

Predialysis Systolic Blood Pressure Correlates Strongly with Mean 24-Hour Systolic Blood Pressure and Left Ventricular Mass in Stable Hemodialysis Patients¹

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ABSTRACT

This study used a 24-h ambulatory blood pressure (ABP) monitor to study the relationship between dialysis room-measured blood pressures (BP) and mean 24-h systolic and diastolic ambulatory BP (SABP and DABP) with left ventricular mass (LV) in a group of 35 stable hemodialysis patients. Predialysis and postdialysis systolic and diastolic blood pressure data were collected for the 12 dialysis treatments before the wearing of the ABP device, and the means of these values are reported. All patients were maintained on the same antihypertensive medications for 3 months before the study and had a stable hematocrit value of $30 \pm 3\%$ during this time period. There was no difference detected between daytime and nighttime ABP. SABP was a mean of 4.7 mm Hg below predialysis systolic BP ($P = 0.004$) and DABP was a mean of 3.7 mm Hg below predialysis diastolic BP. There was a strong correlation between SABP and predialysis systolic BP ($r = 0.67$, $P = 0.0001$); however, postdialysis diastolic BP correlated better with DABP than did predialysis diastolic BP. In addition, LV mass correlated with SABP ($r = 0.35$, $P = 0.03$) and predialysis systolic BP ($r = 0.35$, $P = 0.03$). There was no apparent correlation between either pre- or postdialysis diastolic BP with LV mass. It was concluded that predialysis systolic BP and postdialysis diastolic BP correlates strongly with SABP and DABP. Furthermore, predialysis systolic BP correlates with LV mass in hemodialysis patients. If the deleterious effects of hypertension in

this patient population are to be avoided, it is the predialysis systolic BP that needs to be controlled: It is insufficient to be satisfied with good postdialysis BP control, if patients are hypertensive before beginning dialysis.

Key Words: Hemodialysis, left ventricular mass, blood pressure, ambulatory blood pressure

Left ventricular (LV) hypertrophy is present in up to 70% of hemodialysis patients (1,2). Increased LV mass is an established predictor of subsequent cardiac events in both uremic and nonuremic patients (3–5). A strong association has been found in nonuremic patients between levels of systolic and diastolic blood pressure (BP) and LV mass. However, in hemodialysis patients it has been much more difficult to show such a relationship because of the many factors affecting LV mass (6). In particular, correction of anemia in this patient population has been shown to markedly reduce LV mass (7–9).

It has been suggested that in nonuremic patients, 24-h ABP provides a better measurement of mean daytime BP and correlates better with target-organ damage than do single office BP readings (10,11). Recently, there have been a number of reports describing the use of 24-h ABP devices in hemodialysis patients, and it has been suggested that these devices provide a more accurate reflection of mean 24-h BP than dialysis room-measured BP (12–14).

The purpose of this study was to examine the relationship between dialysis room-measured BP and mean 24-h ABP, and the relationship between these measurements of BP and LV mass in a group of stable hemodialysis patients who had been maintained at a hematocrit value of 30 ± 3 for the previous 3 months and who had not had any adjustments in their antihypertensive medication during this study period. It is hoped that by better understanding how dialysis room-measured blood pressure relates to mean 24-h BP and to markers of end-organ damage from hypertension (such as LV mass), physicians may be better able to manage hypertension in ESRD patients.

METHODS

Patient Selection

Thirty-five hemodialysis patients were enrolled in this study. To be included, each patient had to have a stable hematocrit value of between 27 and 33% for the previous 3 months before enrollment in the study. In addition, only patients who had been on the same antihypertensive regi-

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men during this period were included. Twenty-six patients were on antihypertensive medications at the time of this study, which included calcium channel blockers ($N = 17$), angiotensin-converting enzyme inhibitors ($N = 8$), beta blockers ($N = 9$), and minoxidil ($N = 4$). The etiology of ESRD was diabetes ($N = 15$), hypertensive nephrosclerosis ($N = 10$), glomerular disease ($N = 4$), and etiology unknown ($N = 9$).

Blood Pressure Monitoring

Twenty-four-hour ABP was measured using the Stuart Medical ambulatory blood pressure machine (Baltimore, MD). The device was fitted 15 min before the start of hemodialysis, and the device was programmed to measure blood pressure every 30 min for 24 h. All patients were counseled to relax their arms on their sides when the device was recording, and advised to take their routine antihypertensive medications on the day they wore the device. To be included in the study, each patient had to have had greater than 80% successful BP readings. All BP readings were included in the final analysis. Daytime was defined as between 7 a.m. and 10 p.m. and nighttime as between 10:01 p.m. and 6:59 a.m. The mean systolic and diastolic BP (SABP and DABP) for the 24-h period were calculated. Systolic and diastolic load were defined as the percentage of BP recordings above 140 and 90 mm Hg, respectively, during the 24-h time period.

Predialysis BP was recorded after the patients had rested quietly for 10 min while seated, using a standard technique with a recently calibrated aneroid sphygmomanometer by nonphysician personnel who were known to the patients. Phase Five was used to determine diastolic pressure. Postdialysis BP was recorded by a similar technique while the patient was seated. Predialysis and postdialysis systolic and diastolic blood pressure, and interdialytic weight-gain data was collected for the 12 dialysis treatments completed before the wearing of the ABP and for the period during which the ABP device was worn, and the means of these values are reported.

Echocardiograms

Echocardiograms were recorded by skilled technicians utilizing an ultrasound imaging system, on the days between dialysis. All M mode studies of the LV cavity were guided by two-dimensional echo using an optimal long-axis view. Measurements were made according to the recommendations of the American Society of Echocardiography using the leading edge to leading edge convention (15). At least three measurements were made and averaged. The cardiologist measuring the echocardiogram was blinded to the BP readings for the patient. Left ventricular mass was calculated using anatomically correct regression equations of Devereux and Reichek (16). Left ventricular mass index (LVMI) was derived by correcting the left ventricular mass for a body surface area of 1 m². LV hypertrophy was considered to be present if the LVMI was greater than 150 g/m² for men and 130 g/m² for women.

Validation of Ambulatory Blood Pressure Device Data

The accuracy of the ABP monitor was initially validated using a standard protocol (17). Two registered nurses were trained in the technique of BP recording until they consistently obtained 90% of BP readings within 5 mm Hg of an expert (a physician experienced in BP recording). Simultaneous BP recordings were then made by way of a T piece that

connected the ABP device to a mercury sphygmomanometer. Twenty-five patients were recruited from the renal clinics at Duke University Hospital and 70 BP recordings were made, with systolic BP varying between 110 and 200 mm Hg and diastolic BP between 65 mm Hg and 120 mm Hg. The systolic and diastolic BP recorded by the nurses was compared with that recorded by the ABP device.

The strength of association between various measures of BP and echocardiographic left ventricular mass was assessed by the product moment correlation coefficients and its test of significance. Paired and unpaired *t* tests were used as appropriate, to examine differences between continuous variables.

RESULTS

Twenty-five subjects participated in validation of the device, each of whom had three recordings each of systolic and diastolic BP. The mean systolic BP recorded by nurses was 146.3 ± 25.4 mm Hg and the mean systolic blood pressure recorded by the ambulatory BP device was 147.69 ± 26.8 mm Hg. The mean diastolic BP recorded by the nurses was 84.6 ± 12.5 mm Hg and that by the device was 85.4 ± 12.4 mm Hg. These were not statistically significant differences. Eighty-five percent of recordings were within 5 mm Hg of the nurses' readings, which corresponds to British Hypertension Society protocol Grade A (17). The accuracy of the device was similar over the range tested for both systolic and diastolic BP.

Thirty-eight patients wore the ABP device. However, three patients either took the device off before 24 h, or less than 80% of the recordings were valid and thus were excluded from further analysis. There were 23 men and 12 women, of whom 30 were black and five white. The mean age of the patients was 43 ± 10 yr, and they had been dialyzed for a mean of 26 ± 8 months. The mean hematocrit value during the 3 months before enrollment was 31.5%.

The SABP and DABP were 150 ± 18 mm Hg and 74.2 ± 10 mm Hg, respectively. The predialysis systolic BP was 160.5 ± 19.7 mm Hg, which was significantly higher than the postdialysis systolic BP of 133 ± 19.7 mm Hg ($P = 0.0001$). Similarly, the predialysis diastolic BP was 82.1 ± 9.3 mm Hg, significantly higher than the postdialysis diastolic BP of 75.9 ± 11.2 mm Hg ($P = 0.0007$). There was no statistically significant difference between mean daytime and nighttime systolic or diastolic ABP.

SABP was an average of 4.7 mm Hg ($P = 0.004$) below that of predialysis systolic BP, and DABP was an average of 3.7 mm Hg ($P = 0.002$) below that of predialysis diastolic BP. There was a strong correlation (Figure 1) between SABP with predialysis systolic BP ($r = 0.67$, $P = 0.0001$). However, DABP correlated better with postdialysis diastolic BP ($r = 0.5$, $P = 0.0021$) than with predialysis BP.

The mean weight gain between dialysis treatments was 3.3 ± 1.5 kg. There was no correlation between either SABP, DABP, or predialysis systolic or diastolic BP, and interdialytic weight gain during the period when the ABP the device was worn or during the 12

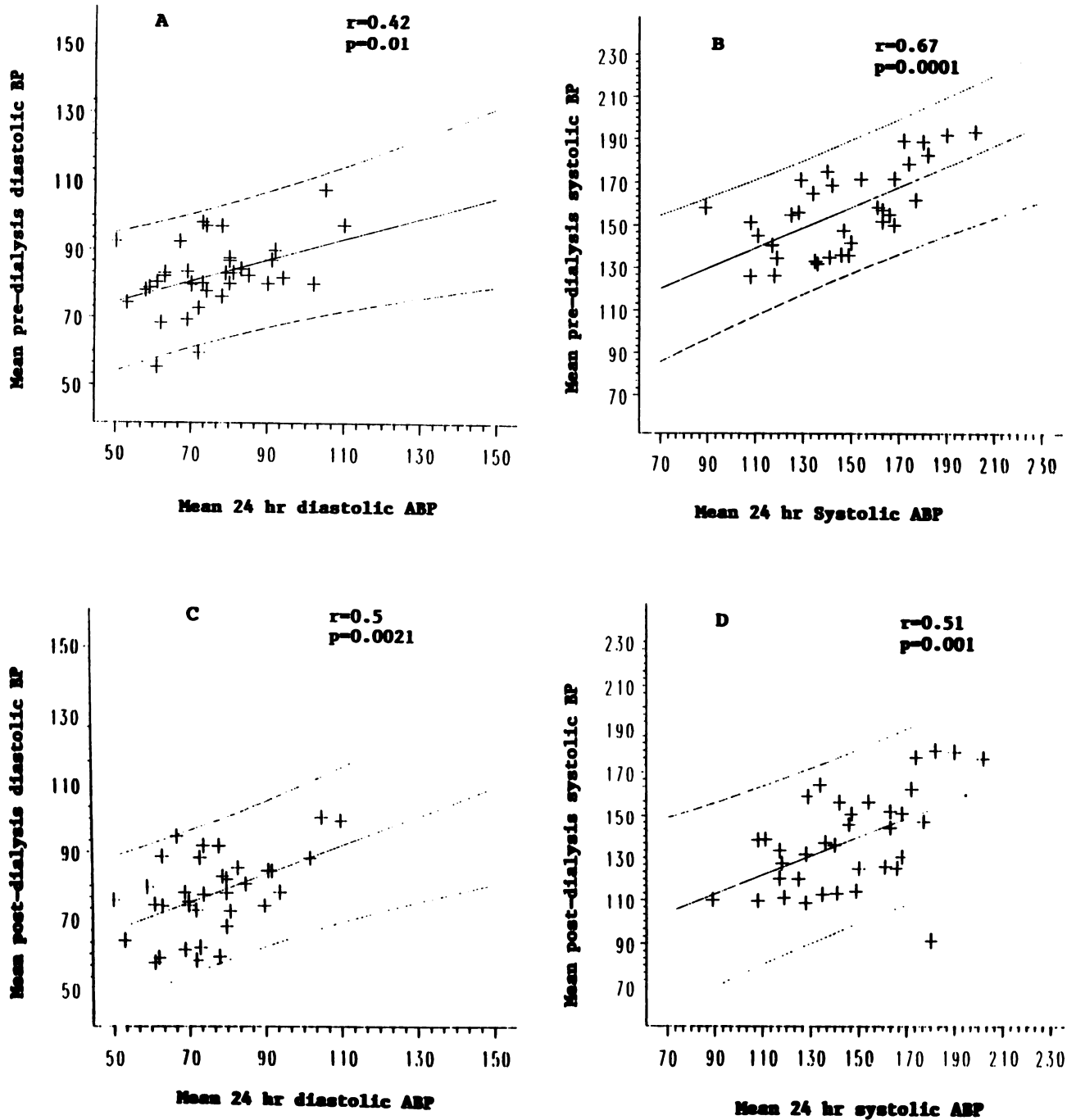


Figure 1. (A) Relationship between mean 24 hr diastolic ABP and mean post-dialysis diastolic BP. (B) Relationship between mean 24 hr systolic ABP and mean pre-dialysis systolic BP. (C) Relationship between mean 24 hr diastolic BP and mean post-dialysis diastolic BP. (D) Relationship between mean 24 hr systolic ABP and mean post-dialysis systolic BP. Straight lines are regression lines, and dotted lines are 95% confidence intervals of regression lines.

previous dialysis treatments, nor was there a correlation between interdialytic weight gain and LVMI.

Eighty-one percent of patients demonstrated LV hypertrophy as previously defined. Patients with LV hypertrophy had significantly higher SABP, systolic

load, and predialysis systolic BP (Table 1). Five of the seven patients without LVH were normotensive. There was no difference in DABP, predialysis diastolic BP, postdialysis systolic BP, or postdialysis diastolic BP between patients who had LV hypertrophy and those

TABLE 1. Mean systolic and diastolic blood pressure measurements (in mm Hg) for patients with and without left ventricular (LV) hypertrophy

Blood Pressure Measurement	No LV Hypertrophy (N = 7)	LV Hypertrophy (N = 28)	P
Mean 24-h Systolic ABP	135.6 ± 30.3	148 ± 26.4	P = 0.02
Mean 24-h Diastolic ABP	78 ± 17	74 ± 12	P = NS
Daytime Systolic Load (%)	35.8 ± 34	55.3 ± 32	P = 0.03
Daytime Diastolic Load (%)	27.1 ± 36	17.9 ± 18.7	P = NS
Mean Predialysis Systolic BP	146 ± 9.4	161 ± 22	P = 0.04
Mean Predialysis Diastolic BP	82 ± 12	82.5 ± 10.1	P = NS
Mean Postdialysis Systolic BP	135 ± 21	140.2 ± 23	P = NS
Mean Postdialysis Diastolic BP	79.6 ± 14.2	76 ± 10.7	P = NS

who did not. Left ventricular mass index (LVMI) correlated (Figure 2) with SABP ($r = 0.35$, $P = 0.03$) and predialysis systolic BP ($r = 0.35$, $P = 0.03$). DABP, predialysis diastolic BP, and postdialysis systolic or diastolic BP did not correlate with LVMI.

DISCUSSION

Before this study, it had been unclear which BP—predialysis, postdialysis systolic, or postdialysis diastolic—has the greatest influence on the risk of LV hypertrophy development in uremic patients. Historically, in nonuremic subjects, it had been the diastolic BP that was considered the value most associated with end-organ damage from hypertension (18). Recent data now suggest that the systolic BP is more strongly linked to cardiovascular risk than either the diastolic pressure or the mean arterial pressure (19,20). Although these associations have been determined in patients with essential hypertension, it has

been unclear whether this applies to the ESRD patient. In the studies presented here, we have clearly demonstrated that the predialysis systolic and postdialysis diastolic BP most accurately reflects mean 24-h SABP and DABP. Furthermore, predialysis systolic BP correlated more closely with one marker of end-organ damage from hypertension (*i.e.*, LV mass) than either was predialysis diastolic BP or postdialysis systolic or diastolic BP (Figure 2).

We found that predialysis systolic BP correlates closely with SABP, but overestimates daytime BP by approximately 3 to 4 mm Hg. This finding is at variance from other studies of nonuremic patients that have compared ABP monitoring to clinic-measured BP. O'Brien *et al.*, in a study of 815 healthy subjects, noted that mean ambulatory BP was an average of 4/2 mm Hg greater than clinic-measured BP (21). However, it is not surprising that predialysis BP would somewhat overestimate mean daytime BP, as we and

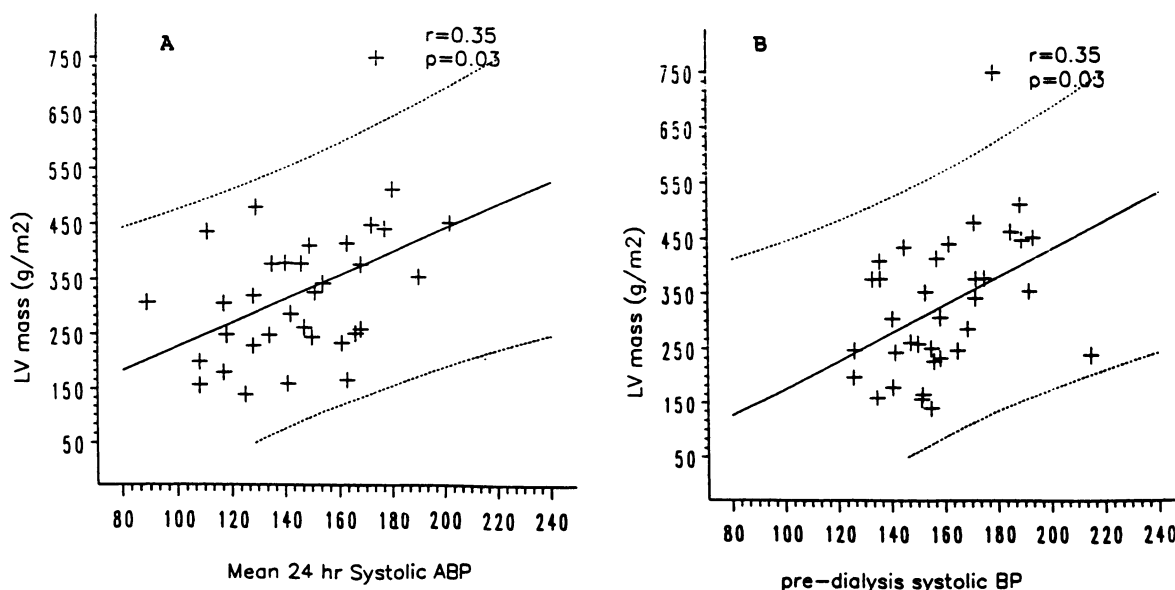


Figure 2. (A) Relationship between mean pre-dialysis systolic BP and left ventricular mass. (B) Relationship between mean 24 hr systolic ABP and left ventricular mass. Straight line is regression line, and dotted line is 95% confidence interval of regression line.

others have shown that the dialysis procedure reduces both systolic and diastolic BP.

In nonuremic hypertensive patients, a relationship has been known to exist between LV mass and BP for many years. Furthermore, in these nonuremic patients, LV hypertrophy can be reversed with long-standing BP control. Until recently, it had been difficult to show a relationship between BP and changes in LV mass in uremic patients. Harnett *et al.* were initially unable to find a relationship between systolic BP and LV mass in hemodialysis patients (22). However, in their more recent observation, Harnett and colleagues noted a higher systolic BP among hemodialysis patients who developed LV hypertrophy during follow-up, compared with those who did not (23). Similarly, Canella *et al.* demonstrated that reducing systolic and diastolic BP in hemodialysis patients results in a considerable reduction in LV mass (24). London *et al.* showed a strong relationship between LV mean wall thickness and systolic BP; they did not, however, comment on the relationship between systolic BP and LV mass (25). This difficulty in demonstrating a relationship between LV mass and BP in ESRD patients could be related to the multifactorial origin of myocardial hypertrophy, and, in particular, to the pronounced effect of anemia in determining the level of LV mass (7-9). In this study, we chose a carefully selected group of patients on stable antihypertensive medications and with stable hematocrit values in order to study the independent effect of arterial blood pressure on LV mass. Thus this group of patients may not be totally reflective of the majority of dialysis patients who have frequent adjustments in their antihypertensive medications. We may have selected out a group of patients with less severe hypertension than our general dialysis population. However, it is reasonable to assume that if this group of patients with less severe hypertension has a correlation between predialysis systolic BP and SABP with LV mass, patients with higher levels of systolic BP will also demonstrate a similar correlation. In addition, this group of patients has a high proportion of black patients (reflecting the prevalence of ESRD among black patients in Durham, NC and the southeastern United States) who are known to have greater LV mass than white patients.

Other authors have attempted to study the relationship between pre- and postdialysis-measured BP and 24-h ABP. Kooman *et al.* (12) studied a group of 22 HD patients and compared the pre- and postdialysis systolic and diastolic BP with the mean 44-h interdialytic BP and noted that the postdialysis systolic BP correlated best with the mean systolic BP during the 44-h period. Rodby *et al.* performed a similar study (14), although he used a more sophisticated statistical analysis of the data. These studies are clearly quite different in design from our study, which may explain the discrepant findings. We were interested to study how the mean 24-h ABP correlates with the average pre- and postdialysis systolic and diastolic BP and

with LV mass. To avoid the considerable variability in predialysis BP between individual treatments, we chose to look at the mean pre- and postdialysis systolic and diastolic BP for the previous 12 treatments. It would have been preferable to study ambulatory BP for the entire 44-h interdialytic period; however, in initial studies, we were unable to persuade our patients to wear the ABP device for more than 24 h. Kooman *et al.* and Rodby *et al.* did not look at the relationship between measures of BP and LV mass.

Few practicing clinical nephrologists will argue that the volume status of the ESRD patient has a considerable influence on the blood pressure. However, we were unable to demonstrate a correlation between either SABP or DABP or predialysis BP and interdialytic weight gain. This finding is in agreement with the observations of Kooman *et al.* and Rodby *et al.* (12,14), who were unable to find a relationship between interdialytic weight gain and increase in BP during the interdialytic period.

Achieving an adequate dry weight is clearly important in controlling BP in hemodialysis patients. However, removal of large volumes of fluid during a short dialysis treatment frequently induces hypotension. Dialysis-induced hypotension can be further exacerbated by antihypertensive medications. Patients are frequently advised not to take antihypertensive medications on the day of dialysis in an effort to avoid this complication; however, it appears from our observations that this advice will lead to inadequate control of BP and consequent LV hypertrophy. It is important to devise strategies for control of BP in ESRD patients that will provide continuous 24-h control of BP. It may be that some of the newer antihypertensive medications with a longer half-life will provide more continuous control of BP in dialysis patients (as they have been shown to do in nonuremic patients) while avoiding some of the hypotensive episodes induced by taking antihypertensive medications before dialysis. Further studies in this area are needed. Control of BP in hemodialysis patients requires a careful balance between achieving adequate volume status by ultrafiltration, limited volume gains between dialysis treatments, and judicious use of antihypertensive medication.

In conclusion, we have shown that in stable hemodialysis patients, predialysis systolic BP correlate closely with SABP. Furthermore, the predialysis systolic BP and SABP correlate best with LV mass. Thus it appears essential to control predialysis systolic BP in hemodialysis patients to avoid the long-term consequences of increased LV mass.

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