

Evaluation of Critical Limb Ischemia by Transcutaneous Oxygen Pressure and Skin Perfusion Pressure Measurement

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Abstract: The purpose of this study was to investigate whether measurements of transcutaneous oxygen pressure (tcPO₂) and skin perfusion pressure (SPP) may provide essential information on critical limb ischemia. The tcPO₂ of the lower extremities was investigated in 16 normal young adult, 11 normal elderly subjects, 26 patients with acute arterial occlusion in 26 legs, and 74 patients with arteriosclerosis obliterans in 80 legs. Measurements of tcPO₂ were done under steady-state conditions at the dorsum of the foot. The SPP of the lower extremities was investigated in 33 normal young adult, 5 normal elderly subjects and 31 patients with arteriosclerosis obliterans in 35 legs. SPP measurements were done at the first toe and the dorsum of the foot. In conclusion, measurements of resting tcPO₂ values and SPP values were useful in deciding whether or not there was an urgent need for therapy, whether or not arterial reconstruction had been successful, and in diagnosing critical limbs ischemia. (Jpn. J. Vasc. Surg., 14: 577-582, 2005)

Key words: Transcutaneous oxygen pressure, Skin perfusion pressure, Arteriosclerosis obliterans, Critical limb ischemia, Acute arterial occlusion

Introduction

Various methods have been used for the objective evaluation of ischemic limbs. Methods for evaluating intermittent claudication include near-infrared spectroscopy¹⁾ and measurement of recovery time using the ankle-brachial index (ABI) after a treadmill exercise.²⁾ In this study, we attempted to evaluate ischemic limbs by measuring transcutaneous oxygen pressure as well as skin perfusion pressure, which has recently attracted attention, in normal subjects and patients with arteriosclerosis obliterans (ASO) caused by chronic arterial occlusion and acute arterial occlusion.

Materials and Methods

1) Transcutaneous oxygen pressure

We selected 16 limbs from 16 normal young adult (10 men and 6 women from 20 to 24 years of age, with an average age of 21 years), 11 limbs from 11 normal elderly subjects (10 men and 1 woman from 56 to 72 years of age, with an average age of 63 years), 80 limbs from 74 patients with ASO (66 men and 8 women from 41 to 86 years of age, with an average age of 69 years), of which 28 limbs were classified as Fontaine Stage II and 52 limbs in Stage III-IV, and 26 limbs from 26 patients with acute arterial occlusion (18 men and 8 women from 48 to 86 years of age, with an average age of 70 years). The study was conducted from April 1995 to May 2003.

After patients were at rest in a supine position for 20 minutes, their ankle blood pressure was measured using an Ultrasonic Doppler Flow Detector (Parks Medical Electronics Inc., Tokyo, Japan). The transcutaneous oxygen pressure (tcPO₂) at rest was measured at the dorsum of the foot using a

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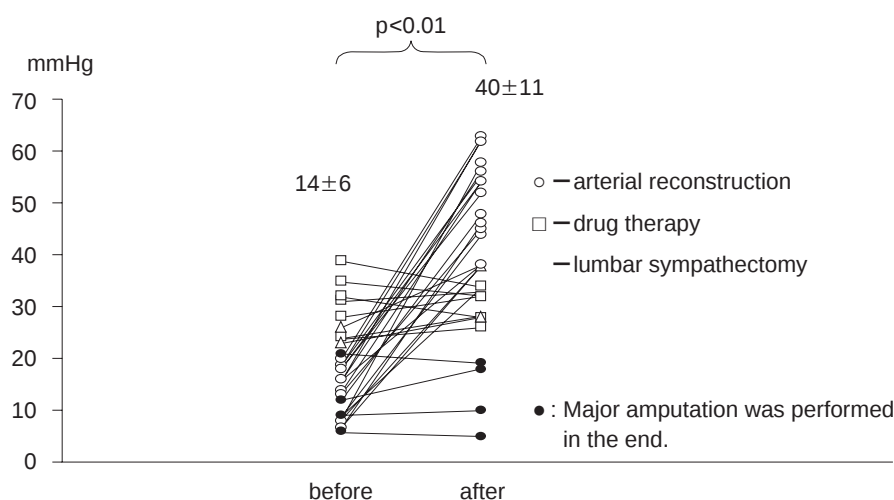


Fig. 1 TcPO₂ before and after therapy in patients with ASO.

PO₂ Monitor 8000 (Kohken Medical Co., Ltd., Osaka, Japan). Measurements in all groups were performed both before and after therapy.

2) Skin perfusion pressure

We selected 66 limbs from 33 normal young adult (13 men and 20 women from 20 to 22 years of age, with an average age of 20 years), 10 limbs from 5 normal elderly subjects (all men from 51 to 72 years of age, with an average age of 64 years) and 35 limbs from 31 patients with ASO (26 men and 5 women from 51 to 83 years of age, with an average age of 70 years), of which 27 limbs were classified as Fontaine Stage II and 8 were in Stage III-IV. The study was conducted from December 2002 to October 2003.

After patients were at rest in a supine position for 10 minutes, their skin perfusion pressures were measured at the first toe and the dorsum of the foot using a LASERDOPP® (Vasamedics, Inc., London, UK). Blood pressure was then measured at the ankle and first toe using a formABI/PWV® (Colin Corporation, Nagoya, Japan).

To assess statistical significance, Student's unpaired and paired t-tests were performed and a p-value of less than 0.05 was taken to indicate a statistically significant difference.

Results

1) TcPO₂ in normal subjects and patients with ASO

Normal young adult had an average tcPO₂ of 62 ± 9 mmHg,

while in normal elderly subjects it was only 49 ± 7 mmHg ($p=0.0473$). Patients with ASO in Fontaine Stage II had a tcPO₂ of 40 ± 11 mmHg, and those in Stage III-IV were 14 ± 6 mmHg. However, no significant difference was observed between normal subjects and patients with stage II ASO with respect to the tcPO₂. The tcPO₂ of patients in Stage III-IV was significantly lower than that of normal elderly subjects ($p=0.0064$) (Fig. 1).

2) TcPO₂ before and after therapy in patients with ASO

Therapy for patients with ASO consisted of arterial reconstruction such as a bypass operation, lumbar sympathectomy and medication. The tcPO₂ was 14 ± 6 mmHg before therapy and 40 ± 11 mmHg after therapy. Major amputation was performed on 4 limbs although all of these patients had received arterial reconstruction. Of these, 1 limb had a tcPO₂ of 21 mmHg before therapy and 19 mmHg after therapy. Amputation was performed after two months because ulcers did not disappear. Another limb was amputated after one month when ulcer persisted despite a tcPO₂ of 12 mmHg before therapy that slightly elevated to 18 mmHg after the therapy. The other 2 limbs had a tcPO₂ of 10 mmHg or lower both before and after the reconstruction. Necrosis developed, and amputation was performed (Fig. 1).

3) TcPO₂ in normal subjects and patients with acute arterial occlusion

All of the patients with acute arterial occlusion had under-

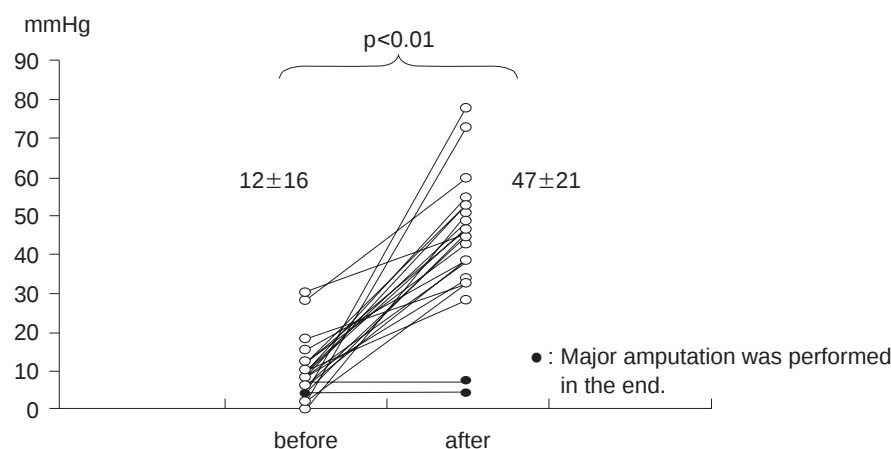


Fig. 2 TcPO₂ before and after therapy patients with acute arterial occlusion.

gone arterial reconstruction. The tcPO₂ significantly improved from 12 ± 16 mmHg before reconstruction to 47 ± 21 mmHg after reconstruction. Amputation was performed on 2 limbs despite the arterial reconstruction. Of these, 1 limb had a tcPO₂ of 4 mmHg before therapy and 3 mmHg after therapy, and the other limb had a tcPO₂ of 7 mmHg before therapy and 8 mmHg after therapy (Fig. 2).

4) Relationship between ankle pressure and tcPO₂

No significant correlations were observed between ankle blood pressure and the tcPO₂ at rest in all patients ($y=14.2 \pm 0.05x$, $r=0.278$, NS). Significant correlations were observed between ankle blood pressure and the tcPO₂ at rest in patients without chronic dialysis or diabetic complications ($y=7.55 \pm 0.20x$, $r=0.612$, $p<0.05$). No significant correlations were observed between ankle blood pressure and the tcPO₂ at rest in chronic dialysis patients or patients with diabetic complications ($y=15.48 \pm 0.03x$, $r=0.185$, NS).

5) Skin perfusion pressure at the first toe and the dorsum of the foot in control subjects

Normal young adult had skin perfusion pressures of 48 ± 12 mmHg at the dorsum of the foot and 70 ± 18 mmHg at the toe. The skin perfusion pressure was significantly higher at the toe.

6) Skin perfusion pressure at the dorsum of the foot in normal subjects and patients with ASO

Normal subjects had a skin perfusion pressure of 48 ± 12 mmHg at the dorsum of the foot, and normal elderly subjects

50 ± 12 mmHg. No significant difference was observed between the two groups. Patients in Fontaine Stage II had a skin perfusion pressure of 40 ± 14 mmHg, and patients in Stage III-IV 18 ± 8 mmHg. No significant difference was observed between patients in Stage II and normal subjects with respect to skin perfusion pressure. Patients in Stage III-IV had a skin perfusion pressure significantly lower than that of patients in Stage II ($p<0.001$). There were no patients for whom measurement was impossible (Fig. 3).

7) Toe brachial index (TBI) in normal subjects and patients with ASO

Significant difference was observed between patients in Stage II and normal subjects. Patients in Stage III-IV had a TBI significantly lower than that of patients in Stage II, but there were 15 limbs for whom measurement was impossible.

8) Relationship between toe pressure and skin perfusion pressure at the first toe

The relationship between toe skin perfusion pressure and toe blood pressure was examined in all patients. As shown in Fig. 4, when the x axis represents toe blood pressure, and the y axis represents toe skin perfusion pressure, correlations were obtained with the expression $y=3.6+0.7x$ ($r=0.718$, $p<0.001$). Toe skin perfusion pressure was about 70% of toe blood pressure (Fig. 4).

Discussion

We were unable to review the detailed relationship be-

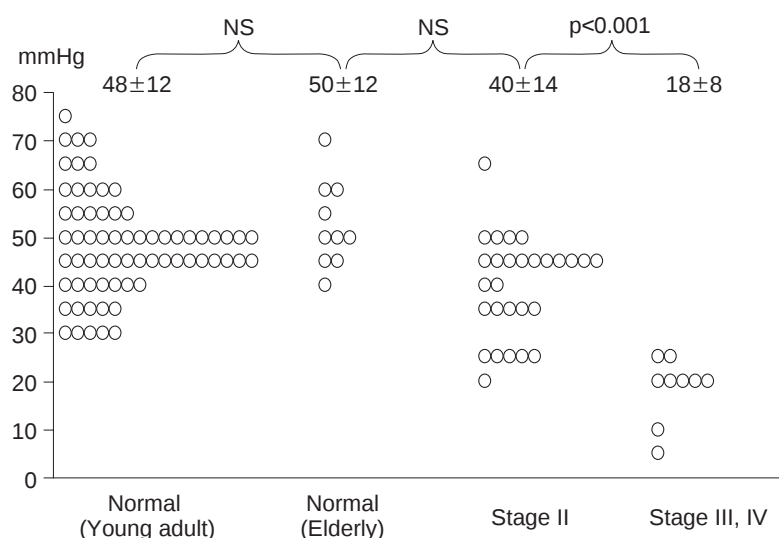


Fig. 3 Skin perfusion pressure at the dorsum of the foot in control subjects and patients with ASO.

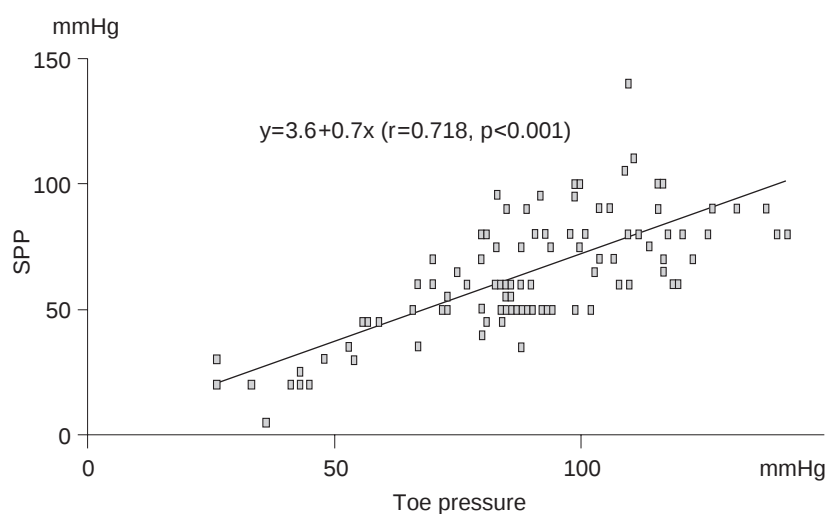


Fig. 4 Relationship between toe pressure and skin perfusion pressure at the first toe.

tween $tcPO_2$ and skin perfusion pressure (SPP) in our study, because they were not measured in the same cases on the same day. Therefore, we considered results obtained by each method.

The $tcPO_2$ monitoring was developed by Huch et al.³⁾ This method transcutaneously measures oxygen tension while heating the skin to induce local hyperemia. This noninvasive method has been used to evaluate peripheral circulatory failure.

In addition to the measurement of $tcPO_2$ at rest, proposed measurements include the $tcPO_2$ indices by Masten et al.,⁴⁾ the regional perfusion index by Hauser et al.,⁵⁾ the $tcPO_2$ during oxygen inhalation or exercise by Yamamoto⁶⁾ and Ohgi et al.,⁷⁾ the rate of $tcPO_2$ by changing position by Caspary et al.⁸⁾ and T2/T1 values by Franzeck et al.⁹⁾ In this study, only $tcPO_2$ at rest was measured.

Among normal subjects, the $tcPO_2$ at rest was compared

between young subjects and elderly subjects. The $tcPO_2$ was significantly lower in elderly subjects, which is consistent with the results of Ohgi et al. Since there are many elderly patients in the disease groups, elderly patients were assumed as control. The $tcPO_2$ at rest was compared according to Fontaine stage, which classifies severity of ASO. No significant difference was observed between patients in Fontaine Stage II and the control group, but significant difference was observed between patients in Stage III-IV and the control group. Therefore, this method would be unsuitable for evaluation of intermittent claudication, but it would be suitable for evaluation of severely ischemic limbs.

The Trans-Atlantic Inter-Society Consensus (TASC)¹⁰⁾ defines a severe ischemic limb as having an ankle blood pressure of 50 mmHg or lower or a toe blood pressure of 30 mmHg or lower. However, ankle blood pressure is elevated in diabetic patients and dialysis patients due to arterial calcification and hence cannot be precisely evaluated in many cases. The ABI and the $tcPO_2$ correlated well in patients with ASO in Fontaine Stage III-IV, except for diabetic patients and dialysis patients. On the other hand, no correlation was observed in diabetic patients or dialysis patients. Therefore, evaluation by $tcPO_2$ is necessary.

Lalka et al.¹¹⁾ reported that a severely ischemic limb requiring an operation was determined when the $tcPO_2$ at rest was 22 mmHg or lower at the dorsum of the foot or the ratio of $tcPO_2$ at the dorsum of the foot and the precordial region was 0.46 or lower. Further, Scheffler et al.¹²⁾ reported that, when the $tcPO_2$ at rest at the dorsum of the foot was 10 mmHg or lower in the supine position and 45 mmHg or lower in the sitting position, rest pain, ulcer or necrosis was less likely to be improved by conservative therapies. According to Ubbink et al.,¹³⁾ when the $tcPO_2$ at the dorsum of the foot was 30 mmHg or higher, the limb-saving rate after one year was 88%. On the other hand, when the $tcPO_2$ was lower than 10 mmHg at the dorsum of the foot, the limb-saving rate was only 17%. TASC¹⁰⁾ predicted that cure could not be expected when the $tcPO_2$ was lower than 20 mmHg, and that a cure could be expected when the $tcPO_2$ was 40 mmHg or higher. In our cases, ASO patients with acute arterial occlusion or chronic arterial obstruction underwent major amputation when they had a $tcPO_2$ of 20 mmHg or lower

after therapy. Our results were consistent with these reports.

Another measurement using a LASERDOPP® measures SPP by utilizing a laser Doppler technique. This method can measure SPPs at very low levels, and could measure the pressures more easily in a shorter time than the transcutaneous oxygen pressure measurement.

The SPPs measured at the dorsum of the foot and the toe were compared in normal subjects. As a result, toe SPP was found to be higher. It is estimated that this is because skin blood flow may be blocked even with a low pressure since the skin of the dorsum of the foot is thinner than the toe skin. Therefore, it would be necessary in evaluation to recognize differences according to site.

The relationship between normal subjects and patients with ischemic limbs was examined. No significant difference was observed between patients in Stage II and normal subjects. The SPP of patients in Stage III-IV was significantly lower than that of patients in Stage II. This indicates that this measurement cannot be used for evaluation of patients with mild ischemia, but it is useful for evaluation of patients with severe conditions. Adera et al.¹⁴⁾ claim that SPP measurement is useful for determination of the amputation level of ischemic limbs and possible cure of ulcer, and that ulcer will be cured when the SPP is 30 mmHg or higher. We will further examine SPP according to the site in consideration of these results.

The relationship between toe SPP and toe blood pressure was examined. Correlations were observed between these parameters, and it was revealed that toe SPP was about 70% of toe blood pressure. This suggests that toe SPP can be used to estimate the toe blood pressure of patients with severe conditions in which toe blood pressure cannot be measured.

$tcPO_2$ and SPP measurements each have advantages and disadvantages

The advantage of $tcPO_2$ is that we cannot measure the pressure of the circumference of an ulcer if there is an ulcer, while we cannot measure SPP when there is a large ulcer on the dorsum of foot, because a cuff cannot be put around the foot.

The weak points of $tcPO_2$ values are that they are lower if lung function is bad and measurement takes longer than that for SPP.

Thus, it was considered that ischemic limbs could be ex-

aminated more closely by combining these two methods.

Conclusion

Transcutaneous oxygen pressure and SPP were measured in normal subjects and patients with ASO or acute arterial occlusion in lower limbs, and the following results were obtained.

1. Since many patients in Fontaine Stage III-IV are diabetic patients or dialysis patients with pseudo-hypertension, measurement of transcutaneous oxygen pressure is necessary as a more objective evaluation.
2. Patients who have a transcutaneous oxygen pressure of 10 mmHg or lower need to reconstruct blood circulation urgently, otherwise necrosis will develop and amputation will need to be performed.
3. When transcutaneous oxygen pressure was 20 mmHg or lower, ulcer was not cured, and major amputation was necessary.
4. The SPP could be measured using LASERDOPP® more easily in a shorter time than the transcutaneous oxygen pressure measurement.
5. In normal subjects, the SPP is higher at the dorsum of the foot than at the toe. Care is needed when evaluating the SPP.
6. The SPP correlated well with toe blood pressure, and was about 70% of toe blood pressure.

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