LEFT VENTRICULAR PERFORMANCE IN CHRONIC RENAL FAILURE BEFORE AND AFTER HEMODIALYSIS ASSESSED BY SYSTOLIC TIME INTERVALS

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The purpose of the present study was to examine noninvasively the myocardial performance before and after hemodialysis in 40 patients of chronic renal failure. Using systolic time intervals, the following results were obtained.

1) Left ventricular ejection time was shortened significantly. The reduction of circulating blood volume estimated by the body weight change seemed to be responsible for this finding. 2) Pre-ejection period seemed to be a sensitive indicator of the left ventricular performance in hemodialysis. 3) The less the circulating blood volume, the less the suppression of cardiac performance. 4) Left ventricular function in patients without cardiomegaly was improved. 5) Left ventricular function tended to improve in the young age group.

The present study demonstrated that the left ventricular performance tended to be suppressed in older age patients, in patients with cardiomegaly and in the cases with excessive removal of circulating blood volume during dialysis. The significance of noninvasively obtained left ventricular hemodynamic parameters in patients with hemodialysis was discussed.

THE hemodynamics in patients on chronic hemodialysis is influenced by many factors associated with chronic renal failure such as anemia, hypertension, electrolytes and acid-base imbalance and myocardial damage. Furthermore, the effect of arteriovenous shunting and hemodialysis per se make the hemodynamic changes more complicated and unexplicable. Since the first study of Del Greco and Simon,¹ many investigators²⁻⁷ have reported the hemo-

dynamic changes following hemodialysis by invasive method, but difficulties exist in performing successive invasive studies in parallel with clinical course. Although the systolic time intervals (STIs) established by Weissler⁸⁻¹² have been criticized the tendency to make some overestimation, still they remain as one of the useful quantitative methods for determining left ventricular performance.¹³⁻¹⁷ Previously, we have demonstrated that the systolic time intervals correlated well with parameters of left ventricular function obtained by invasive methods.^{18,19}

The purpose of this report is to study the hemodynamic changes using STIs in 40 cases with chronic renal failure before and after hemo-

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Fig.1. Changes in the heart rate and STIs following arteriovenous shunting. Vertical lines represent standard deviation.

dialysis, and in 6 of these the effect of arteriovenous shunting was also examined.

MATERIALS AND METHODS

Forty patients were studied, 18 males and 22 females under chronic hemodialysis. Cases with primary heart disease or extensive pericardial effusion were excluded from this study. The mean age of the cases was 47.3 years (range: 20 to 75). The average duration of the dialysis prior to this study was 1.5 years. The mean value of hematocrit and the cardiothoracic ratio (CTR) were $21.3 \pm 4.3\%$ and $52.4 \pm 5.8\%$, respectively. Coil of Hollow-Fiber hemodialyzers have been used for chronic hemodialysis at a dialysate flow rate of 500 ml/min and blood flow rate of 200 ml/min. The average time needed for each hemodialysis was 5 hours.

Electrocardiogram, phonocardiogram and carotid pulse tracing were simultaneously recorded according to the methods previously describ-

Fig.2. Changes in the blood pressure and heart rate following hemodialysis.

Fig.3. Changes in the STIs following hemodialysis. Horizontal dotted lines indicate the normal range.

ed.¹⁸⁻²² STIs were recorded immediately before and after the hemodialysis. Before starting chronic hemodialysis, 6 patients (mean age 45.3 years) also had STI determinations before and

Fig.4. Changes in the STIs following hemodialysis. Cases were divided into three subsets according to the amount of body weight reduction after dialysis.

Fig.5. Changes in the STIs in 12 cases with and 28 cases without cardiomegaly following hemodialysis.

seven days after the arteriovenous shunting.

The four basic STIs consisted of R-R interval, pre-ejection period (PEP), left ventricular ejection time (LVET) and total electromechanical systole (QS2). Indices were corrected by Weissler's formula.¹⁰ Thus, $\Delta QS2$, ΔET and ΔPEP were obtained by subtracting predicted values corresponding to the heart rate from observed values. No patients were on digitalis. Control group consisted of 40 normal subjects.

RESULTS

Arteriovenous shunting:

Changes of the heart rate and STIs before and after shunting in 6 patients were summarized in Fig. 1. All the changes were statistically insignificant.

Hemodialysis:

a) Changes in STIs: Heart rate increased significantly with hemodialysis ($P < 0.05$) (Fig. 2),

but no significant change was observed in blood pressure. Significantly higher $\Delta QS2$ and ΔET declined to lower normal ranges after the dialysis ($P < 0.01$) (Fig. 3). A slightly higher ΔPEP ($P < 0.05$) tended to reduce during dialysis and reached down to the normal level. Relatively higher PEP/LVET ratio (0.337 ± 0.057) further increased significantly ($P < 0.05$) after dialysis (0.370 ± 0.064).

b) Effect of body weight reduction after dialysis: Forty cases were subdivided into 3 groups according to the amount of body weight reduction after dialysis (Group 1: 14 cases of a reduction of less than 1 kg; Group 2: 19, 1 to 2 kg; and Group 3: 7, more than 2 kg) (Fig. 4). There was no significant difference in $\Delta QS2$, ΔET , ΔPEP and PEP/LVET before dialysis among 3 groups, but after hemodialysis, the decrease of ΔET was significantly marked in Group 3, so that PEP/LVET ratio significantly increased ($P < 0.05$), which was significantly higher than that of Group 1 ($P < 0.05$).

Fig. 6. Changes in the STIs following hemodialysis. Cases were divided into three subsets according to the age.

Fig. 7. Changes in the STIs following hemodialysis. Cases were divided into three subsets according to the duration of hemodialysis.

c) Effect of cardiac size: In Fig. 5, changes in STI in cases with and without cardiomegaly of more than 50% in CTR were shown. Before dialysis, ΔQS₂, ΔET and ΔPEP were high in patients with cardiomegaly. However, statistical significance was seen only in ΔQS₂ ($P < 0.01$), so that there was no significant difference in PEP/LVET ratio. After dialysis, significant increase in PEP/LVET ratio was noted only in the group with cardiomegaly.

d) Effect of age: In Fig. 6, the changes of STIs are shown for various age groups. Before dialysis, there was no statistical significance in ΔQS₂ among 3 age groups, though a tendency of shortening was seen in the youngest age group. After dialysis, ΔQS₂ in each group shortened significantly ($P < 0.01$), and it was especially marked in the youngest age group. Before dialysis, ΔET was significantly short ($P < 0.01$) in the youngest age group. After dialysis, ΔET became short significantly ($P < 0.01$) in each group, and the difference was no longer observed among 3

groups. Before dialysis, no significant difference of ΔPEP was seen in all 3 groups, but after dialysis, it remained unchanged in the middle and old age groups, while some reduction was noted in the youngest age group. PEP/LVET ratio increased in the middle and old age groups, whereas it was significantly reduced ($P < 0.05$) in the youngest age group after dialysis.

e) Effect of duration of hemodialysis: There was no statistical difference in STI indices in respect to the duration of dialysis.

f) Blood catecholamine level: The blood catecholamine level measured randomly in 6 cases disclosed no change by dialysis.

DISCUSSION

Changes in the STIs caused by arteriovenous shunting in the present study is well compatible with the previous reports^{5,23} though the reports concerning hemodynamic effects of temporary occlusion of A-V shunt still controversial^{3,6} As

far as our observations are concerned, however, the effect of shunting is negligible.

On the other hand, the hemodynamic effects of hemodialysis are still controversial^{1,4,5,6,24}. The important factors responsible for the hemodynamics in chronic dialysis cases seem to be an enhanced shunt flow by the perfusion pump and a decrease in the circulating blood volume or in the venous return by the loss of body fluids. Since no significant change in blood pressure was observed after dialysis and since the calculated STIs were corrected for the heart rate, change in the STIs seems to be influenced by cardiac contractility, circulating blood volume or cardiac output. High STI indices are possibly due to the increase in circulating blood volume or the increase in preload, which were demonstrated previously by invasive methods^{1,4,6,7,24}. Increase in Δ PEP is presumed to be indicative of impaired cardiac contractility. Therefore, marked increase in Δ QS2 was observed. In accordance with many previous invasive studies^{4,5,6,24}, significantly decreased Δ QS2 and Δ ET may suggest a decrease in cardiac output or stroke volume. On the other hand, Δ PEP did show a tendency to shorten after dialysis probably because of an increase in cardiac contractility. The possible role of hyperadrenergic state could also be a contributing factor for the shortenings of QS2, LVET and PEP. Ishigami²⁵ observed a significant increase in serum catecholamine concentration after dialysis, but we failed to reconfirm this finding. An increase in PEP/LVET ratio after dialysis indicates proportionately marked shortening of LVET without any significant prolongation of PEP. Therefore, the increase in PEP/LVET ratio may not indicate the impaired cardiac contractility.

Effect of the decreased circulating blood volume following dialysis on the cardiac contractility may be assessed by the changes in the STIs and body weight reduction. The reduction of LVET in the cases with body weight reduction, and the group of shortened PEP in the group with body weight reduction of less than 1 kg and increased PEP/LVET ratio in the group with more than 2 kg suggest a decrease in circulating blood volume with resultant decrease in LVET.

The tendency to increase in Δ ET and Δ PEP before dialysis noted in the cardiomegaly group may suggest the presence of congestion due to increased circulating blood volume and suppressed cardiac contractility. The possibility of

congestion is further supported by the fact that greater body weight reduction was observed in the group with cardiomegaly. Significant reduction in Δ PEP ($P < 0.05$) observed in the group without cardiomegaly suggests an improvement of cardiac contractility in the group with normal CTR.

The significant reduction of Δ PEP and PEP/LVET ratio observed in the youngest age group suggests the absence of harmful effects on the cardiac contractility in this age group. In fact, some degree of the improvement of cardiac contractility could be expected after hemodialysis in this group.

Although duration of hemodialysis has no appreciable effects on STIs, this may be due to the limited periods of observation. Further study is mandatory to reach the conclusion.

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