Effect of Body Position on Skin Perfusion Pressure in Patients With Severe Peripheral Arterial Disease

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Background: Skin perfusion pressure (SPP) has been shown to be useful in the assessment of the severity of peripheral arterial disease (PAD), and ulcers can be cured when the SPP is ≥ 30 – 40 mmHg. The purpose of this study was to determine the best body position for measuring SPP in patients with severe PAD.

Methods and Results: We studied 24 limbs of 18 patients with PAD whose SPP was ≤ 40 mmHg. After patients had been resting supine for 10 min (Position I), their SPP was measured at the dorsum of the foot with a laser Doppler probe. Following measurement in the supine position, SPP was measured in the sitting position after the foot had been extended horizontally for 10 min (Position II), and in the sitting position after the foot had been lowered vertically for 10 min (Position III). SPP increased significantly from Position I to Positions II and III (25.3 ± 10.9 mmHg, 40.6 ± 12.7 mmHg, and 73.4 ± 17.7 mmHg, respectively; $P < 0.0001$). In all patients, SPP values exceeding 30 mmHg were obtained in Position III.

Conclusions: The best SPP values were obtained in Position III, which is the ideal position for peripheral arterial circulation in patients with severe PAD. (*Circ J* 2012; **76**: 2863–2866)

Key Words: Body position; Critical limb ischemia; Peripheral arterial disease; Skin perfusion pressure

Various methods have been used to objectively evaluate ischemic limbs and it has been suggested that healing of trophic lesions is impossible if the skin perfusion pressure (SPP) is < 30 – 40 mmHg.^{1–5}

SPP measurement was first reported in 1970.⁶ Initially, the blood pressure at the capillary vascular bed was measured by topically injecting a radioactive substance and applying pressure with a blood pressure monometer. This method, however, was not widely used because of its high cost, complexity and invasiveness. Later, a laser Doppler technique for measuring SPP was established as a method of evaluating skin tissue viability.^{7,8} Because very low levels of SPP can be measured more simply, less invasively, with higher reproducibility, and in a shorter time by this method, it is widely used. This method is especially useful for patients with severe calcification of the arterial walls, in whom ankle and toe pressure is not reliable. It is mainly used to determine the level of amputation of ischemic limbs when it is difficult to save a limb, or to predict the prognosis of ulcer healing.^{1–5} It has been reported that viability is poor if the SPP is 30–40 mmHg or below.^{1–5} However, there are no data on the relationship between body position and SPP.

In the present study, we measured the SPP of patients with severe peripheral arterial disease (PAD) while they were in various positions to determine the ideal position to improve the SPP values.

Methods

Study Population

For this study, 24 limbs of 18 patients with PAD (9 males, 9 females; age 60–90 years, average: 76.5 ± 8.3 years) whose SPP was < 40 mmHg were enrolled. Written informed consent was given by each subject after a detailed explanation of the purpose and procedures of this study. The protocol was approved by the Ethical Panel of Naganoken Koseiren Shinonoi General Hospital.

SPP Measurements

After patients had rested supine for 10 min (Position I, **Figure 1A**), the SPP was measured at the dorsum of the foot using LASER-DOPP (Vasamedics, St. Paul, MN, USA) with a laser Doppler probe. The laser Doppler flow sensor was secured within the bladder of the blood pressure cuff, which contained a transparent polyvinyl chloride window, so that low measurements could be made during cuff inflation and deflation. The pneumatic cuff was first inflated to a suprasystolic pressure. At this pressure, the laser Doppler flux was less than 0.1 volume percent. The cuff was stepwise deflated in 10 mmHg decrements to 50 mmHg and then in 5 mmHg decrements to below 50 mmHg. The pressure was maintained for 15 s at each pressure interval. Deflation was continued until 2 consecutive increases in laser Doppler scan

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Figure 1. Patients' positions during measurement of skin perfusion pressure (SPP). Position I is lying supine (**A**), Position II is sitting with the foot extended horizontally (**B**) and Position III is sitting with the foot lowered vertically (**C**).

Table. Patients' Clinical Characteristics

Age	76.5±8.3 years
Males	9 (50%)
Fontaine III/IV	15 (63%)/9 (37%)
Ankle-brachial index	0.42±0.24
Diabetes	11 (61%)
Hypertension	13 (72%)
Dyslipidemia	6 (33%)
Current smoker	8 (44%)
Hemodialysis	8 (44%)

flux were noted. The first increase in the laser Doppler output represents the initiation of blood flow into the regional micro-circulation and was taken to be the foot SPP. Following measurement in the supine position, SPP was measured with the patient in the sitting position after the foot had been extended for 10 min (Position II, **Figure 1B**) and after the foot had been lowered for 10 min (Position III, **Figure 1C**).

Statistical Analysis

Continuous variables are expressed as mean±standard deviation.

Figure 2. Changes in the mean skin perfusion pressure (SPP) values among the different positions. The mean SPP value in Position I was 25.3±10.9 mmHg and it significantly increased to 40.6±12.7 mmHg in Position II ($P=0.0002$), and to 73.8±16.8 mmHg in Position III ($P<0.0001$).

tion (SD), whereas discrete variables are given as absolute values, percentages, or both. Continuous variables were compared using the Friedman test. Dunn's procedure was performed as a post-hoc test. Results were considered statistically significant at $P \leq 0.05$.

The relationship of the SPP in the supine position to the changed value or changing rate of SPP in other positions was assessed using linear regression and Pearson correlation coefficients.

Results

The patients' clinical characteristics are shown in the Table. There were 15 limbs in Fontaine Stage III and 9 limbs in Stage IV. The baseline ankle-brachial index was 0.42 ± 0.24 .

In all patients, SPP increased from Position I to Position II or III, and the average SPP increased significantly from Posi-

tion I to Position II or III (Figure 2; 25.3 ± 10.9 mmHg, 40.6 ± 12.7 mmHg, 73.4 ± 17.7 mmHg, respectively; $P < 0.01$). In all patients, SPP values > 30 mmHg were obtained in Position III.

There was a significant negative linear correlation between SPP in Position I and the percent change in SPP from Position I to Position II (Figure 3A; $r = -0.786$, $P < 0.0001$) or Position III (Figure 3B; $r = -0.832$, $P < 0.0001$).

Discussion

Noninvasive measurement of limb systolic pressure is used as the standard for assessing the severity of PAD. However, arterial rigidity associated with medial calcification may interfere with measurement of the ankle pressure.^{9–11} These phenomena are observed more commonly in patients with diabetes mellitus and those undergoing dialysis. Measurement of the pressure at the ankle will not detect isolated obstruction in the more

distal artery. In contrast, toe systolic pressure can detect distal lesions and is a more useful parameter.^{9,12} However, the presence of skin ulcers, gangrene, or previous digital amputation may preclude measurement of toe pressure.¹⁰

The measurement of SPP is a noninvasive test that is useful in the assessment of PAD, especially to determine the optimal level for amputation, and to assess critical limb ischemia.¹⁻⁵ Similar to toe pressure, SPP reflects the presence of distal lesions. However, it is not affected by arterial wall calcification. SPP can also be measured in the limb when skin lesions of the toe or digital amputation preclude measurement of toe pressure.

Other noninvasive tests for PAD, such as tcPO₂, have been reported to show good results for predicting healing after amputation.^{13,14} One criticism of tcPO₂ for predicting amputation wound healing is the wide range of values reported by different investigators as the cutoff for critical ischemia.¹⁵ Differences in the electrical specifications of the tcPO₂ equipment have been implicated. This problem has not been observed with SPP measurement and for this reason SPP is considered as the most useful noninvasive test in patients with severe PAD.

It has been shown that ulcers will heal when SPP is ≥ 30 –40 mmHg.¹⁻⁵ According to our results, SPP changes significantly depending on the body position at the time of measurement. In all patients, SPP values exceeding 30 mmHg were obtained in Position III, the sitting position with the foot lowered vertically, which is the ideal position for patients with severe PAD from the viewpoint of SPP. Gravity might cause this phenomenon. When we follow a patient using SPP, we have to evaluate the value in the same position each time.

The treatment of severe PAD is challenging. Obviously, revascularization is the prime therapy for patients with severe PAD. In fact, it has been shown that major amputations decrease and limb salvage improves with the development of a revascularization strategy such as open bypass surgery or endovascular intervention.^{16,17} However, revascularization is sometimes impossible because of the poor general condition, infection, severe calcification, or poor distal run-off in patients with severe disease. New therapies, such as gene therapy^{18,19} or Waon therapy,²⁰ are actively being studied, but are not yet available for clinical use. Therefore, we need additional therapeutic options for patients with severe end-stage PAD. It has been shown that limb salvage can even be achieved without revascularization in most patients with arterial insufficiency and uncomplicated chronic nonhealing limb ulcers when we treat them only with appropriate conservative management.²¹ Against this background, and based on our results, maintaining Position III, sitting with the foot lowered vertically, may be ideal for the peripheral arterial circulation and a valuable, manageable option for patients with end-stage PAD. We do not usually pay attention to the body position of the patients, but it may be useful to consider positioning as adjunctive management. We found a significant negative linear correlation between SPP in Position I and the percent change in SPP from Position I to Position II or III. In other words, the worse the baseline SPP, the more the patient benefited from changing position.

It is obvious that better SPP values are obtained in Position III, but it is not only SPP that controls the clinical outcome of a critical limb. In the real world, venous return may be interrupted in a sitting position with the foot lowered vertically, and lower extremity edema may be frequently observed. Edema may interrupt the wound healing process in patients with end-stage PAD. Clinical experience in the real world is needed to determine whether this position can be a valuable therapeutic option for end-stage PAD.

Conclusions

We obtained the best SPP values in Position III, the sitting position with the foot lowered vertically. In other words, this position is ideal for peripheral arterial circulation in patients with severe PAD.

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