Influence of Preload Reduction on Left Ventricular Diastolic Function in Hemodialysis Patients with Left Ventricular Hypertrophy

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Abstract

Objectives: The purpose of this study was to assess how the preload reduction affects left ventricular (LV) diastolic function in hemodialysis patients with LV hypertrophy.

Methods: Subjects included 14 patients with LV hypertrophy receiving hemodialysis. The subjects underwent echocardiographic and pulsed Doppler examinations before and after hemodialysis, and the data were analyzed to determine the LV end-diastolic volume (EDV) and maximal early diastolic transmitral flow velocity (E). Similarly, a color M-mode Doppler image of LV filling flow was recorded before and after hemodialysis, and the flow propagation velocity (FPV) during early LV filling phase was measured. And then, 1) EDV, and FPV/E as a parameter of LV diastolic function were compared before and after hemodialysis, 2) the relation between the %degree of FPV/E (%FPV/E) improvement and the %degree of EDV (%EDV) decrease was assessed.

Results: 1) EDV decreased significantly after hemodialysis (p<0.01), 2) FPV/E increased in all of the subjects and increased significantly after hemodialysis compared with before hemodialysis (p<0.01). 3) There was a significant positive correlation between %FPV/E and %EDV (r=0.515, p<0.05).

Conclusion: We propose that the preload reduction improves the LV diastolic function in hemodialysis patients with LV hypertrophy, and that this improvement could be dependent on the preload reduction.

Key Words

Left ventricular hypertrophy, Left ventricular diastolic function, Preload reduction, Flow propagation velocity

Introduction

The major cause of cardiac dysfunction is diastolic dysfunction in patients with left ventricular (LV) hypertrophy. Indeed, a case of congestive heart failure due to an impairment of the left ventricular diastolic function despite a preserved systolic function has been recognized6. Given a preload reduction is one of the important therapeutic strategy of congestive heart failure, it is important to assess the effect of preload reduction on the LV diastolic function in patients with LV hypertrophy.

The purpose of this study was to assess how the preload reduction affects left ventricular (LV) diastolic function in hemodialysis patients with LV hypertrophy.

Methods

Subjects

Subjects included 14 patients (11 male and 3 female, mean age: 62.4±6.9 years) with LV hypertrophy receiving hemodialysis, which had been un-
changed for several weeks. Median time on hemodialysis was 43.4±36.5 (range, 8 to 149) months (Table 1). The etiology of the renal failure was hypertension (hypertensive nephropathy) in 7 patients, diabetes mellitus (diabetic nephropathy) in 2 patients, and combination of hypertension and diabetes mellitus in 5 patients. Echocardiographic and Doppler examination including conventional pulsed Doppler and color M-mode Doppler techniques were performed before and after hemodialysis. The presence of LV hypertrophy was established when the LV mass (LVM) obtained from echocardiography was >215 g. All subjects had normal sinus rhythm. All subjects gave their informed consent after receiving an explanation of the procedures and their possible clinical benefit.

Echocardiographic Study

Echocardiograms were obtained using a TO-SHIBA SSH-160A equipped with a 2.5-MHz transducer. Two-dimensional targeted M-mode echocardiogram was recorded in each patient with simultaneous recording of II-lead electrocardiogram and phonocardiogram before and after hemodialysis. On the M-mode LV echocardiogram, LV end-diastolic dimension (LVDd), LV end-systolic dimension (LVDs), diastolic wall thickness of interventricular septum (IVSTh) and posterior wall thickness (PWTh) were measured. The LV internal dimension and diastolic septal and posterior wall thickness were measured at the peak of R wave of the electrocardiogram. LV end-diastolic volume (EDV) and LV end-systolic volume (ESV) were determined using the formula of Teichholz and colleagues, and ejection fraction (EF) was calculated as (EDV-ESV)/EDV×100 (%). LV mass (LVM) was calculated using the following formula validated by Devereux and Reichek:

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LVM (g) = 1.04 \times ((LVDd + IVSTh + PWTh)^3 - (LVDd)^3) - 13.6.
\]

Table 1. Clinical and Echocardiographic Findings of the Study Subjects

| Age (years) | 62.4 ± 6.9 |
| Gender(Male/female) | 11/3 |
| Median time on hemodialysis | 43.4 ±36.5 |
| Heart Rate (beats/min) | 73.9 ± 9.7 |
| LVDd (mm) | 52.3 ± 4.5 |
| LVM (g) | 329.0 ± 75.6 |
| EF (%) | 64.2 ± 9.7 |

Doppler Study

Pulsed Doppler imaging was performed with reference to a two-dimensional echocardiographic image from the apical two-chamber view in each patient. The pulsed Doppler sample was placed at the mitral leaflet tips to obtain maximal transmitral flow velocities during the LV filling phase, and the maximal early diastolic transmitral velocity (E) were measured. Color M-mode Doppler imaging of the LV filling flow in early diastolic phase were recorded, and flow propagation velocity in early diastolic phase (FPV) were measured as the slope of the flow wave front during the early LV filling (Fig. 1). The ultrasound beam was interrogated from the apex of the heart towards the center of the mitral orifice as parallel to the LV filling flow as possible. Measurements were obtained from an average of three consecutive cardiac cycle. To correct the influence of various peak early transmitral flow velocities, the ratios obtained by dividing FPV by E (FPV/E) was calculated as a parameter of the LV diastolic function.

Then, 1) heart rate, EF, and EDV were compared before and after hemodialysis, 2) FPV/E as a parameter of LV diastolic function was compared before and after hemodialysis, 3) relation between %degree of the improvement of FPV/E (%FPV/E) and %degree of the decrease of EDV (%EDV), %FPV/E and LVM, and %FPV/E and EF were assessed.

The echocardiogram and the Doppler imaging were recorded by a cardiologist, and evaluations and measurements of echocardiogram and Doppler examinations were made by another cardiologist blinded to the subjects.

Statistical Analysis

Values are expressed as means±SD, and comparisons were assessed by the Student’s paired t-test. Differences were considered significant at p values of <0.05. Simple regression analysis was employed to test correlations.

Results

1) There were no significant changes in heart rate and EF after hemodialysis compared with before hemodialysis value (Table 2), 2) EDV decreased in all of the subjects and decreased significantly after hemodialysis (p<0.01, Fig. 2). 3)
FPV/E increased in all of the subjects and increased significantly after hemodialysis compared with before hemodialysis (p<0.01, Fig. 2). 4) There was a significant positive correlation between %FPV/E and %EDV (r=0.515, p<0.05, Fig. 3). 5) There were no correlation between %FPV/E and LVM (r=0.017) or EF (r=0.259).

Discussion

The major findings shown by this study are that 1) LV diastolic dysfunction was improved by hemodialysis-related volume reduction, and that 2) the improvement of the LV diastolic function correlated to the preload reduction in hemodialysis patients with LV hypertrophy.

There have been conflicting reports on the effect of hemodialysis-induced changes in LV diastolic function. Gupta et al.\(^5\) reported that isovolumic relaxation time and deceleration time of early filling phase obtained by Doppler echocardiogram were improved after hemodialysis, whereas Sadler et al.\(^6\) reported that acute effects of hemodialysis included reduced early diastolic filling velocity of the left ventricle, with no change in late atrial filling. Rozich et al.\(^7\) reported that hemodialysis alters the loading conditions of the left ventricle, such that early diastolic filling becomes impaired and late atrial-assisted filling does not increase in a compensatory fashion. In our view, the index of LV diastolic function is an important factor leading to this conflict. Concerning the effect of hemodialysis on LV diastolic function, Sadler et al.\(^6\) described that main effects of hemodialysis on LV function is preload reduction caused by volume reduction. Rozich et al.\(^7\) reported that reduction in effective circulating blood volume resulted in a decrease pressure difference between the left atrium and ventricle, and affects on parameter of LV diastolic function. In addition, Chakko et al.\(^2\) reported that hemodialysis without fluid removal does not alter the LV diastolic filling pattern. Rozich et al.\(^7\) only suggested that increased calcium concentration by hemodialysis may have affected myocardial diastolic function.

Therefore, we proposed that the main effect of hemodialysis on LV function is preload reduction for considering the several previous reports\(^2,5,6,7\).

Doppler-derived parameters, which have been widely used to assess the LV diastolic function are

![Figure 1. Measurement of LV flow propagation velocity. LV filling flow was recorded using color M-mode technique, and flow propagation velocity was measured as the slope of the flow wave front during LV filling (white arrow).](image)

| Table 2. Heart Rate (HR) and Ejection Fraction (EF) Before and After |
|-------------------------|-----------------------------|----------------|
|                        | before HD | after HD | p value |
| HR                     | 73.9 ± 5.7 | 75.9 ±13.8 | NS      |
| EF                     | 64.2 ± 9.7 | 59.6 ±11.4 | NS      |

NS: Not significant
known to be pre-load dependent\(^{8,9}\). In this study, FPV/E was used as a parameter of the LV diastolic function. The LV flow propagation velocity using color M-mode Doppler technique has recently attracted attention as a useful noninvasive parameter for evaluating LV diastolic function\(^{10}\). Several studies\(^{11-13}\) have been published on the LV flow propagation velocity and emphasized its usefulness for assessing diastolic dysfunction and some advantages for conventional non-invasive parameter obtained by pulsed Doppler examination. Brun. et al.\(^{10}\) demonstrated that the flow propagation velocity during early filling reduced in patients with LV hypertrophy and seems to be highly dependent on the LV relaxation rate, and suggested that LV flow propagation velocity could be an important tool in...
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studying diastolic function. Takatsuji et al. demonstrated that FPV was free of pseudonormalized transmitral flow velocity pattern, and Naguch et al. reported that the flow propagation velocity was useful as a noninvasive parameter of LV diastolic function in patients with atrial fibrillation. In addition, several reports demonstrated that the ratio of FPV to E was appropriate for evaluating LV diastolic function by the preload effect on the early transmitral flow velocity. FPV/E is as a noninvasive parameter that may remain unaffected by changes in preload, and it may serve as an adequate parameter of LV diastolic function in this study.

The main cause of LV diastolic dysfunction is decrease of LV compliance caused by increase of LV chamber stiffness. In patients with LV hypertrophy, increase of LV mass and myocardial fibrosis due to an increase in the amount of collagen in the LV myocardium result in an increase of the LV chamber stiffness. LV chamber stiffness is determined by the level of operating pressure and the diastolic pressure-volume relation, and indicated as the slope of a tangent to the pressure-volume relation in diastolic phase. Because the diastolic pressure-volume relationship is curvilinear, stiffness is lower at smaller volumes and higher at larger volume. Gaasch W et al. described that such preload-dependent changes in the LV chamber stiffness occur during any acute alteration in ventricular volume. Since the slope of the pressure-volume curve becomes steeper in LV hypertrophy, change in the pressure is large for the change in the LV volume. Therefore, preload dependency of the LV chamber stiffness is easy to be emphasized in patients with LV hypertrophy. The results of the present study appeared to reflect the preload dependency of LV chamber stiffness.

One of the important initial treatment of congestive heart failure is aimed at reducing pulmonary venous pressure and congestion, and such treatment usually requires therapy with diuretics. Administration of diuretics results in a reducing pulmonary congestion caused by decrease of circulatory blood volume. In the present study, we propose that the preload reduction improves the LV diastolic function. We suggest that the effect of diuretics in the therapy of congestive heart failure may be caused by not only preload reduction, namely shift of the point towards the left on the Frank-Starling ventricular function curve, but also improvement of the LV diastolic function.

In conclusion, we propose that the preload reduction improves the LV diastolic function in hemodialysis patients with LV hypertrophy, and that this improvement could be dependent on the preload reduction.

References

10) Brun P, Tribouilloy C, Duval A, Iserin L, Meguira A, Pelle G and Dubois-rande J. Left ventricular flow propagation during early fil-


肥大心の左室拡張機能におよぼす前负荷軽減の影響

抄録

目的：前負荷軽減が肥大心の拡張機能にどのような影響を及ぼすかについて検討することを目的とした。

方法：対象は血液透析が行われている左室肥大患者14例で、透析前後で心エコー・超音波Doppler記録を行い、左室拡張末期容積（EDV）、拡張早期左室流入最大血流速度（E）を計測した。同時にカラーモードDoppler法により拡張早期左室内血流伝播速度（FPV）を計測した。次いで、1）EDVと、左室拡張機能の指標としてFPV/Eを透析前後で比較検討した。また2）FPV/Eの改善率（%FPV/E）とEDVの減少率（%EDV）の相関について検討した。

結果：1）EDVは透析後に有意に減少した（p<0.01）。2）FPV/Eは全例において透析後に増加し、透析前後で有意に増加した（p<0.01）。3）%EDVと%FPV/Eとの間に有意な正の相関がみられた（r=0.515, P<.05）。

結論：肥大心の左室拡張機能は前負荷軽減により改善し、その程度は前負荷軽減の程度に依存すると考えられた。

索引用語

左室肥大、左室拡張機能、前負荷軽減、左室内血流伝播速度

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