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When Is the Best Moment to Assess the Ankle Brachial Index: Pre- or Post-Hemodialysis?

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Key Words
Ankle brachial index · Peripheral arterial disease · Dialysis

Abstract
Background: Cardiovascular disease is an important cause of death in patients on dialysis. Peripheral arterial disease (PAD) is a prognostic factor for cardiovascular disease. The ankle brachial index (ABI) is a noninvasive method used for the diagnosis of PAD. The difference between ABI pre- and post-dialysis had not yet been formally tested, and it was the main objective of this study. ***Methods:*** The ABI was assessed using an automated oscillometric device in incident patients on hemodialysis. All blood pressure readings were taken in triplicate pre- and post-dialysis in three consecutive dialysis sessions (times 1, 2, and 3). ***Results:*** One hundred and twenty-three patients (85 men) aged 53 ± 19 years were enrolled. We found no difference in ABI pre- and post-dialysis on the right or left side, and there was no difference in times 1, 2, and 3. In patients with a history of PAD, the ABI pre- versus post-dialysis were of borderline significance on the right side ($p = 0.088$). ***Conclusion:*** ABI measured pre- and post-dialysis presented low variability. The ABI in patients with a history of PAD should be evaluated with caution. The applicability of the current method in predicting mortality among patients on hemodialysis therefore needs further investigation.

Introduction

Cardiovascular disease is the most common cause of death in patients with end-stage renal disease [1, 2]. It is well known that the diagnosis of peripheral arterial disease (PAD) is a prognostic factor of cardiovascular disease [3, 4]. The easiest and most commonly used noninvasive method for the diagnosis of PAD is measurement of the ankle brachial index (ABI) [5]. A low ABI ratio (<0.9) is an independent risk factor for cardiovascular disease including fatal and nonfatal complications [6, 7]. Recently, a higher ABI (>1.3) was also associated with cardiovascular morbidity and mortality [8, 9].

With respect to patients on hemodialysis, few studies have shown that the ABI is associated with mortality [10] and ventricular hypertrophy [11, 12]. In these studies, the ABI was assessed by an ABI form device or a Doppler but without distinguishing between pre- and post-dialysis. As of yet, there is no agreement on the methodology for ABI assessment [13]; a lack of consensus on standardization, and the accuracy and repeatability of ABI readings, has certainly been questioned in the literature [14]. Also, thus far, the best moment to assess the ABI, pre- or post-dialysis, has not been well defined.

Hemodynamic changes can occur during hemodialysis, which can modify vascular and autonomic proper-

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Table 1. Characteristics of the population studied

Variable	
Age, years	53 ± 19
Male gender	68.5
Hypertension	99.2
Diabetes	43
Smoking habits	29.3
Systolic blood pressure, mm Hg	140.3 (128.2–155.0)
Diastolic blood pressure, mm Hg	80.0 (70.0–89.0)

Values are expressed as percents, means ± SD, or medians (interquartile ranges).

ties and impact on blood pressure. A variable amount of fluid is removed by ultrafiltration during hemodialysis. Even when the patient does not experience any hemodynamic impairment, a redistribution of fluid from the interstitial to the intracellular compartment occurs. There are significant drops in extracellular fluid from the trunk, legs, and arms, but the magnitude is greatest in fluid from the legs [15]. As the ABI represents the ratio of the ankle to brachial systolic pressure [16], it can be affected by dialysis resulting in a different value pre- versus post-dialysis. There has been no study, to our knowledge, comparing ABI obtained pre- and post-dialysis until this point. The aims of this study were: first, to provide an opportunity to compare ABI pre- and post-dialysis on different days and on the right and left sides, separately addressing patients with a history of PAD, and second, to ascertain the reliability of ABI measurement by two simultaneous oscillometric devices in a group of incident patients undergoing hemodialysis.

Methods

This study was designed to assess the applicability of ABI determination with the employment of an automated oscillometric blood pressure device in incident patients on hemodialysis, comparing pre- and post-dialysis as well as the right and left sides.

Study Population

This study prospectively included thrice-weekly hemodialysis incident patients who were recruited from the hemodialysis clinic of the Hospital das Clinicas, São Paulo, Brazil, from February 2008 to January 2010. Demographic characteristics, smoking habits, and medical history of diabetes, hypertension, and PAD were recorded. To be eligible for this study, patients had to have started regular hemodialysis within the past month. Exclusion criteria were: major amputation of lower or upper limbs and arteriovenous fistula in both arms and both legs. None of the subjects had atrial fibrillation, which can interfere with oscillometric measurement of the blood pressure. All recruited patients were eligible for the study, agreed to participate, and signed the consent form. The research protocol was reviewed and approved by local the Ethics Board (under No. 2603/08).

Ankle Brachial Pressure Index Measurement

All measurements were made in the same dialysis room with a controlled temperature (22 ± 2°C) and with patients in a sitting position with legs straight. The measurements were done using two oscillometric devices (Omron 705 CP; Omron Corp., Tokyo, Japan) simultaneously to measure the blood pressure in the upper and lower extremities. Standard calibration of the devices was performed just before study initiation and every 4 weeks during the recruitment process. Cuffs were comfortably set in place, adjusted to the arm above the cubital malleolus with the cuff directed towards the brachial artery trajectory, and directed toward the trajectory of the posterior tibial artery. One oscillometric pressure reading was taken at each extremity. For those cases with error(s), a second reading was tried. Each series of measurements was in the following order: right arm and leg (simultaneously) and left arm and leg (simultaneously). This sequence was only interrupted in case of the presence of an arteriovenous fistula. In this last case, only the contralateral limb was assessed. Measurements pre-dialysis, were performed with the patient at rest in the supine position 5 min after the beginning of the session. Measurements post-dialysis were performed in the last 5 min of the dialysis session. All blood pressure readings were taken in triplicate pre- and post-dialysis (three consecutive dialysis sessions: times 1, 2, and 3). The protocol was performed by the same examiner in all situations. During the study, only raw blood pressure values were recorded and stored on a database for later ABI calculation.

The ABI was calculated in 4 different situations: (1) 3 different measuring days, (2) right and left sides, (3) pre- and post-dialysis, and (4) in the presence or absence of PAD.

Statistical Analysis

The statistical analysis was performed in a systematic intraobserver fashion, with an observer repeating measurements using the same oscillometric monitor on 3 separate examination days, 48 h apart (times 1, 2, and 3), in the 3 consecutive dialysis sessions. Relationships between right and left side blood pressures and between pre- and post-dialysis were examined by Spearman's rho coefficient. A pairwise t test was used to evaluate the effect of hemodialysis on ABI calculation (comparing pre- and post-dialysis). Blood pressure measurements on the right (rBP) and left sides (lBP) in the consecutive sessions were compared by Friedman's test. The coefficient of variation was obtained across these 3 different measurements days. The intraobserver correlation was obtained. A Bland-Altman plot was drawn to assess the variability of all measurements pre- and post-dialysis. Data are presented as means ± SD or as medians and interquartile ranges as appropriate. Qualitative variables are expressed as percentages. $p \leq 0.05$ was considered statistically significant. Analyses were performed using SPSS 17.0.1 (SPSS, Inc., Chicago, Ill., USA).

Table 2. ABI values on the right and left sides pre- and post-dialysis

	Time 1	Time 2	Time 3
Right side			
ABI pre-dialysis	1.18 (1.03–1.33)	1.18 (1.05–1.20)	1.18 (1.07–1.29)
ABI post-dialysis	1.18 (1.09–1.31)	1.16 (1.03–1.28)	1.20 (1.08–1.30)
Left side			
ABI pre-dialysis	1.19 (1.04–1.31)	1.18 (1.05–1.30)	1.19 (1.09–1.32)
ABI post-dialysis	1.20 (1.08–1.29)	1.17 (1.06–1.28)	1.21 (1.09–1.33)

Values are expressed as medians (interquartile ranges).

Results

A total of 123 patients (38 women and 85 men) were enrolled into the study. Characteristics of the population studied are shown in table 1. The intraobserver correlation was high (r = 0.85).

ABI on Different Measuring Days (Times 1, 2, and 3)

The coefficient of variation across 3 times pre- and post-dialysis, on the right and left sides, and in patients with a history of PAD was less than 5.

ABI on the Right versus Left Side

A pairwise t test using the first setting of measurements on the right and left sides showed no difference in ABI (1.16 ± 0.24 vs. 1.17 ± 0.22, p = 0.565). The rBP and lBP in the consecutive sessions (times 1, 2, and 3) presented similar medians: from 124 to 160 mm Hg for systolic rBP (p = 0.205), from 69 to 92 mm Hg for diastolic rBP (p = 0.212), from 125 to 158 mm Hg for systolic lBP (p = 0.982), and from 70 to 92 mm Hg for diastolic lBP (p = 0.160). Univariable analysis revealed that the best correlation on the right side was between the systolic blood pressure in time 2 and that in time 3 (r = 0.71, p < 0.001), and on the left side the best correlation was between the systolic blood pressure in time 2 and that in time 3 (r = 0.65, p < 0.001).

ABI Pre- versus Post-Dialysis

The consecutive ABI calculated pre- and post-dialysis on the right and left sides are shown in table 2. No significant difference was found when comparing pre- and post-dialysis ABI on the right side (p = 0.152) and on the left side (p = 0.829). The ABI obtained from the right side pre- versus post-dialysis were correlated in times 1, 2, and 3 (p < 0.001). The same was observed on the left side, with a significant correlation between ABI pre- versus post-dialysis in times 1, 2, and 3 (p < 0.001). The ABI post-dialysis obtained the best results as assessed by the Friedman test in all sessions (times 1, 2, and 3), with p = 0.831. We found no difference in the ABI obtained from measures of blood pressure pre- versus post-dialysis in the entire population (table 3). Figure 1 shows a Bland-Altman plot comparing pre- and post-dialysis measures.

Table 3. Correlation of ABI pre- and post-dialysis on each measurement day

	Significance
Right side	
Time 1 post-dialysis versus time 1 pre-dialysis	0.161
Time 2 post-dialysis versus time 2 pre-dialysis	0.582
Time 3 post-dialysis versus time 3 pre-dialysis	0.114
Left side	
Time 1 post-dialysis versus time 1 pre-dialysis	0.890
Time 2 post-dialysis versus time 2 pre-dialysis	0.933
Time 3 post-dialysis versus time 3 pre-dialysis	0.623

By Wilcoxon's signed-rank test.

ABI in the Presence or Absence of PAD

A history of PAD was observed in 24 patients (19.5%). Eighteen of these patients were men (75%) and 20 of these patients presented diabetes (83.3%). A comparison between patients with and without a history of PAD is shown in table 4. Patients with a history of PAD presented lower ABI pre-dialysis on the right side (p = 0.013). There was no other significant difference between patients with and without a history of PAD. We found no difference between ABI pre- and post-dialysis in patients without a history of PAD for both the right and left sides (p = 0.497 and p = 0.939, respectively) in patients without

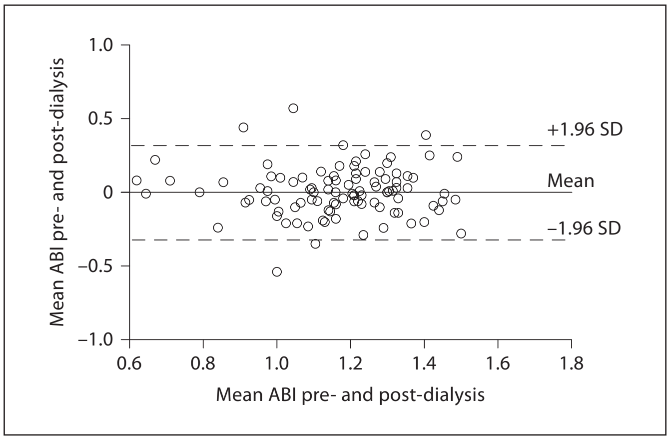

Fig. 1. Bland-Altman scatter plot of the differences between pre- and post-dialysis ABI assessed using an oscillometric device. Dotted lines represent the upper (0.33) and lower (–0.32) limits of agreement.

Table 4. ABI according to the history of PAD

	With a history of PAD (n = 24)	Without a history of PAD (n = 99)	p
Right side			
ABI pre-dialysis	1.07 (0.90–1.29)	1.19 (1.08–1.33)	0.013
ABI post-dialysis	1.19 (1.01–1.29)	1.18 (1.09–1.32)	0.205
Left side			
ABI pre-dialysis	1.08 (0.91–1.34)	1.20 (1.06–1.31)	0.166
ABI post-dialysis	1.13 (1.02–1.26)	1.20 (1.10–1.30)	0.301

Values are expressed as medians (interquartile ranges).

a history of PAD. Regarding patients with a history of PAD, there was no difference in ABI pre- versus post-dialysis on the left side (p = 0.794). However, this difference was of borderline significance on the right side (p = 0.088).

Discussion

This study demonstrates for the first time a comparison between ABI pre- and post-dialysis. Our results showed a good relationship between ABI pre- and post-dialysis measured using two automatic oscillometric devices simultaneously. Our technique seems to be fairly reproducible, as indicated by high correlation coefficients. To our knowledge, this is the first study to describe and quantify the intraobserver reliability of ABI assessments in a group of incident patients on hemodialysis, as well as pre- and post-dialysis.

ABI determination in clinical practice can be performed using a properly validated simple oscillometric device. Intraobserver validation is extremely important, as is the use of a method that is observer dependent. Observer variability has been a problem ever since blood pressure measurements began as far back as the 1940s. We focused on the difference between pre- and post-dialysis and the difference between consecutive sessions of dialysis. We found no difference when comparing blood pressures obtained from 3 consecutive dialysis sessions (times 1, 2, and 3). However, the most important result came from the fact that no difference in ABI pre- and post-dialysis was observed, mainly in patients without a history of PAD. The difference between ABI pre- and post-dialysis in patients with a history of PAD was not significant on the left side but was of borderline significance on the right side. The reason this tendency was observed is unclear. One possible explanation is that asymmetric peripheral disease could affect the blood pressure more in one limb than in others, and in our PAD patients the blood pressure post-dialysis had an influence on the ABI calculation. Therefore, in patients with a history of PAD, we should be aware of this possibility and the ABI should be evaluated with caution. Except for this specific situation, our findings point to similar ABI calculations even after dialysis, despite the potential for hemodynamic impairment. Besides, the pre-dialysis assessment occurred in the first 5 min after the session had begun. Therefore, no delay in dialysis room routine is justified as it relates to ABI measurement.

The ABI can be measured using the Doppler technique (considered a gold standard method) or a pneumatic pressure cuff. The use of Doppler-measured ABI for PAD diagnosis is limited because of time and the required training. The reliability of ABI measured using automatic blood pressure cuffs has been studied with conflicting results in the general population [17–21]. The Doppler technique to assess the ABI is described as a gold standard method. However, the oscillometric technique is not a contrasting method. By making ABI more accessible in daily clinical practice, a greater number of patients with established PAD may be diagnosed. Since it is practical, simple, and easy to perform, ABI measurement with two simultaneously oscillometric devices can be repeated more often during clinical follow-up and for research proposals. The results of the present study indicate that the measurement of ABI by the oscillometric technique using two devices simultaneously is reproducible and simple. The validity and reproducibility of the measurement of ABI intraobserver and interperiod evaluations were high with a low SD for measurement difference. With the method proposed in our study, physicians can therefore easily perform ABI measurements in the daily nephrology practice or at bedside.

A few limitations of our study should be considered when interpreting these findings. The observed variability may be different in measurements obtained under conditions that differ from those in our study. Our study did not address the accuracy of blood pressure measurements taken with the Omron device. Only one type of automatic blood pressure cuff was used. Thus, we cannot systematically extrapolate our results to other devices available on the market.

In summary, our technique for measuring ABI presented a low intraobserver variability. Furthermore, ABI obtained from blood pressures measured pre- or post-dialysis were comparable, which can yield new options for the routine evaluation of ABI. This offers the potential to measure ABI in clinical practice, thereby improving both the detection and monitoring of PAD among patients on hemodialysis. Patients with a history of PAD should have their ABI estimated more carefully, including measurements on the right and left side as well as pre- and post-dialysis. Although it is regarded as a routine test, a great deal of further work is required before a consensus can be reached on a standardized technique for ABI. Moreover, the applicability of the current method in predicting mortality among patients on hemodialysis needs further investigation.

Disclosure Statement

None.

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