

Is estimation of laser Doppler skin perfusion pressure appropriate during hemodialysis enforcement?

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Citation

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Abstract

The laser Doppler skin perfusion pressure (SPP) testing is expected to be beneficial for assessment of lower extremity peripheral artery disease (PAD) in patients on hemodialysis (HD). However, it is inconsistent at what timing SPP should be measured in relation to HD procedure. We measured each SPP value before, during, and after HD in 12 limbs of 6 patients without diabetes or PAD. There were not significant differences among mean SPP values, which were 90mmHg (SD=15), 83mmHg (SD=10), 89mmHg (SD=12), and 86mmHg (SD=16) at predialysis, 2-hr, 3-hr, and postdialysis, respectively. Results of this study suggest that compensatory responses to volume loss could contribute to maintain cutaneous perfusion during ultrafiltration of fluid. The laser Doppler SPP examination is likely to be useful even during or after HD. However, it seems that the SPP evaluation during or after HD requires carefulness.

INTRODUCTION

Peripheral arterial disease (PAD) is common in patients with end-stage renal disease. The assessment of arteriosclerotic complication is of particular important and interest for patients on hemodialysis (HD) (^{1,2,3,4}). However, ankle/brachial index (ABI) is not always a good indicator in patients with end-stage renal disease (⁵). The laser Doppler skin perfusion pressure (SPP) testing is a microcirculatory measure and reflects perfusion at the level of the skin. The applicability of SPP has become wider (^{6,7,8}), and is expected to be beneficial for assessment of lower extremity PAD in patients on HD (^{9,10}). The timing of SPP measurement in HD patients varies with each institution. Briefly, SPP value is conventionally measured before HD or at non-dialysis day. However, in some institutions, SPP measurement was performed after or during HD. Ultrafiltration dialysis is accompanied by fluid removal and may develop a reduction in blood pressure during HD. Reduced plasma refilling and peripheral vasoconstriction as a result of volume loss would lead to a reduced SPP. It is quite a problem that there is no opinion as for the timing of SPP measurement. I reported the variation of SPP values associated with HD time-course.

METHODS

This study enrolled 6 outpatients with stable disease conditions, who had been treated with ordinary chronic regular HD more than for 4 hours. All patients were dialyzed

three times a week. Preceding this study, ABI was evaluated with form PWV/ABI (Nippon Colin, Komaki, Japan) and toe/brachial index (TBI) was evaluated with VaSera VS-1000 (Fukuda Denshi, Tokyo, Japan). Patients with diabetes mellitus and PAD were excluded. The SPP test using SensiLase PAD3000 (Kaneka, Osaka, Japan) was started to perform at least fifteen minutes after patient lay on the bed. SPP was measured with a laser sensor assembly (LSA) attached on the patient's foot and with a pressure cuff wrapped around both the foot and LSA. Systolic blood pressure (SBP), pulse rate (PR) and SPP were measured at four time points, predialysis; 2-hr and 3-hr later the initiation of HD; and postdialysis. Continuous monitoring of % blood volume reduction was evaluated by CRIT-LINE III (Hemametrics, Salt Lake City, UT, USA) during HD session.

The study was conducted according to the declaration of Helsinki. It was also fully explained to all patients, especially focusing on the purpose of the study and precise procedures, before enrollment. All patients agreed to participate in the research and gave oral informed consent.

Data are given as means and standard deviations. Changes in ultrafiltration of fluid, % blood volume reduction, SPP, SBP, and PR were analyzed using repeated measures analysis of variance. Statistical significance was defined at the level of $p < 0.05$.

RESULTS

The participants in this study were 5 women and 1 man. The mean age was 64.7 (SD=14.4, range 47-83) years, and the mean duration of dialysis was 85.5 (SD=63.2, range 27-182) months. Their primary renal diseases were chronic glomerulonephritis in 4 cases, polycystic kidney disease in 1 case, and hypertension in 1 case. The mean body mass index (BMI) was 21.2 (SD=2.0, range 19.0-23.7) kg/m². The mean ultrafiltration volume (removal of fluid) during HD was 2.6 (SD=0.9, range 1.5-4.3) L. Four patients were treated with antihypertensives, two patients were treated with antiplatelets, and one patient was treated with a sympathomimetic agent. The present characteristics and HD treatment details are shown in Table 1.

Figure 1

Table 1. The present characteristics and HD treatment details.

Case	Age	Sex	Cause of renal failure	Duration of dialysis (month)	BMI (kg/m ²)	Time of HD session (hr)	Ultrafiltration of fluid (L)	Dialyzer membrane
Case 1	83	F	Hypertension	28	20.0	3	2.5	EVAL
Case 2	47	F	Glomerulonephritis	182	23.3	3	4.3	EVAL
Case 3	79	F	Glomerulonephritis	27	23.7	4	2.2	PS
Case 4	68	M	Glomerulonephritis	73	19.0	4	2.4	PES
Case 5	34	F	Glomerulonephritis	140	19.9	4	1.5	CTA
Case 6	37	F	Polycystic kidney	38	21.3	4	2.5	CTA

M: male; F, female; EVAL: ethylene-vinyl alcohol copolymer; PS: polysulfone;

PES: polyethersulfone; CTA: cellulose triacetate

Measurements of ABI, TBI and SPP were carried out in 12 limbs. The mean value of ABI was a level of 1.16 (SD=0.10, range 0.94-1.27), the mean value of TBI was a level of 0.70 (SD=0.13, range 0.51-0.91), and the mean value of SPP at predialysis was a level of 90 (SD=15, range 65-118) mmHg (Table 2).

Figure 2

Table 2. Subject demographic data of ABI, TBI and SPP.

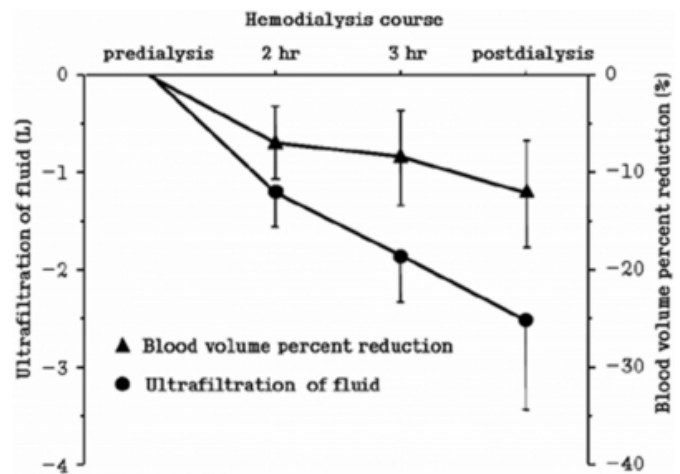
Case	Site	ABI	TBI	SPP predialysis (mmHg)
Case 1	R	1.01	0.59	94
	L	0.94	0.56	75
Case 2	R	1.23	0.91	99
	L	1.27	0.79	95
Case 3	R	1.11	0.51	74
	L	1.14	0.70	65
Case 4	R	1.24	0.80	102
	L	1.18	0.80	118
Case 5	R	1.19	0.69	98
	L	1.14	0.82	98
Case 6	R	1.23	0.54	77
	L	1.22	0.73	80

R: right foot; L: left foot.

The time-course in ultrafiltration of fluid, %blood volume reduction is shown in Fig. 1.

Figure 3

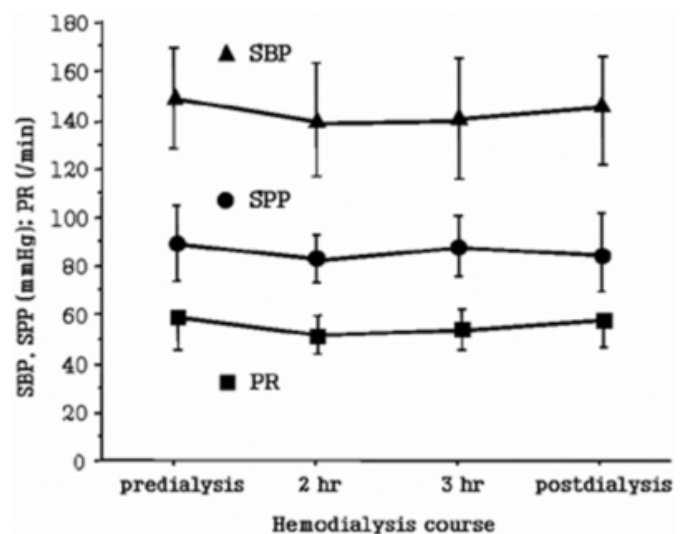
Fig. 1. Time-course in ultrafiltration of fluid, %blood volume reduction. Data are means +/- standard deviations.



The time-course in SBP, PR and SPP is shown in Fig. 2.

Figure 4

Fig. 2. Time-course in SBP, PR and SPP. Data are means +/- standard deviations.



The amount of ultrafiltration of fluid (removal of fluid) significantly increased and blood volume significantly decreased steadily throughout HD session. SBP decreased down to 2-hr later and thereafter continued to increase gradually. HD resulted in a significant decrease in PR with a trough at 2-hr later and thereafter continued to increase gradually. However, there were not significant differences among SPP values during HD time-course.

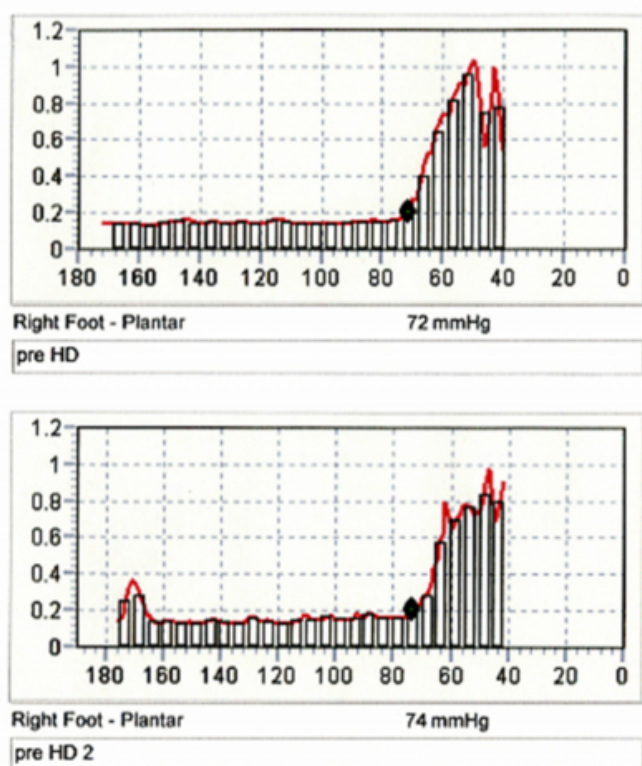
DISCUSSION

The laser Doppler SPP measurement is an objective, noninvasive, diagnostic test for the assessment of PAD, and has become to apply for patients on HD (8). SPP value is an

indirectly measured wedge pressure of the artery supplying blood to the region of skin compressed by the pressure cuff. Capillary red blood cell velocity is assessed by a marked increase in perfusion occurs during a pressure cuff deflation. SensiLase PAD3000 system measures the pressure using laser Doppler following a controlled, automated release of occlusion from a blood pressure cuff and offers the value automatically. Technical problem is the presence of edema that makes an estimate of SPP unreliable. Inadvertent movement of subjects caused some measurement failures in the SPP testing. If the patient is restless it may not be possible to obtain adequate readings. The reproducibility (average of coefficient of variation) in SPP measurement using SensiLase PAD3000 was 5.3% (ranged 1.4-8.7%) in our preliminary data in 10 limbs of 5 healthy subjects. Fig. 3 shows typical test results in one subject in the present study.

Figure 5

Fig. 3. Typical SPP test results in one subject. The SPP value is automatically analyzed and marked on the SPP graph. Values measured repeatedly are shown as 72mmHg (upper panel) and 74mmHg (lower panel).



SPP value is thought to be influenced by several factors such as systemic blood pressure, autonomic nervous function. The usual manifestation of hemodynamic instability during ultrafiltration dialysis (in which fluid removal occurs) is hypotension. An individual subjected to volume loss is able

to maintain blood pressure by employing mechanisms that involve the autonomic and cardiovascular systems. One compensatory response to volume loss is vasoconstriction of the venous side of the circulation, particularly in the splanchnic and dermal beds. Vasoconstriction redistributes volume to the central circulation. Plasma refilling, by fluid transfer from the extracellular and intracellular compartments, is also maintained. Abnormalities in autonomic function are commonly present in patients with chronic renal failure (^{11,12}). With the volume removal accompanied by HD, reductions in central venous pressure and in arterial blood pressure would be expected to unload baroreceptors and thus reduce their tonic restraint on the vasomotor center, resulting in reflex increases in sympathetic outflow to the heart and peripheral circulation to help maintain blood pressure. Chronic hemodialysis patient, particularly in elderly or with diabetes, often demonstrates decreased venous compliance and disturbances in these compensatory steps, and is thus prone to develop hypotension during dialysis procedure. No previous study investigated the association between body fluid removal by ultrafiltration and the variation of SPP value. It is inconsistent when SPP should be measured as for the HD timing. In the present study, SPP did not show significant differences among before, during and after HD treatment. Results of this study suggest that compensatory responses to volume loss could contribute to maintain cutaneous perfusion during ultrafiltration.

Several potential limitations exist. First, medicated patients were studied, and thus medications may have affected cardiovascular responses and cutaneous perfusion. It is now considered ethically problematic to perform a complete washout of medications. Second, the present study excluded patients with diabetes. They are at higher risk for PAD, and sensitive to intradialytic hypotension. In the current study, symptomatic intradialytic hypotension did not occur. Consequently, it was unlikely that changes in SPP would be observed during routine HD treatment. However, it is uncertain whether these results might be applicable to patients with diabetes or severe PAD. Disturbances in arterial and autonomic function may contribute to impaired mobilization of fluid into the central circulation and may ensure the decline in SPP during HD. Rather, when the development of a reduced SPP accompanied by ultrafiltration was seen, disturbance in arterial function or impaired autonomic function might presumably exist. This is an area worthy for future investigation. In future, further study to confirm the relationships between SPP and

disturbances in arterial and autonomic function in such individuals would be helpful. Third, various dialysis membranes were used in this study. It seems that reactions from the patients as the result of blood contact with the membrane materials may not be uniform. The major limitation of the present study is the relatively small number of patients were recruited. Larger studies will give more definite results. However, this study was unique in that the measurement was carried out in a serial HD course.

In conclusion, in patients without diabetes mellitus or severe PAD, the laser Doppler SPP examination is likely to be useful during or after HD. However, SPP value was not examined in patients with diabetes or PAD in this study. It seems that the SPP evaluation during or after HD requires carefulness. If the development of a reduced SPP accompanied by ultrafiltration was seen, disturbance in arterial function or impaired autonomic function might presumably exist.

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