Pre- and Postdialysis Blood Pressures Are Imprecise Estimates of Interdialytic Ambulatory Blood Pressure

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BP readings that are obtained in the dialysis unit are commonly used to make therapeutic decisions by clinicians and to predict morbidity and mortality by epidemiologists. Dialysis unit BP are also incorporated in the recent guidelines to target BP control. The magnitude of the difference, overestimation or underestimation, and agreement between dialysis unit BP and ambulatory BP (ABP) are unknown. Articles were selected from Medline to identify those that reported both ABP and dialysis unit BP in hemodialysis patients. Bias was calculated as the difference between dialysis unit and the corresponding ABP. Agreement limits between the BP measurement techniques were assessed by pooled SD of the difference using Bland-Altman methods. Predialysis systolic BP generally overestimated ABP by a variable amount. The heterogeneity between BP measurements did not allow for pooling of the estimates. The agreement limits between the two BP was 41.7 to −25.2 mmHg. Predialysis diastolic BP also generally overestimated the ABP with wide agreement limits (23.7 to −18.9 mmHg). In contrast, postdialysis BP underestimated average ABP with wide agreement limits for both postdialysis systolic BP (33.1 to −36.3 mmHg) and diastolic BP (19.3 to −23.9 mmHg). Dialysis unit BP measurements are imprecise estimates of ABP. Better methods are needed for the assessment of BP in hemodialysis patients for clinical decision making.

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Hypertension is perhaps one of the most pervasive problems of patients with ESRD. Although current guidelines that focus on cardiovascular disease in dialysis patients call for hypertension control as a top priority, the vast majority of patients who are on hemodialysis are hypertensive and control rates are poor (1). For practical reasons, BP assessment and antihypertensive treatment in patients with ESRD is performed on the basis of measurements that are made either immediately before or after dialysis. Such time-honored practice is widely accepted and formally recommended by clinical guidelines. The recent National Kidney Foundation Kidney Disease Outcomes Quality Initiative guidelines suggest that predialysis and postdialysis BP should be <140/90 and <130/80 mmHg, respectively (2).

Population-based studies, including the recent Pressioni Arteriose Monitorate e Loro Associazioni (PAMELA) (3) and Ohasama studies (4) and studies on patients who had hypertension and were referred to a specialist clinic in the Dublin Outcome Study (5), have demonstrated clearly that ambulatory BP monitoring (ABPM) provides more accurate prognostic information than office BP, an issue that seems to be of particular relevance in the elderly. In a recent analysis of the ABPM substudy of the Systolic Hypertension in Europe (Syst-Eur) trial (6), ABPM and clinic BP did not identify the same patients for antihypertensive treatment, and ABPM was a better predictor of cardiovascular outcomes than clinic BP. These considerations are of relevance to patients with ESRD because uremia is a strong catalyst of the aging process and because patients with ESRD are older, with an average age of 60 yr.

Given that the population with ESRD is elderly and the relationship between ABPM and cardiovascular outcomes and total mortality has scarcely been studied, we examined the magnitude of the difference between ABPM and pre/postdialysis BP. We hypothesized that if there were substantial differences, especially when differences between the two methods of measurements were unpredictable, then the two methods of measurement may have differing prognostic significance. The primary objective of this systematic analysis was to determine the magnitude of the difference and the variability in the difference between BP that is recorded in the dialysis environment, before and after the dialysis procedure, and ABPM that is performed simultaneously in the hemodialysis population.

Materials and Methods

Published studies that had reported paired ABP and pre/postdialysis BP in patients who were undergoing conventional three times a

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Table 1. Deographic and clinical characteristics of studies included in meta-analysis[a]

Study	Year	*n*	Population	Age (yr)	% Diabetes	IDWG (kg)	% on BP Medications	No. of BP Medications in Users	Systolic		
									ABPM	Pre-HD	Post-HD
Kooman (35)	1992	22	Four hypotensive, six normotensives, 12 hypertensive patients studied	54	0%	2.8 ± 1.4	54.5%	Median of two drugs in hypertensives	129 ± 36	142 ± 42	124 ± 24
Cheigh (21)	1992	53	Treated hypertensive hemodialysis patients, 58% men, 47% black	53 ± 13	30%	2.9 ± 0.9	100.0%	NA	158.6 ± 22.7	163.9 ± 27.7	154.0 ± 29.6
van de Borne (36)	1992	13	Hemodialysis patients without uncontrolled hypertension	NA	0%	1.8 ± 0.7	15.4%	NA	127 ± 28.8	144 ± 18.0	135 ± 18
Huisman (31)	1995	12	Normotensive hemodialysis patients, all white, eight men	56 ± 14	8%	2.3 ± 1.2	0.0%	None	126.5 ± 17	140.8 ± 20.3	121.2 ± 18.1
Erturk (37)	1996	40	No exclusion criteria specified, 73% male	31.6 ± 8.9	0%	2.6 ± 1.1	77.5%	1.6	138.4 ± 24.6	134.5 ± 25.5	130.3 ± 22.7
Conlon (33)	1996	35	Stable Hct between 27 and 33% for previous 3 mo and no change in BP medications during the same period; 66% men, 86% black	43 ± 10	43%	3.3 ± 1.5	74.3%	1.5	150 ± 18	160.5 ± 19.7	133 ± 19.7
Elisaf (40)	1996	12	Hypertensive hemodialysis patients included in this meta-analysis	54	NA	NA	100.0%	NA	156 ± 19	157 ± 11	146 ± 19
Savage (22)	1997	27	Hemodialysis patients on dialysis >6 mo, 67% men	43.8 ± 13.3	0%	1.6 ± 0.8	55.6%	1.7	132 ± 19.2	138.7 ± 17.5	129.7 ± 18.8
Mitra (28)	1999	40	Randomly selected	61.5 ± 14.8	25%	1.34 ± 0.72	78.0%	1.5 ± 1	140 ± 21	157 ± 22	124 ± 31
Zoccalli (38)	1999	64	Patients on hemodialysis for at least 3 mo, without heart failure; excluded patients acutely ill	49.3 ± 15.9	0%	4.5 ± 1	39.1%	NA	135.3 ± 24.2	140.7 ± 18.2	NA
Berns (23)	1999	28	Chronic dialysis patients participating in an anemia correction trial; only baseline data used for this meta-analysis; 86% black	61.2 ± 11	54%	NA	NA	NA	153.7 ± 25	154.8 ± 22.3	144.3 ± 24.2
Conlon (34)	2000	31	Chronic dialysis patients participating in an anemia correction trial; only baseline data used for this meta-analysis; 74% black	54.7 ± 12.5	NA	NA	83.9%	1.5	148.3 ± 26.5	152.1 ± 25.2	NA
Canella (32)	2000	55	Availability of optimal chest acoustic window, dialysis age of at least 6 mo; patients with diabetes, coronary artery disease, significant valvular regurgitation, CHF, frequent intradialysis hypotension and severe anemia were excluded	range 24–74 yr	0%	2.5		1.2	126 ± 19	142 ± 15	135 ± 16
Peixoto (44)	2000	21	Repeated ambulatory monitoring to assess reproducibility of ABPM; 67% men; only study 1 included in this meta-analysis	53 ± 16	NA	2.3 ± 1.5		NA	140 ± 21	142 ± 16	136 ± 17
Agarwal (29)	2001	70	Patients needing ABPM for evaluation of hypertension or its treatment; 77% blacks, 54% male	59 ± 17	34%	2.9	57.1%	1.98 ± 0.89	144 ± 22	158 ± 21.8	144.6 ± 22.4
Nishikimi (24)	2001	35	Consecutive dialysis patients on dialysis for >6 mo	59.5 ± 14.7	37%	2.1 ± 1.2	68.6%	NA	134.2 ± 16.5	156.0 ± 24	136.0 ± 23.1
Fagugli (25)	2002	66	Hypertensive hemodialysis patients; excluded those on dialysis <6 mo, Kt/V <1.2, and presence of CHF or reduced LV systolic function	56.2 ± 17.6	15%	4.2 ± 1.6%	NA	1.9 ± 1.2	147.6 ± 16.5	146.7 ± 16.2	NA
Santos (30)	2003	71	Patients without unstable CHF, coronary heart disease, or atrial fibrillation who successfully completed ABPM; 50% men	45 ± 14	14%	2.3 ± 1.02	62.0%	1.7 ± 1.0	136 ± 22	151 ± 28	143 ± 26

[a]ABPM, ambulatory BP monitoring; CHF, congestive heart failure; Hct, hematocrit; HD, hemodialysis; IDWG denotes interdialytic weight gain; LV, left ventricular.

week hemodialysis were searched on Medline. Subsequently, bibliographies of published articles were searched for additional studies that were not captured in the initial search. Studies that reported ABP without pre/postdialysis BP, those that were performed only in children, and those that used long-duration or more frequent hemodialysis alone were excluded.

Statistical Analyses

The differences between the dialysis unit BP, *i.e.*, predialysis systolic (SBP) and diastolic (DBP), and postdialysis SBP and DBP and the corresponding ABPM BP (SBP or DBP) were calculated. When the SD of the difference (SDD) was not reported, we calculated it using the following formula:

$$SDD = \sqrt{SD_{amb}{}^2 + SD_{hdunit}{}^2 - 2\gamma SD_{amb} \cdot SD_{HDunit}}$$

where SD_{amb} is the SD of the ABP, SD_{hdunit} is the SD of the hemodialysis unit BP, and the γ is the covariance between the two BP (7). The covariance was imputed from pooled covariance when they were not reported. The common correlation coefficient was transformed to z (Fisher transform). The mean weighted z (z_w) was calculated using the following formula (7):

$$z_w = \frac{\sum_{i=1}^{k}(n_i - 3)z_i}{\sum_{i=1}^{k}(n_i - 3)}$$ to its corresponding r value.

The 95% confidence interval was calculated for each study as the 2.5th to 97.5th percentile of the t-distribution with n-1 degrees of freedom. The fixed-effects model (8) was used to calculate the mean weighted difference between ABP and dialysis unit BP (WMD) as follows:

Table 1. Continued

Diastolic			Ambulatory BP Measurement	BP Measurement	Reference
ABPM	Pre-HD	Post-HD			
72 ± 18	79 ± 16	74 ± 22	SpaceLabs 90207, 48 h, including the dialysis session	Dialysis BP was measured after 15 min of rest before and after dialysis	(31)
88.7 ± 16.6	87.9 ± 18.0	88.9 ± 20.1	SpaceLab 90207 monitor placed 1 h before dialysis for 48 h	NA	(17)
73 ± 14.2	81 ± 10.8	77 ± 10.8	TM2421 (A&D Engineering); 25-h recording after the dialysis session; first hour excluded	Supine BP after 10 min rest preHD and 20 min rest postdialysis	(32)
76.1 ± 8.9	86.6 ± 12.5	76.2 ± 11.1	SpaceLabs 90207, 48 h, including the first and second dialysis sessions	Not stated	(27)
93.7 ± 15.1	85.3 ± 13.8	79.1 ± 15.6	Pressurescan, ERKA, excluded bracketing dialysis sessions	Single measurements bracketing the ABPM recorded in the dialysis unit by one physician in duplicate using a mercury sphygmomanometer	(33)
74.2 ± 10	82.1 ± 9.3	75.9 ± 11.2	Stuart Medical ABP monitor, 24-h recording that included the first dialysis session	Average of 12 predialysis readings recorded after quiet rest for 10 min in seated position by nonphysicians using a calibrated aneroid sphygmomanometer	(29)
93 ± 11	89 ± 10	82 ± 10	SpaceLabs 90207, included the dialysis session	Average of three recordings in seated position, 15 min before or after dialysis	(35)
80.8 ± 15.0	85.5 ± 14.9	81.5 ± 12.2	SpaceLabs 90207, 48 h, started postdialysis	Not stated	(18)
71.7 ± 11	78 ± 10	70 ± 13	TM2421 (A&D Engineering); recording included the dialysis session	PreHD measurement over 10 dialysis sessions averaged; BP also was measured over various time points	(24)
78.8 ± 14.1	80.2 ± 11.8	NA	Takeda 2420 model 7 or SpaceLabs 90207 on a nondialysis day over 24 h	Predialysis BP were averaged over 1 mo (12 readings)	(34)
80.2 ± 12.3	81.3 ± 12.2	73.9 ± 10.5	SpaceLabs 90207, 44 h, excluded bracketing dialysis sessions	After 5 min of quiet rest	(19)
75.0 ± 12.5	82.6 ± 14.7	NA	Stuart Medical ABP monitor, 24-h recording that included the first dialysis session	Predialysis BP after 10 min of quiet rest while seated; BP obtained every 4 wk for 28 wk	(30)
76 ± 12	80 ± 9	77 ± 9	SpaceLab 90207 monitor placed before dialysis for 24 h and then 15 min before the next dialysis	Average of 12 predialysis and postdialysis reading obtained by the nurses in the month preceding the study	(28)
81 ± 16	79 ± 10	77 ± 9	SpaceLab 90207 monitor and QuietTrak monitors used; interdialytic monitoring	Five hemodialysis surrounding ABPM averaged	(39)
81 ± 11	85.2 ± 9.9	78.7 ± 9.8	SpaceLabs 90207, 44 h, excluded bracketing dialysis sessions	Two-week dialysis unit BP were averaged	(25)
79.4 ± 12.2	78.6 ± 13.0	75.0 ± 12.9	TM2421 (A&D Engineering); 48-h recording that included one dialysis session	NA	(20)
80.7 ± 10.4	81.6 ± 7.8	NA	TM2421 (A&D Engineering); interdialytic 48 h	Average of 1 mo predialysis BP measurements	(21)
83 ± 14	83 ± 15	81 ± 14	SpaceLabs 90207, 44 h, excluded bracketing dialysis sessions	Auscultatory measurements using standard guidelines and mercury sphygmomanometers	(26)

$$WMD = \frac{\sum_{i=1}^{k} w_i y_i}{\sum_{i=1}^{k} w_i}$$

where y_i is the difference between ABP and dialysis unit BP and w_i is the weight of the study calculated by the following formula:

$$w_i = \frac{1}{SDD_i^2/n_i}$$

The SE of the WMD was calculated as follows:

$$SE_{WMD} = \sqrt{\frac{1}{\sum_{i=1}^{k} w_i}}$$

The 95% confidence interval of WMD was calculated as follows:

$$\text{WMD} \pm 1.96 \times \text{SE}_{\text{WMD}}$$

The agreement limits between ABP and the corresponding hemodialysis unit BP were calculated as WMD ± 2 SDD_{WMD} (9). The SDD_{WMD} was calculated by multiplying the SE_{WMD} by the square root of the total number of patients who participated in the studies. However, it must be pointed out that the appropriateness of using the Bland-Altman approach for the analyses of pooled data is not clear.

The homogeneity of the difference between hemodialysis unit BP and ABP was calculated with the test statistic:

$$Q = \sum_{i=1}^{k} w_i (y_i - WMD)^2$$

where Q is a χ^2 statistic with k − 1 degrees of freedom.

The mean difference and the limits of agreement (±2 SD) between

Study	n	PreHD SBP - Syst ABP (mm Hg)	SDD	Weight (%)
van de Borne, 1992	13	17	20.9	1.2%
Elisaf, 1996	12	1	13.9	2.5%
Huisman, 1995	12	14.3	13.4	2.7%
Conlon, 2000	31	3.8	20.3	3.0%
Berns, 1999	28	1.1	18.7	3.2%
Peixoto, 2000	21	2	15.2	3.7%
Kooman, 1992	22	13	14.7	4.1%
Erturk, 1996	40	-3.9	19.6	4.2%
Nishikimi, 2001	35	21.8	17.3	4.7%
Cheigh, 1992	53	5.3	20.3	5.2%
Savage, 1997	27	6.7	14.5	5.2%
Mitra, 1999	40	17	16.9	5.7%
Conlon, 1996	35	10.5	15.4	6.0%
Santos, 2003	71	15	20.4	6.9%
Canella, 2000	55	16	17.2	7.5%
Zoccali, 1999	64	5.4	17.5	8.5%
Agarwal, 2001	67	13.5	17.1	9.3%
Fagugli, 2002	66	-0.9	12.8	16.3%
Summary	692		16.7	100.0%

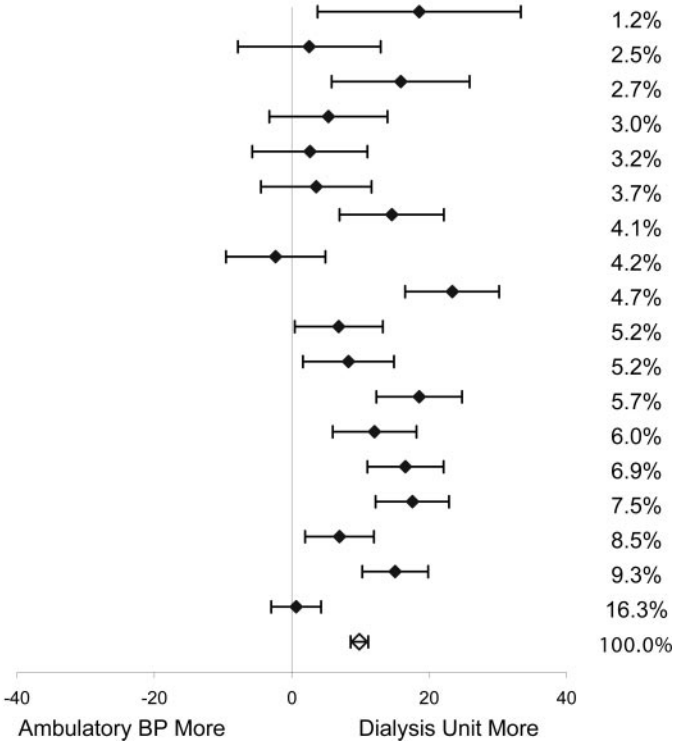

Figure 1. Weighted mean difference between predialysis (preHD) systolic BP (SBP) and systolic ambulatory BP (Syst ABP) and their 95% confidence intervals (CI) are shown. Studies are arranged according to their weights, calculated as discussed in Materials and Methods. The summary measure could not be estimated because of heterogeneity between studies.

ABP and pre- and postdialysis BP were calculated using Bland-Altman plots (9). In this analysis, if the 95% confidence interval of the bias includes zero, then the test is unbiased. The SD of the difference is used as an index of agreement between the BP pairs. Analysis was carried out using a Microsoft Excel spreadsheet (MS Office 2000; Microsoft, Redmond, WA), and results were considered significant for two-tailed $P < 0.05$.

Results

Characteristics of the studies that were included in this analysis are shown in Table 1. Studies that did not report dialysis unit BP (10–17), average overall ABP (11,18), or timing of ABP recording in relation to dialysis (19,20) were excluded. In studies in which the pre/postdialysis BP and ABP were reported separately for two groups (21–25), results were pooled by taking the square root of the weighted average of the variances. In two studies, the correlation coefficients between ABP and pre/postdialysis BP but not the SD of the routine BP were reported (26,27). Data from these studies were used to calculate pooled correlation coefficients but not for calculating the weighted mean difference between BP.

Qualitative Analysis

Eighteen studies that were published over 11 yr with an aggregate of 692 patients met our criteria for inclusion in this analysis. The demographic and clinical characteristics that are relevant to this systematic review are summarized in Table 1. Most studies excluded unstable patients or those who had been on dialysis for <3 to 6 mo. Many studies enrolled consecutive or random patients (24,28–30), but some selected normotensive individuals only (31) or hypertensive individuals only (21,25) or required the availability of a good acoustic window for performance of echocardiograms (32). Three trials had prespecified hematocrit cutoffs for ABP monitoring as a result of participation in anemia correction trials (23,33,34).

The average ages reported varied from 31.6 to 61.2 yr. At least six studies excluded patients with diabetes (22,32,35–38). The average interdialytic weight gain ranged between 1.3 and 4.5 kg. The proportion of patients who were taking antihypertensive medications varied from 0 to 100% with a median of 65%. In those who were taking antihypertensive medication, the individual number of medications averaged between 1.5 and two medications in most studies.

For ABP recordings, 11 studies used the SpaceLabs 90207 monitor, four studies used Takeda TM2421 monitor, and the remaining used either Stuart Medical or Pressurescan monitors. The duration or monitoring varied from 24 to 48 h, with some studies including and others excluding the dialysis session itself.

BP measurement was described inadequately by many studies. Standardized methods are those that use the recommended technique for BP measurement as described by Rahman *et al.* (39); these methods were used in only seven studies (23,30,33,34,36,37,40), whereas others used "routine"

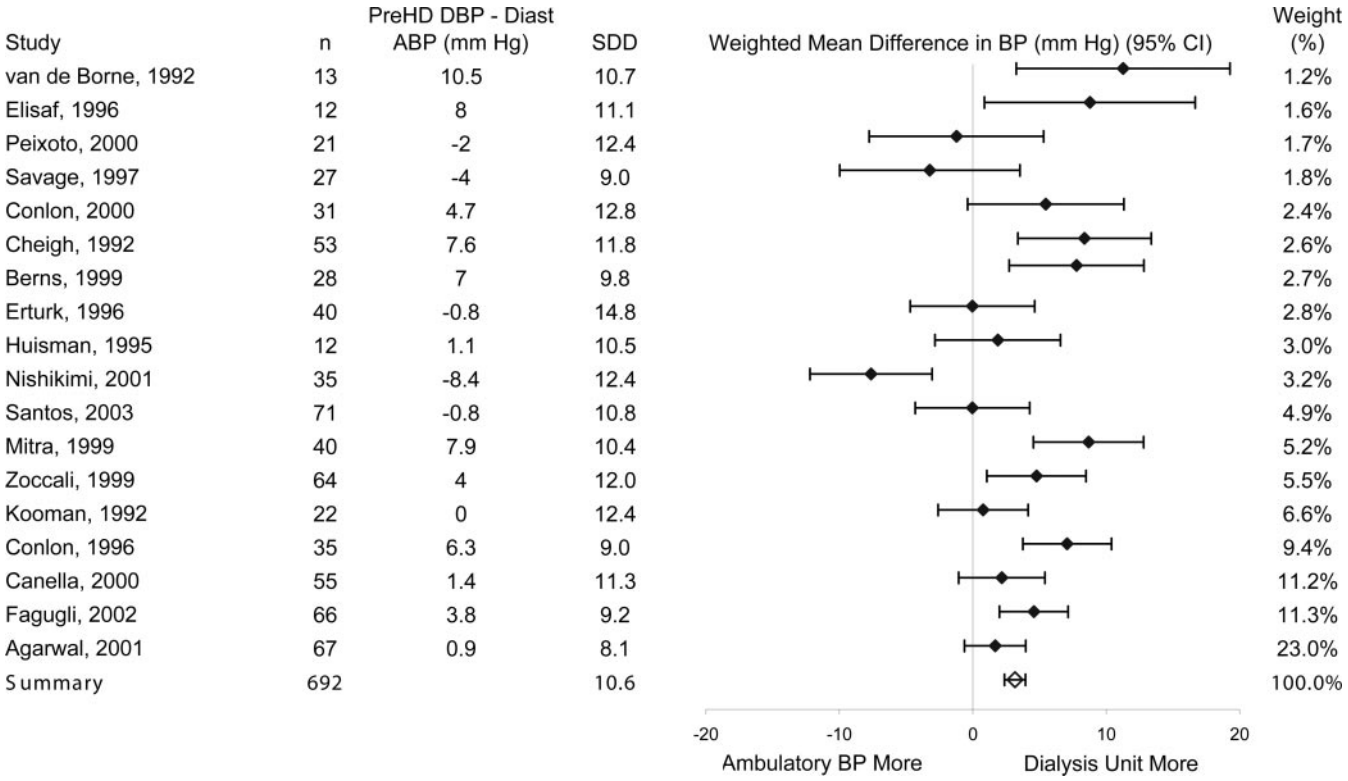

Figure 2. Weighted mean difference between preHD diastolic BP (DBP) and diastolic ambulatory BP (Diast ABP) and their 95% CI.

measurements. The latter do not use a specified method for the measurement of BP. BP were averaged in some studies over several weeks to months, whereas others took single-visit recordings.

Quantitative Analysis

Figure 1 shows the results of the difference between systolic ABP and predialysis SBP. Positive numbers indicate greater estimation by dialysis unit BP. There was substantial heteroge-

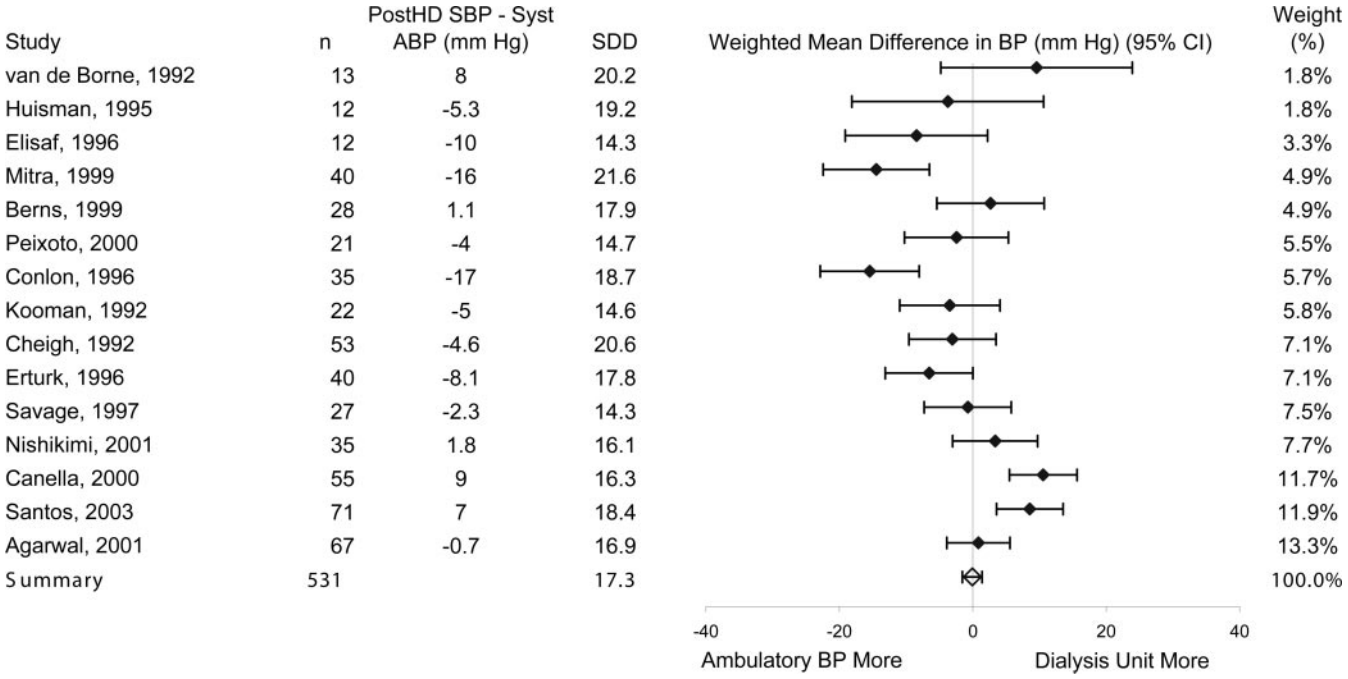

Figure 3. Weighted mean difference between postdialysis (postHD) SBP and Syst ABP and their 95% CI.

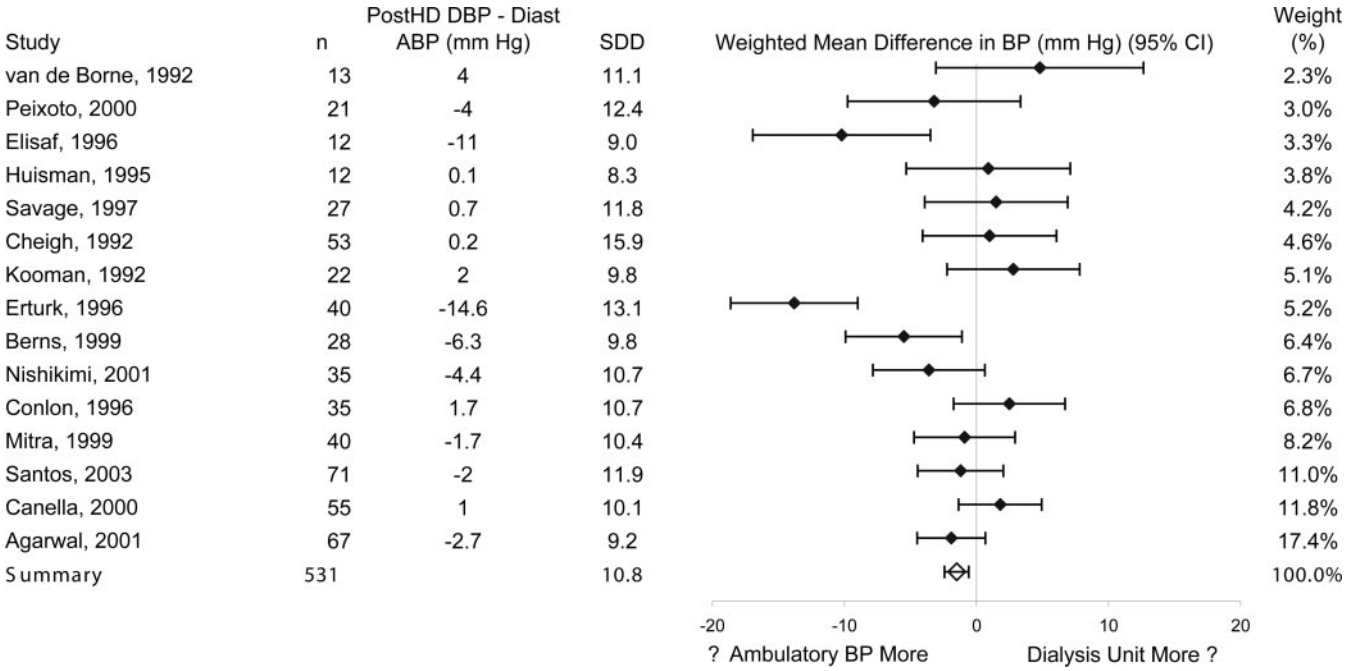

Figure 4. Weighted mean difference between postHD DBP and Diast ABP and their 95% CI.

neity among studies. Therefore, pooled estimates of overestimation were not possible by the standard meta-analytic methods. The SD of the difference of the pooled observations was 16.7 mmHg. Therefore, the limits of agreement between the two methods were 41.7 mmHg to −25.2 mmHg. Predialysis DBP also overestimated ABP, but heterogeneity between studies precluded pooling of data (Figure 2). Agreement limits were similarly wide (23.7 to −18.9 mmHg).

Three studies did not report postdialysis BP; therefore, the number of paired ABP and dialysis unit BP recordings were

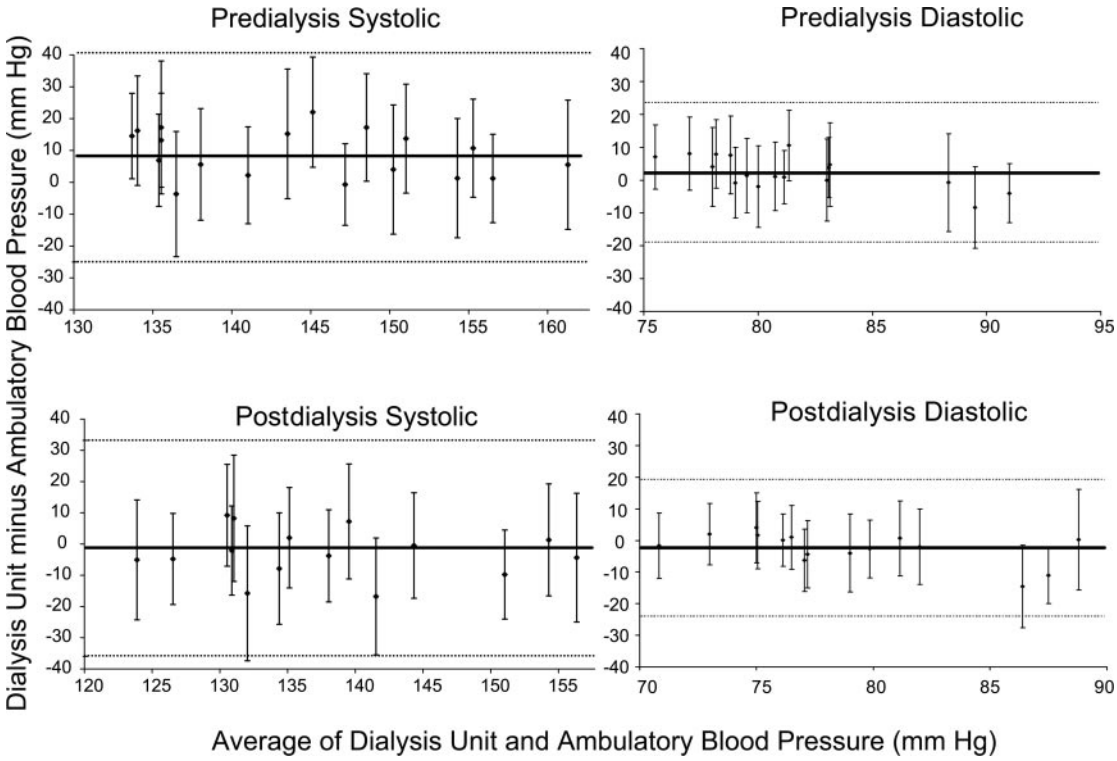

Figure 5. Average of the dialysis unit BP are plotted against the differences in BP. The error bars reflect the SD of the differences. The solid horizontal line is the mean bias; the dotted lines are the limits of agreement between the two BP.

reduced to 531. In contrast to predialysis BP, postdialysis SBP generally underestimated systolic ABP by a variable amount (Figure 3), but the agreement limits were wide (33.1 to −36.3 mmHg). Similarly, postdialysis DBP generally underestimated diastolic ABP (Figure 4) with wide limits of agreement (19.3 mmHg to −23.9 mmHg).

There was large heterogeneity among studies; therefore, it may not be appropriate to pool the estimates of the differences between paired BP (ambulatory and dialysis unit). When differences between each pair of BP values were plotted against their average (Figure 5), no trend toward increasing error or variability was seen with varying BP. Furthermore, the agreement limits between BP were wide.

To further explore the causes of heterogeneity, we evaluated the following factors:

1. Selection factors. Studies that specified normotensive or hypertensive individuals or a hematocrit threshold or an acoustic window were grouped together (studies with selection bias) and compared with those that did not specify such exclusions (studies without selection bias).
2. Diabetes. Studies that specifically excluded diabetes were grouped together and compared with those that did not have such exclusion.
3. Type of ambulatory BP monitor. SpaceLabs 90207 was compared with non-SpaceLabs 90207 model.
4. Studies that specified standardized measurements were compared with "routine measurement."

Table 2 shows the results of these analyses. None of the factors considered were sufficient to explain the heterogeneity. The bias in the measurement remained except for the DBP using standardized measurement. Finally, there was no relationship between size of the study and the difference between BP.

Sensitivity Analysis

All analyses were repeated after exclusion of studies that did not report SD of differences or correlation coefficients between the two BP. These results are shown in Table 3. For predialysis BP, the estimates continued to be biased when studies that did not report SDD or *r* were excluded. Nevertheless, the SDD was similar with or without inclusion of these studies. In contrast, when studies without pooled correlation coefficients were considered, postdialysis BP did not demonstrate statistically significant underestimation. More important, precision, measured by the SDD, remained unchanged.

Discussion

The major finding of this systematic review is that dialysis unit BP have poor agreement with ABP. Predialysis BP were biased estimates of SBP and DBP by a variable amount. Higher predialysis measurements are possible because of increased intravascular volume, withholding antihypertensive medications just before treatment, white coat effect, and lack of standardized measurements. Whereas postdialysis BP seem to be less biased, the poor agreement with ABP precludes their use to predict ABP with any precision. Accordingly, current techniques for recording BP in the dialysis unit are insufficient to predict ABP. The results of the sensitivity analysis support the conclusions drawn from the pooled data.

These findings are of importance both to clinicians and to epidemiologists. For clinicians, the wide agreement limits point out that dialysis unit BP cannot be taken as surrogates of true BP. Therefore, a single high BP recording should not elicit a "knee-jerk reaction" of lowering the BP. From a public health standpoint, these data suggest that pre/postdialysis BP are different from ABP. Accordingly, they may have different prognostic connotations. Studies that use pre/postdialysis BP do not find a relationship between hypertension and outcomes (41,42). Low, not high, BP are found to be more closely related to mortality in hemodialysis patients (41–43). Well-powered studies in representative samples of dialysis patients now are needed to assess whether BP recording outside the dialysis environment, such as *via* ABPM

Table 2. Analysis of factors to explain heterogeneity between studies with respect to predialysis BP[a]

	n	SBP				DBP			
		Bias	95% CI	SDD	Q	Bias	95% CI	SDD	Q
Selection bias									
yes (7)	280	5.7	3.8 to 7.6	16.0	70.7	3.1	1.9 to 4.4	10.5	39.8
no (11)	412	10.3	8.6 to 12	17.3	69.2	1.9	0.8 to 2.9	10.7	62.2
Diabetes									
yes (12)	471	8.2	6.7 to 9.7	16.6	96.7	2.5	1.6 to 3.5	10.3	51
no (6)	221	8.4	6.2 to 10.7	17.1	331	2.0	0.47 to 3.5	11.6	41
ABPM									
SpaceLabs (11)	432	9.6	7.9 to 11.2	17.2	41.5	3.4	1.3 to 3.4	11.2	29.8
non-SpaceLabs (7)	260	6.4	4.5 to 8.4	16.0	92.3	2.5	1.3 to 3.7	9.8	62.1
Dialysis unit BP measurements									
standardized (7)	230	7.0	4.6 to 9.4	18.5	33.9	1.5	−0.01 to 2.9	11.4	56.9
"routine" (11)	462	8.8	7.3 to 10.2	16.0	100.2	2.8	1.8 to 3.7	10.3	40.2

[a]Bias, difference between dialysis unit BP and ABP; DBP, diastolic BP; Q, Q statistic for heterogeneity, all significant at $P < 0.001$; SBP, Systolic BP; SDD, SD of the difference.

Table 3. Bias and precision of dialysis unit BP with and without pooled estimates of correlation coefficients

	Results with Pooled Correlation Coefficients				Results without Pooled Correlation Coefficients			
	Bias	95% CI	SDD	Limits of Agreement	Bias	95% CI	SDD	Limits of Agreement
Pre-HD systolic	8.3	7.0 to 9.5	16.7	41.7 to −25.2	13.5	11.2 to 15.8	16.2	45.9 to −18.8
Pre-HD diastolic	2.4	1.6 to 3.2	10.6	23.7 to −18.9	5.4	3.9 to 6.8	10.2	25.8 to −15.1
Post-HD systolic	−1.6	−3.1 to −0.2	17.3	33.1 to −36.3	−1.0	−3.4 to 1.4	16.8	32.6 to −34.6
Post-HD diastolic	−2.3	−3.2 to −1.4	10.8	19.3 to −23.9	−0.3	−1.7 to 1.1	9.7	19.1 to −19.6

or home measurements, provides better prognostic information in this population.

This systematic review places in a wider perspective the poor agreement between pre/postdialysis BP and ABPM (30). κ coefficients for agreement between 44-h interdialytic ABP and pre/postdialysis BP ranged from 0.32 to 0.60, indicating fair to moderate agreement (30). Similarly, Agarwal and Lewis (29) reported that a 2-wk averaged predialysis BP of >150/85 mmHg or a postdialysis BP of >130/75 mmHg had at least 80% sensitivity in diagnosing hypertension but had poor specificity. The combined analyses (Bland-Altman plots) clearly show that the agreement between pre/postdialysis BP and ABPM is poor. Perhaps, in every day clinical practice, outside the realm of research studies, the difference between ABPM and pre/postdialysis BP is more pronounced, yet most clinical decisions are based on BP that is measured during dialysis.

How can we improve the estimation of BP in hemodialysis patients? Rahman *et al.* (44) suggested that standardizing the technique of BP measurement is associated with statistically lower pre- and posthemodialysis BP. More than half of the SBP and one third of the DBP were erroneous by >10 mmHg when comparing usual with the standardized technique. On average, standardized measurement of BP recording was associated with 14.3/7 mmHg lower predialysis and 13.6/4.4 mmHg lower postdialysis BP when compared with the "usual" techniques used in the dialysis unit. The magnitude of this error of SBP should attenuate the difference between predialysis BP and systolic ABP. Standardized techniques were used by several studies that were included in this review. Erturk *et al.* (37) did not observe substantial differences in the recordings when using a standardized technique, but others (23,30,33,34,36,40) did. Studies that used the standardized measurements had as much variability in the difference between pre/postdialysis BP and ambulatory measurements as did nonstandardized studies. Therefore, our analysis does not support the hypothesis that standardized BP recordings can precisely predict ABP. Similarly, the type of ABP monitor used, presence or absence of diabetes, and exclusion or inclusion of studies that reported specific criteria for recruitment were insufficient to explain the heterogeneity between the studies.

Some limitations of our analysis should be pointed out. The BP measurement techniques, either "routine" or ambulatory, were not the same among studies. For example, ABP may be obtained two or three times every hour and may lead to more or less precise estimates. Similarly, as pointed out above, the techniques of predialysis BP are variable across studies. Although this may introduce some "noise," it is unlikely to lead to completely different conclusions from those obtained through this analysis. Publication bias is a limitation of many analyses. Perhaps publications that favor the new technology of ABPM are more likely to get published than those that show no difference *versus* regular measurements.

Prospective studies are needed to assess accurately BP in hemodialysis patients. ABP recording provides the most reproducible way to assess BP in dialysis patients and provides information on the day–night change in BP that may be of prognostic significance (43–46). Studies now are needed to compare standardized measurement technique (39), self-recorded BP (47), and BP recorded at other time points, such as 20 min after dialysis (28), to predict ABP. The main results of this review demonstrate lack of solid data to back the Kidney Disease Outcomes Quality Initiative guideline recommendations regarding BP goals in hemodialysis patients. We believe that self-recorded BP (home) monitoring is a promising technique that, *via* involvement of patients in the delivery of their health care, may improve BP management. Although we could not pool the results of various studies by meta-analysis, it seems that dialysis unit BP still may be useful in a qualitative sense (29).

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