and measured photon attenuation. Images were processed with the standard reconstruction algorithm.

**Calculation of myocardial perfusion**

For the PET studies, regions of interest (ROIs) were drawn on the left ventricle (LV) myocardium on an average of four midventricular transaxial planes covering the septum, anterior wall, lateral wall and the whole LV myocardium. An LV cavity ROI was drawn and used as the input function.
for determination of the LV time–activity curve [19]. The ROIs outlined in the baseline images were copied to the images obtained after dipyridamole administration. Regional myocardial perfusion (ml/g tissue per min) was calculated with a single compartment model [20]. To enhance the accuracy of the measurements, the mean blood flow values at rest and after dipyridamole were calculated and used in the further analysis.

CPR was defined as the ratio of myocardial perfusion after dipyridamole to baseline. Because basal myocardial perfusion is closely related to the rate–pressure product (RPP, an index of myocardial work), basal myocardial perfusion values were corrected for RPP for each individual by the following equation: corrected basal myocardial perfusion = measured basal myocardial perfusion × (mean RPP of all the subjects/individual RPP). Because myocardial perfusion during dipyridamole-induced vasodilatation was closely related to perfusion pressure [almost equal to the mean arterial pressure (MAP)], myocardial perfusion values during dipyridamole-induced vasodilatation were corrected by the MAP for each individual by the following equation: corrected hyperaemic myocardial perfusion = measured hyperaemic myocardial perfusion × (mean MAP of all the subjects/individual MAP).

**Endothelial function test**

All studies were performed using an Acuson Sequoia ultrasound machine with an 8/15 MHz linear array transducer. Two experienced vascular sonographers blinded to clinical and laboratory characteristics of the study subjects performed the scans. Brachial artery diameter was measured from B-mode ultrasound images. In all studies, scans were obtained at rest and during reactive hyperaemia. The subjects laid quietly for 10 min before the scan in the stable room temperature between 20 and 25°C. The left brachial artery was scanned in longitudinal section 2–15 cm above the antecubital crease. Depth and gain settings were optimized. When a satisfactory transducer position was found, the position was marked on the skin and the arm remained in the same position throughout the study. A resting scan was performed, and arterial flow velocity was measured using a Doppler signal. Increased flow was then induced by inflation of a pneumatic tourniquet placed around the forearm (distal to scanned part of the artery) to a pressure of 250 mmHg for 4.5 min, followed by pressure release [21].

A second scan was taken 30–120 s after the cuff deflation. The flow velocity recording was repeated during the first 15 s after the cuff was released. All brachial ultrasound scans were recorded on super-VHS videotapes for later analysis. The arterial diameter was measured at a fixed distance from an anatomic marker (e.g. fascial plane) using ultrasonic calipers. Measurements were taken at end diastole (incident with the R wave on a continuously recorded ECG) from the anterior to the posterior intima lumen interface (i-line). The hyperaemic diameter was recorded continuously for 2 min. Maximal FMD was defined as the greatest percentage change relative to the baseline diameter and used in the analyses.

**Statistical analysis**

Results are expressed as mean value ± SD. Normality of variables was assessed by the Shapiro–Wilks test. Student’s paired t-test was used for normally distributed variables. The comparison between the groups was performed by the t-test or the Kruskal–Wallis test as appropriate. All statistical analyses were performed with the SAS statistical program package (SAS Institute Inc., Cary, NC, USA). Statistical significance was inferred at $P < 0.05$.

**Results**

**Study subjects**

The characteristics of the study subjects are shown in Table 1. Healthy volunteers were non-smokers. Three of the patients were smokers, all of them from the CKD 5 group. All CKD patients were on antihypertensive medication. All but one patient used either angiotensin-converting enzyme inhibitor (ACEI) or angiotensin receptor blocking agent (ARB). Diuretics were used by 16 out of 22 patients, calcium channel blockers by 9 and beta blockers by 9. Nine patients had a combination of three and four patients a combination of four antihypertensive medications.

The blood haemoglobin (B-Hb) level was lower in patients with CKD than in the controls ($P < 0.05$). The WHO criteria for anaemia (B-Hb < 130 g/l in men and < 120 g/l in women) were fulfilled in one patient in the CKD 3 group, in three patients in the CKD 4 group and in all six patients in the CKD 5 group. Hb did not show any significant correlation with myocardial perfusion values. Only three patients used erythropoetin: one in the CKD 4 group (erythropoetin β 4000 IU per 10 days) and two in the CKD 5 group (one with erythropoetin β 4000 IU per 10 days and the other with darbepoetin 20 µg per week).

Total cholesterol concentration was higher in the CKD 3 group. In the CKD 5 group, high-density lipoprotein (HDL) cholesterol and total cholesterol were lower ($P < 0.05$) and the use of statins more frequent than in other groups. Calcium phosphorus product (Ca × Pi) was higher in the CKD 5 group (Table 1). It did not show any significant correlation with myocardial perfusion values.

High-sensitivity CRP was clearly higher in CKD patients as compared to controls, but this trend was not statistically significant (4.3 ± 6.0 versus 1.2 ± 0.5). It did not correlate with the myocardial blood flow. Brain natriuretic peptide (proBNP) levels were higher in CKD patients than in healthy controls, and there was a statistically significant negative correlation between proBNP levels and eGFR. Figure 2 (Spearman correlation coefficient—0.79, $P < 0.0001$).

**Haemodynamic measurements during imaging**

HR increased significantly at maximal vasodilatation in all CKD patients and controls ($P < 0.05$) (Table 2). There was no difference in blood pressure levels between the groups either at rest or during the maximal vasodilatation (Table 2).

**Echocardiography**

Echocardiography was performed on 18 out of 22 patients and all the controls. The data were not available for four
Table 2. Haemodynamic measurements during imaging

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>HR (bpm) at rest</th>
<th>HR (bpm) at max</th>
<th>MAP (mmHg) at rest</th>
<th>MAP (mmHg) at max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>10</td>
<td>57 ± 6</td>
<td>77 ± 12*</td>
<td>101 ± 8</td>
<td>98 ± 9</td>
</tr>
<tr>
<td>CKD 3</td>
<td>5</td>
<td>63 ± 11</td>
<td>84 ± 5*</td>
<td>97 ± 4</td>
<td>97 ± 3</td>
</tr>
<tr>
<td>CKD 4</td>
<td>11</td>
<td>64 ± 10</td>
<td>86 ± 7*</td>
<td>103 ± 7</td>
<td>102 ± 9</td>
</tr>
<tr>
<td>CKD 5</td>
<td>6</td>
<td>63 ± 7</td>
<td>78 ± 10*</td>
<td>94 ± 9</td>
<td>92 ± 13</td>
</tr>
</tbody>
</table>

MAP = mean arterial pressure. Values are mean ± SD. *P < 0.05 HR at maximal vasodilatation compared to resting values in all groups.

Table 3. Myocardial perfusion and coronary flow reserve

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean myocardial blood flow at rest (ml/min/g tissue)</th>
<th>Mean myocardial blood flow at stress (ml/min/g tissue)</th>
<th>Mean myocardial perfusion reserve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>10</td>
<td>0.87 ± 0.14</td>
<td>2.47 ± 0.85</td>
<td>2.93 ± 1.05</td>
</tr>
<tr>
<td>CKD 3</td>
<td>5</td>
<td>1.18 ± 0.18*</td>
<td>3.30 ± 1.28</td>
<td>3.21 ± 1.31</td>
</tr>
<tr>
<td>CKD 4</td>
<td>11</td>
<td>1.25 ± 0.32*</td>
<td>3.17 ± 1.21</td>
<td>2.67 ± 1.06</td>
</tr>
<tr>
<td>CKD 5</td>
<td>6</td>
<td>1.27 ± 0.19*</td>
<td>2.61 ± 1.04</td>
<td>2.12 ± 0.82</td>
</tr>
</tbody>
</table>

Values are mean ± SD. *P < 0.001 controls versus CKD 3–5.

Fig. 3. Baseline myocardial perfusion in relation to eGFR. eGFR = estimated glomerular filtration rate according to MDRD study equation; Spearman correlation coefficient—0.63, P = 0.001.

patients: one from the CKD 4 group and three from the CKD 3 group. According to the ECG, none of these four patients had left ventricular hypertrophy (LVH). The left ventricular mass (LVM) (pooled CKD 3–5 versus controls, 223 ± 57 versus 234 ± 52 g, NS) and left ventricular mass index (LVMi) (117 ± 22 g/m² in controls versus 114 ± 26 g/m² in CKD patients, NS) were similar in patients and controls. The left atrium (LA) diameter was 35 ± 3 mm in healthy controls and 39 ± 4 in CKD patients, P < 0.01.

Myocardial blood flow and coronary flow reserve

RPP-corrected myocardial perfusion at baseline was higher in patients with CKD than in healthy controls. The increase in baseline perfusion was statistically significant as compared to healthy controls, P < 0.001, and negatively correlated with eGFR (Spearman correlation coefficient—0.63, P = 0.0001) (Table 3, Figure 3). The hyperaemic myocardial perfusion was not different between the groups leading to equal CFR in all groups (Table 3). However, there was a tendency to diminished CFR according to the stage of CKD.

Table 4. Brachial artery flow mediated peak dilatation

<table>
<thead>
<tr>
<th></th>
<th>Controls</th>
<th>CKD 3</th>
<th>CKD 4</th>
<th>CKD 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resting brachial artery diameter (mm)</td>
<td>3.6 ± 0.5</td>
<td>3.3 ± 0.6</td>
<td>3.7 ± 0.6</td>
<td>3.4 ± 1.2</td>
</tr>
<tr>
<td>FMD (%)</td>
<td>9.6 ± 2.5</td>
<td>6.0 ± 5.0*</td>
<td>5.7 ± 4.6*</td>
<td>5.6 ± 3.2*</td>
</tr>
</tbody>
</table>

FMD = flow mediated dilatation, peak %. Values are mean ± SD. *P < 0.03 controls versus CKD 3–5.

Brachial artery flow-mediated dilatation

The brachial artery diameter at rest was comparable in all groups. The brachial artery FMD response was higher in healthy controls than in CKD patients. No statistically significant differences between the three CKD groups were found, although there was a trend towards lower values according the stage of CKD (Table 4).

Discussion

We investigated whether coronary and peripheral artery dysfunction develop in early stages of CKD. We demonstrate that coronary hyperaemic perfusion and CFR are well preserved in CKD patients, while the myocardial perfusion at rest is increased. The increased resting perfusion is observable already in mild CKD, and it correlates with the degree of eGFR. Similarly, the FMD, a marker of peripheral endothelial function, was abnormal in all CKD patient groups.

Despite the evidence of more frequent coronary atherosclerosis in patients with CKD [22–24], quantitative perfusion and perfusion reserve in these patients have been sparsely studied. In a study of 605 patients referred for invasive coronary angiography, CFR was evaluated using...
intracoronary adenosine [25]. It was found that patients with reduced GFR had lower CFR than those with normal GFR. Based on that study, it is not possible to know whether this was caused by increased resting or decreased hyperaemic flow velocities since these were not reported. Even more importantly, the decrease was quite modest (13%) and was completely explained by other variables (gender, age, BMI) and concomitant diseases such as hypertension. In another study, invasive measurements were performed in patients with diabetes but no signs of angiographically evident coronary artery disease were found [26]. One-third of the patients had normal kidney function, and the rest had stage 5 CKD. Decreased CFR both in stenosed and non-stenosed coronary arteries in patients with diabetes and CKD was observed. Interestingly, this decrease was explained mainly by increased flow velocity at baseline rather than an inability to reach the same flow velocity at peak hyperaemia as seen in the control groups. Similar decrease of CFR was also seen in dialysis patients without diabetes [27].

An invasive approach has been typically limited to patients with clinical indications for cardiac catheterization leading to obvious referral bias. Therefore, noninvasive studies are warranted, allowing avoidance of referral bias as well as the effects of other confounding factors and disease for the results. In addition, a major limitation of these studies is the fact that the velocity measurements do not take into account the dilatation of coronary vessel during hyperaemia. Even a small change in vessel diameter has profound effects on total flow. This makes the quantification of volume of blood flow impossible. Furthermore, the mass of myocardium supplied by the measured epicardial artery is another unknown parameter. In the present study, the noninvasive measurement of absolute myocardial blood flow was used in order to avoid the abovementioned technical limitations.

Similar quantification of myocardial perfusion by PET was also used in a recent study [28], in which four prevalent haemodialysis patients without angiographically significant CAD were studied. Predialysis-basal myocardial perfusion values were at similar level to our findings (∼1.3 ml/g/min), and remarkable reduction in global and segmental myocardial flow was detected during haemodialysis. However, unlike in our study, hyperaemic flow or flow reserve was not measured.

**The effects of concomitant factors and diseases**

Several concomitant diseases are seen in patients with CKD, which makes it difficult to dissect the effects CKD itself on vascular pathophysiology. However, our aim was to study the effect of, as selectively as possible, pure uraemia to microvascular function. Thus, in the subject selection process some of the typical confounding factors were excluded. Diabetics as well as patients with symptomatic CAD were not included, and the patient groups were similar in age, BMI and gender. However, patients with CKD had more antihypertensive medication and minor differences in lipid profile, lower Hb levels and higher Ca × Pi, which are characteristic of patients with CKD. Smoking was quite infrequent in our study subjects, which is in line with the low numbers of smokers in the Finnish population according to the recent European WHO report (E80607). Furthermore, based on previous studies, it is unlikely that smoking would affect myocardial perfusion at rest [29].

Hypervolaemia and the activated renin angiotensin system (RAS) have long been acknowledged as major determinants of hypertension in CKD. Even borderline arterial hypertension is associated with alterations in myocardial haemodynamics by reducing coronary vasodilatory capacity. Noticeably, basal myocardial perfusion still remains unchanged compared to healthy controls [30,31]. Hypertension was common in CKD patients also in our study, but actual blood pressure levels were comparable due to antihypertensive treatment. The effect of antihypertensive treatment on myocardial perfusion has been investigated in a number of studies [32–34]. ACEIs, ARBs and calcium channel blockers improve myocardial perfusion during maximal vasodilatation whereas betablockers may reduce it [32,33,35–37]. However, according to these studies they do not seem to have an effect on resting myocardial perfusion. The possible effect of antihypertensive medication was further controlled by our use of RPP-corrected values for myocardial perfusion. Although the effect of antihypertensive treatment cannot be completely excluded in our study results, no effect on resting flow values has been found in previous studies. On the other hand, as antihypertensive medication usually improves myocardial perfusion after hyperaemia, it could explain the well-preserved CFR in our patients.

The effect of ageing on the CV system is similar to that which occurs with hypertension. However, it has been shown that myocardial blood flow under basal and hyperaemia conditions is roughly comparable up to 60 years of age [38].

LVH has been associated with impaired hyperaemic myocardial perfusion [39–41]. However, in our study the LVM and the LVMI were at the same range in both the healthy controls and the CKD patients. Cross-sectional studies show that LVH is the most frequent cardiac alteration in CKD [42,43]. Therefore, it was somewhat surprising that there was not any difference in the LVM between the study groups. It probably reflects the fact that our CKD patients used either ACEIs or ARBs as part of their antihypertensive medication. It is well known that these drugs are potent reducers of LVH in hypertensive patients. LA diameter as well as proBNP was increased in our patients, which implicates a certain stress on the myocardium.

Macrovascular disease develops rapidly in uraemic patients and is responsible for the high incidence of ischaemic heart disease. However, myocardial infarction is responsible for only 30–50% of all cardiac deaths [44]. It has been shown that basal myocardial blood flow remains constant regardless of the severity of coronary artery stenosis [45] up to very severe degree of stenosis (>95% of diameter narrowing). During hyperaemia, flow progressively decreases when the degree of stenosis is >40% or more and does not differ significantly from basal flow when stenosis is 80% or greater [45]. In the present study, hyperaemic flow values were comparable with the controls and, furthermore, well preserved in quantitative terms. Thus, our results implicate that our patients do not have functionally significant coronary artery or microvascular disease. Furthermore, since
the perfusion measurements were performed already during years 2003–04, we have been able to follow-up the patients for 4 years. Only one patient from the CKD stage 4 group has experienced a CV event (coronary artery by-pass operation) during the follow-up. Thus, the clinical data also support the absence of significant coronary heart disease in our patients.

Patients with CKD and patients on haemodialysis treatment show a sustained overactivity of sympathetic nervous system (SNS). Although sympathetic overactivity may lead to increased perfusion due to increased cardiac work load, it also seems to induce increased coronary vascular resistance in hypertensive patients [30]. However, we have previously shown that basal myocardial blood flow is similar in normotensive patients compared to hypertensive patients with higher plasma norepinephrine concentrations [46].

Anaemia is one of the typical findings in CKD patients with GFR <40 ml/min. It has been linked with increased resting coronary flow [47]. Although the level of B-Hb was lower in the CKD patients than in controls, distinct anaemia was only seen in the CKD 5 group. Only one patient in the CKD 3 group fulfilled the WHO criteria for anaemia and yet, the disturbances of the myocardial perfusion were already seen in that group. We did not observe any statistically significant correlation between B-Hb level and basal myocardial perfusion in our study. Only three of the patients were using erythropoiesis-stimulating agent: one in the CKD 4 group and two in the CKD 5 group. It is unlike that erythropoietin had any effect on myocardial perfusion values since the higher levels of flow were already detected in the CKD 3 group.

Endothelial dysfunction

Our study indicates that ED is found in patients with CKD. ED has been implicated in the pathophysiology of several forms of CV disease, including chronic heart failure, diabetes mellitus, hypertension, coronary heart disease and CKD [48,49]. The presence of ED is a predictor of future CV disease [50] and can be observed by measuring FMD [51]. The degree of ED correlates with worsening kidney function; the higher the stage of CKD, the lower the levels of FMD [12,52]. The FMD values of our patients with different stages of CKD were in the same range as reported in these studies. The absence of a negative relationship between declining GFR and FMD in our study may be due to small sample size. A substudy of the LIFE study [53] suggested that FMD and CFR are positively correlated but in many other studies correlation with these two parameters has been weak.

Study limitations

Considering the high incidence of CV disease and mortality among CKD patients, one of the limitations of our study is uncertainty about the anatomical status of the coronary arteries in our patients. However, diabetes and symptomatic angina were both exclusion criteria in our study. Myocardial perfusion values were also normal during stress, which has been very accurate in ruling out significant obstructive CV disease. The patients were followed up for 4 years, and only one CV event was detected among our patients. All our CKD patients had hypertension, although there was no statistically significant difference in systolic or diastolic blood pressure values during the antihypertensive medication compared to healthy controls. Ideally, another control group of hypertensive patients without CKD would have given further information. However, the previous studies on myocardial perfusion in hypertensive patients with or without LVH have shown alterations especially in hyperaemic perfusion. Considering that diabetes is the major cause of CKD in developed countries, these results are applicable only to a fraction of CKD patients. Also the relatively small sample size, limited by the study methodology, may have affected our results.

In conclusion, increased resting myocardial perfusion is present in patients with CKD. Whether this is due to increased myocardial demand, hypervolaemia or increased sympathetic activity remains unclear. Although abnormal endothelial function in the brachial artery is observed in these patients, they retain the ability to increase the myocardial flow during the dipyridamole-induced hyperaemia as well as healthy controls. This suggests that the mechanisms involved in abnormal peripheral and coronary function may be different.

Conflict of interest statement. None declared.

References

The heart in kidney disease


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