SYSTOLIC TIME INTERVALS BEFORE AND AFTER HAEMODIALYSIS

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Summary

We investigated changes of haemodynamics during haemodialysis in 107 patients by noninvasive measurement of systolic time intervals. Heart rate and pre-ejection period index increased and systolic and diastolic blood pressure, left ventricular ejection time and isovolumic contraction time decreased. We found, that if the pre-dialysis ejection fraction (EF) was more than 55 per cent, post-dialysis EF decreased by about 10 per cent. However if pre-dialysis EF was less than 55 per cent, post-dialysis EF increased by five per cent. Regarding cardiothoracic-ratio, Sokolow-Lyon-Index (SLI) and repolarisation disorders we found the most remarkable decrease in EF in patients with normal sized hearts with enlarged SLI and repolarisation disorders.

Introduction

There are various factors implicated in the pathogenesis of heart failure in uraemic patients, for example, coronary heart disease, hypertension, hyperpolaemia, disorders of potassium and calcium metabolism, uraemic pericarditis and anaemia.

We investigated the influence of haemodialysis on cardiac function. As patients are already stressed by multiple punctures and the haemodialysis procedure we used a noninvasive measurement of the systolic time intervals.

Patients and methods

We studied 107 patients, 50 women and 57 men, with a mean age of 54±12 years (range: 23–79) immediately before and after haemodialysis. Dialysis time was normally 3 x 4.5hr and all patients had an acetate dialysate and parallel flow (Gambro Lundia major 11.5μ) or hollow fibre artificial kidneys (Gambro HF 120). The lead II ECG, apexcardiogram, phonocardiogram and carotid pulse tracing were recorded on a Hellige Multiscriptor EK 36 with the patient lying on his left side.
We determined the following parameters: the left ventricular ejection time (LVET), from the upstroke to the incisural notch of the carotid pulse tracing, the pre-ejection period (PEP = QS2 - LVET), the A-wave amplitude (in per cent of the entire systolic contraction wave of the apexcardiogram) and the heart rate (HR). PEP-index was calculated by the PEP-HR regression equation \( PEP_1 = PEP + 0.4 \times HR \), LVET-index by the LVET- HR regression equation \( LVET_1 = LVET + 1.7 \times HR \) for men and \( LVET_1 = LVET + 1.6 \times HR \) for women. The ejection fraction was calculated by using Weissler’s index in Garrard’s formula: \( EF = 1.125 - 1.25 \times PEP/LVET \) [1].

Values obtained in five consecutive cardiac cycles were averaged for each determination. In addition patients body weight and blood pressure were measured before and after haemodialysis.

Furthermore we took into account some clinical parameters, the cardio-thoracic-ratio (CTR), the Sokolow-Lyon-Index (SLI = S in V_2 + R in V_5) and the presence of repolarisation disorders.

Results

The changes in haemodyanmic parameters during haemodialysis are shown in Table I. We found a significant increase in heart rate and pre-ejection period index (PEP_1) and a significant decrease in systolic and diastolic blood pressure, left ventricular ejection time, left ventricular ejection time index, electro-acoustical systole (QA_2), electroacoustical systole corrected for heart rate (QA_21) and the A-wave amplitude. The pre-ejection period, that was not corrected for heart rate did not change significantly. We divided pre-ejection period into QI and the isovolumic contraction time (IVC = time of left ventricular pressure rise) and found a significant prolongation of QI and a significant shortening of the IVC.

**TABLE I. Pre- to post-haemodialysis changes**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>before mean</th>
<th>SD</th>
<th>after mean</th>
<th>SD</th>
<th>mean change</th>
<th>significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (b/min)</td>
<td>76.0</td>
<td>12.7</td>
<td>89.7</td>
<td>15.3</td>
<td>+13.7</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>BP_sys (mmHg)</td>
<td>138.8</td>
<td>21.5</td>
<td>130.6</td>
<td>25.5</td>
<td>-8.2</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>BP_dias (mmHg)</td>
<td>79.3</td>
<td>12.1</td>
<td>75.5</td>
<td>13.8</td>
<td>-3.8</td>
<td>p&lt;0.005</td>
</tr>
<tr>
<td>LVET (sec)</td>
<td>0.288</td>
<td>0.032</td>
<td>0.239</td>
<td>0.031</td>
<td>-0.049</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>LVET_1 (sec)</td>
<td>0.413</td>
<td>0.023</td>
<td>0.387</td>
<td>0.022</td>
<td>-0.026</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>PEP (sec)</td>
<td>0.102</td>
<td>0.017</td>
<td>0.102</td>
<td>0.020</td>
<td>0.000</td>
<td>NS</td>
</tr>
<tr>
<td>PEP_1 (sec)</td>
<td>0.133</td>
<td>0.016</td>
<td>0.138</td>
<td>0.019</td>
<td>+0.004</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>PEP/LVET</td>
<td>0.361</td>
<td>0.076</td>
<td>0.435</td>
<td>0.116</td>
<td>+0.074</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>QI (sec)</td>
<td>0.065</td>
<td>0.009</td>
<td>0.069</td>
<td>0.011</td>
<td>+0.003</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>IVC (sec)</td>
<td>0.037</td>
<td>0.014</td>
<td>0.032</td>
<td>0.016</td>
<td>-0.005</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>QA_2 (sec)</td>
<td>0.391</td>
<td>0.037</td>
<td>0.341</td>
<td>0.034</td>
<td>-0.049</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>QA_21 (sec)</td>
<td>0.547</td>
<td>0.024</td>
<td>0.525</td>
<td>0.021</td>
<td>-0.022</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>A-wave (%)</td>
<td>14.3</td>
<td>5.6</td>
<td>11.2</td>
<td>6.2</td>
<td>-3.1</td>
<td>p&lt;0.001</td>
</tr>
</tbody>
</table>

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Haemodialysis was associated with a significant decrease (p<0.001) of the mean value of ejection fraction (EF) from 67.4 per cent to 58.1 per cent (normal range 60 per cent to 75 per cent). Changes in EF depend on the pre-dialysis EF. In patients with a normal pre-dialysis EF we found a decrease of about 10 per cent whereas patients with a pre-dialysis EF of less than 55 per cent showed an increase of about five per cent (Figure 1). The pre-dialysis EF was also independent of patients age (range: 22.8 to 79.2 years), and duration on haemodialysis (range: 1 to 186 months).

Figure 1. Relationship between pre-dialysis EF and change in EF
Figure 2. Changes in EF during haemodialysis regarding cardio-thoracic-ratio (CTR), Sokolow-Lyon-Index (SLI) and repolarisation disorders

As shown in Figure 2, we divided all patients into different groups considering the presence of repolarisation disorders, enlarged cardio-thoracic-ratio (CTR > 0.5) or Sokolow-Lyon-Index (SLI > 3.5 mV). Patients that had neither repolarisation disorders, nor an enlarged CTR of SLI (column 2) had a pre-dialysis EF of 67.9 per cent and a post-dialysis EF of 57.4 per cent. These values resemble those of the whole group (column 1). Patients with increased CTR, that had no repolarisation disorders and a normal SLI (column 4) had an EF in the upper normal range before haemodialysis and showed only a slight decrease after haemodialysis (from 73.4 per cent to 68.8 per cent, p < 0.05). Patients with normal sized hearts on chest X-ray, but increased SLI with or without repolarisation disorders (columns 5 and 6) showed the most considerable decrease in EF (from 64.6 per cent to 51.3 per cent, p < 0.02 and from 66.8 per cent to 47.0 per cent, p < 0.001), although the pre-dialysis EF was in the lower normal range.

The CTR seems to be a very important factor influencing the change in EF. We found a positive correlation between the change in EF and the CTR (p < 0.01), whereas the pre-dialysis EF did not depend on CTR. The decrease in EF is significantly diminished as the CTR increases.

Mean weight loss in our patients during haemodialysis was 1.9 kg (range: 0.0 to 5.4 kg). The change in the heart rate corrected pre-ejection period was found to correlate to the body weight loss (PEP = 3.692 x BW - 2.057, p < 0.01).

Furthermore, we tried to find differences between digitalised and not digitalised patients (42 were on digitoxin, 65 were not). Neither the pre-dialysis EF,
nor the change in EF during haemodialysis were significantly different in either groups.

Discussion

Invasive measurement of haemodynamic parameters is the most accurate method of estimating heart function; however, this is of limited use in patients on haemodialysis. Goss et al [2] found a decrease in cardiac index of 4.26 to 2.98 l/min/m² and a reduction of stroke index from 51 to 37ml/m² after dialysis. The total systemic resistance increased from 2.025 to 2.968 dyn/sec/cm⁻⁵/m².

In contrast to the invasive methods, noninvasive methods (such as estimating the systolic time intervals and echocardiography) are without danger and can be repeated often. This is of significance when carrying out long-term studies in the same patients.

Similar to results obtained by Bornstein, Zambrano et al [3] we found a shortening of LVET and LVET₁; however we found an increase of heart rate and decrease of systolic and diastolic blood pressure. Bornstein reported unchanged heart rate and blood pressure. In contrast to reports by Endou et al [4] we observed an increase in CI-time and a shortening of isovolumic contraction time. Moreover, we confirmed Prakash and Wegner's [5] observation, that PEP remains the same, however, in our study PEP₁ lengthens.

A lengthening of PEP₁ demonstrates that the time needed to achieve diastolic aortic pressure is also lengthened. This may be due either to a slowed fibre-shortening, or to an increased diastolic aortic pressure, or to both. Because diastolic blood pressure decreases during dialysis, we would expect a shortening of PEP₁. The second factor is a slowed fibre-shortening which may be due to two reasons: a decreased end-diastolic stretch or a reduction of intrinsic contractility. However, shortening of IVC seems to be an argument for an improved intrinsic contractility. When there is a decrease in preload, an increase in IVC is to be expected.

The intensification of contractility could arise from an increase in ionised calcium during haemodialysis and from increased sympathetic activity as a reaction to volume loss and fall in blood pressure.

The lengthening of PEP₁ seems to be predominantly determined by a decrease in preload. This is confirmed by the correlation between changes in PEP₁ and weight loss.

LVET reduction also seems to be determined by a fall in preload with consequent decrease in stroke volume [2].

An improvement of EF in patients with poor pre-dialysis EF was in contrast to a fall in EF found in patients with normal pre-dialysis EF. We attributed this phenomenon to different starting points on the Starling-curve. Patients with poor pre-dialysis EF are on the declining part of the curve (exceeded preload reserve) and due to preload decline experience a left-shift towards a higher section of the curve. Patients with normal pre-dialysis EF (on the rising part of the curve) experience a definitive deterioration of EF due to left-shift.

Patients with enlarged CTR, without repolarisation disorders and with normal
SLI, show an above average high pre-dialysis EF. This is due to an improved end-diastolic stretch. These patients also show a considerably smaller decrease in EF compared to other patients; this is the result of a left-shift on the top of the Starling-curve, which is determined by the falling preload.

In contrast to other groups, patients with hypertrophic (but not enlarged) hearts, who have an especially poor adaptability to volume changes, seem to have a very marked decrease in EF.

In patients with hypertrophic hearts and repolarisation disorders, a strict volume control is especially important. This is necessary because a rapid volume increase can exceed preload reserve, and on the other hand, a rapid volume decrease during haemodialysis can lead to a sharp fall in EF.

References

1 Garrard CL, Weissler AM, Dodge HT. Circulation 1970; 42: 455