Continuous Monitoring of Left Ventricle Function by VEST in Hemodialyzed Patients

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Cardiovascular disease is a major cause of morbidity and mortality in chronic kidney disease. Radionuclide-based methods can be used for analyses on the perfusion of coronary arteries and ventricular function. The present study reports the use of a new procedure for continuous measurements of left ventricle function during a dialytic session with the use of a recently developed portable gamma radiation detector (ventricular function study system). On average, left ventricle ejection fraction and stroke volume progressively and continuously decreased throughout the session (end session versus baseline: −13.8% for ejection fraction, −25.9% for stroke volume, \( P < .02 \)). A biphasic response was found for heart rate: a transient modest decrease (at session midpoint, −4.2%) followed by an increase up to values higher than baseline (end session, +4.7%). Cardiac output decreased by 10.4% at session midpoint (\( P = .023 \) versus baseline) without further reduction in the following hours. Mean changes in systolic pressure paralleled data for cardiac output. Individual changes in indices of left ventricle function were scattered and strongly correlated with thickness of interventricular septum and telediastolic left ventricular volume measured by standard echocardiogram in the interdialytic period (\( R > .75, P < .05 \)).

Data indicate that the ventricular function study system could be a powerful tool for characterization of the profile of left ventricular function in hemodialyzed patients.

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Cardiovascular disease is an important cause of morbidity and mortality in chronic kidney disease (CKD) because CKD patients have a high frequency of coronary artery disease, cerebrovascular disease, peripheral vascular disease, and heart failure regardless of the type of kidney disease.1-3 The epidemics of cardiovascular disease in CKD appear to be caused by the combination of traditional cardiovascular risk factors (hypertension, hyperlipidemia, smoking, diabetes, and so forth) with CKD-related conditions (anemia, hypermetabolism, secondary hyperparathyroidism, and so forth).1-3 Radionuclide-based methods could play a role for the clinical evaluation of cardiac disease in CKD since they are without the contraindications typical of iodinated contrast media and are useful in early and late stages either of coronary artery disease and of heart failure.4 The accuracy and prognostic power of these methods can be increased by stress tests that allow the evaluation of ischemia and ventricular dysfunction also under dynamic conditions.5 The present study reports preliminary data on the use of a new procedure for analyses of left ventricle function changes in the course of a dialytic session.

Methods

The ventricular function study system (VEST, C-VEST system; Capintec Inc., Ramsey, NJ) is a technique for monitoring changes over time in the left ventricle volume and ejection fraction.6,7 The instrument consists of 2 gamma radiation detectors mounted on a hard plastic garment coupled with an ambulatory electrocardiogram (ECG) recording system. The weight of the entire set (garment with detectors plus recorder) is approximately 3.0 kg. The main detector of the instrument is placed over the left ventricle, the second detec-
Data Analysis
Parameters related to left ventricle function in the MUGA study (defined as baseline) were computed starting from the global time-activity curve with the use of a single semiautomated method. Intradialytic data collected by the VEST recorder were expressed as the percent change over baseline after correction for physical decay (calculated as per $^{99m}$Tc half-life). The graphic and numeric data on left ventricle volume and ECG were analyzed automatically with manual editing. Data for single beats were excluded from analyses when the beat duration differed by 20% or more compared with the average calculated for the 4 previous beats. Cardiac output, stroke volume, and ejection fraction were the variables used for the present analyses focusing on 3 time points of the dialytic session (start, midpoint, and end). Data analysis was performed by 2 independent observers (V.C. and P.F.R.), who were blind to patient clinical information.

Patient Selection and Clinical Data
Patients were enrolled in the study after informed consent was obtained and on the basis of the following inclusion criteria: bicarbonate-hemodialysis for at least 6 months (3 session/wk), regular treatment with erythropoietin and anti-hypertensive drugs, absence of previous diagnosis of myocardial infarction, absence of intradialytic hypotension, and absence of clinical signs of heart failure. The Kt/V value was used as an index of dialysis adequacy. A standard echocardiogram was performed in the interdialytic period 1 week before the VEST study. Weight and blood pressure were monitored by automated procedures during the dialytic session in parallel with the VEST study.

Results
Table 1 reports descriptive data for the patients included in the study. Figure 1 shows the time course of mean values for cardiac output, ejection fraction, heart rate, and systolic blood pressure during the hemodialytic session. Cardiac output decreased by 10.4% at the midpoint of the session without further reduction in the following hours. Ejection fraction progressively and continuously decreased throughout the session down to a value 13.8% lower than baseline. A similar trend was found for stroke volume. A biphasic response was found for heart rate: a transient decrease at the midpoint of the session followed by an increase up to values higher than baseline. The changes in systolic pressure were similar to the changes in cardiac output with an initial decrease followed by a stable period. Changes in diastolic pressure were not significant (not shown).

Figure 2 shows the individual changes (end minus start) in cardiac output and ejection fraction. Individual data were scattered, ranging from negative values (decrease) to positive values (increase) for both indices of cardiac activity. Individual changes in cardiac output and ejection fraction measured by VEST were correlated strongly with thickness of the interventricular septum and left ventricle telediastolic volume measured by echocardiogram (Fig 3), not with dialysis-induced body weight change or other variables analyzed ($r < 0.3, P > .5$).
Discussion

Probes and/or miniature detectors of gamma radiation derived from a conventional gamma camera have been investigated by several studies.\textsuperscript{16,17} The VEST apparatus has been used to study indices of left ventricle function when changes are expected in a time period of hours.\textsuperscript{18-20} Investigations have been performed at rest, during routine daily activity, during standardized physical activity, or other interventional tests focusing on myocardial ischemia, cardiac and noncardiac disorders, treatment with drugs, cold stimulation, tilt test, and angioplasty.\textsuperscript{21-31} The use of VEST was proposed also for risk stratification in coronary artery disease.\textsuperscript{32,33} Theoretically, information collected by VEST could be of help for the definition of the time course of the changes in left ventricle function associated with hemodialysis, a condition that is characterized by a very high frequency of various cardiac diseases.

The preliminary data of the present study indicate that VEST could be a powerful tool for investigations of cardiac activity in hemodialysis. Data show that the average trend in the course of hemodialysis is a reduction of cardiac output as expected in the course of a progressive and large reduction of the plasma volume. Changes in heart rate were biphasic, with an initial decrease followed by a later increase. The late heart rate increase likely could reflect an activation of the sympathetic tone that contributes to maintain the stability of cardiac output and systolic blood pressure in the second half of the dialytic session despite the progressive decrease in plasma volume and ejection fraction. Analyses of the individual data indicated a large interindividual variability in the intradialytic changes of indices measured by VEST. Changes of cardiac output ranged from a large

![Figure 1](image1.png)

**Figure 1** Time course of (A) cardiac output, (B) ejection fraction, (C) heart rate, (D) systolic pressure, (E) and stroke volume in the course of a hemodialytic session (means, \(*P < .03\) by paired Student t test versus start).

![Figure 2](image2.png)

**Figure 2** Individual changes (end session value minus start session value) in (A) cardiac output, (B) stroke volume, and (C) ejection fraction.
decrease to a sizeable increase, in contrast with the relatively homogenous decrease in body fluids secondary to hemodialysis. Data from a standard ECG were strong predictors of the findings of VEST. Patients with echocardiographic measures close to the normal range experienced a progressive decrease in cardiac output during hemodialysis. In contrast, patients with septal hypertrophy and left ventricle dilation experienced no change or a slight increase in cardiac output.

Data interpretation must be cautious because of the low number of patients in the present study. Nevertheless, an intriguing possibility raised by the present data are that hemodialyzed patients are extremely sensitive to the preload conditions for their hemodynamic equilibrium. In the presence of left ventricle function that is normal or slightly altered, the extracellular volume expansion that is proper for the predialytic phase could be a factor favoring cardiac performance. Therefore, under these conditions, the rapid depletion of the extracellular fluid volume induced by hemodialysis could decrease the cardiac performance via decreases in venous return and filling pressure. In other words, the hemodialytic session could unmask a diastolic impairment previously counterbalanced by the volume overload and could imply a decrease in cardiac output and ejection fraction caused by the reduced stroke volume. In the second half of the hemodialytic session the increasing heart rate could permit maintenance of a relatively stable cardiac output despite the continuously decreasing stroke volume. The opposite would occur in the presence of left ventricle function that was altered more severely. In this condition, cardiac output does not decrease in the course of the hemodialytic session, perhaps because the predialytic expansion of the extracellular volume is one of the factors contributing to low cardiac performance.

In summary, this study indicates that VEST could be an important tool for the definition of the pattern of left ventricular function in hemodialyzed patients. Data in a small group of patients without clinically overt heart disease show that the changes of cardiac performance in the course of a dialytic session are not the same in all patients. The average trend is a decrease, but there are cases with opposite changes (ie, with an intradialytic increase in cardiac performance) irrespective of changes in body weight and blood pressure. The precise definition of left ventricle function during hemodialysis and of its determinants might be relevant to the treatment and control of epidemics of cardiovascular mortality in hemodialysis.

References


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