PREDICTING AMPUTATION IN SEVERE ISCHAEMIA

THE VALUE OF TRANSCUTANEOUS P_{O_2} MEASUREMENT

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The predictive value of the pedal transcutaneous oxygen tension (tcP_{O_2}) and of the distal systolic blood pressure (SBP) in forecasting the necessity for later amputation has been studied in 26 patients suffering from severe chronic ischaemia of the lower limbs. In all these patients vascular surgery had failed or not been possible, and they were threatened by amputation; they suffered from trophic lesions, or pain at rest, or both. The great toe SBP averaged 10 mmHg (range 0 to 60 mmHg) and the pedal tcP_{O_2} 10 mmHg (range 2 to 45 mmHg). After six minutes of oxygen inhalation there was an increase in pedal tcP_{O_2} of 9 mmHg (0 to 50 mmHg).

After a follow-up period averaging 7 months (range 10 days to 13 months), 13 patients underwent an amputation and nine (five of whom had been amputated) died. The great toe SBP in the patients who required amputation was initially lower than in those who did not. The pedal tcP_{O_2} also was lower in amputated than in non-amputated patients. There was no amputation in the group showing an increase of at least 10 mmHg after six minutes of oxygen inhalation; and conversely, all patients in whom the pedal tcP_{O_2} increased less than 10 mmHg were amputated. Thus increase in the pedal tcP_{O_2} after oxygen inhalation appears the best criterion for estimating the prognosis of severely ischaemic limbs.

Several non-invasive measuring techniques have been proposed for estimating the prognosis of severely ischaemic limbs. Distal systolic blood pressure (SBP) measurements are widely used for estimating the degree of ischaemia (Lassen, Tønnesen and Holstein 1976). Holstein, Krähenbühl and Lassen (1976) followed up 109 patients suffering from severe chronic ischaemia of the lower limbs with trophic lesions and found that the lesions never healed when the great toe SBP was lower than 20 mmHg; conversely, a great toe SBP above 40 mmHg always indicated a better prognosis.

Transcutaneous oxygen tension measurement (tcP_{O_2}) has been introduced for estimating tissue hypoxia in arterial occlusive disease of the extremities (Tønnesen 1978; Matsen et al. 1980; Borzykowski and Krähenbühl 1981; Burgess et al. 1982; Ratliff et al. 1984). The predictive value of the pedal tcP_{O_2} with regard to wound-healing after amputation was studied by Franzeck et al. (1982): the results were disappointing. Recently, Harward et al. (1985), measuring the pedal tcP_{O_2} while patients inhaled oxygen, found that the level at which the distal tcP_{O_2} increased by more than 10 mmHg was the point at which an amputation could be performed.

The aim of this paper is to determine whether distal blood pressure or pedal tcP_{O_2} is a valuable predictor of the prognosis of a chronically and severely ischaemic limb. The predictive value of the pedal tcP_{O_2} increase during oxygen inhalation has also been estimated.

PATIENTS AND METHOD

A polarographic Clark-type electrode (Roche-Kontron 630 Monitor), which heats the skin to 44°C, was used for measuring the pedal tcP_{O_2} (Vesterager 1977; Huch, Huch and Lübbers 1981; Severinghaus 1982). It was calibrated for atmospheric pressure. The probe was fitted to the skin on the dorsum of the foot with a double-faced adhesive ring, between the first and the second metatarsals. The first reading was taken after 20 minutes (Huch, Huch and Lübbers 1973; Krähenbühl and Dubas 1982). The patient was then asked to breathe pure oxygen (10 l/min) for six minutes using a Venturi mask; this produced an inspiratory oxygen fraction of 40%.

The systolic blood pressure was measured in the arm and the ankle with a 14-cm wide cuff and a mercury manometer, using a stethoscope on the arm and a Doppler reader at the ankle (Parks Electronic Model 1010) (Strandness et al. 1967). The great toe SBP was measured with a thin plastic 2.4-cm wide cuff fitted around the proximal phalanx with a mercury strain gauge on the tip of the toe (Plethymograph SP2, Medimatic, Copenhagen) (Nielsen, Bell and Lassen 1972).

Arm, ankle, great toe SBP and pedal tcP_{O_2} were

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© 1988 British Editorial Society of Bone and Joint Surgery
0301-620X/88/3085 \$2.00
J Bone Joint Surg [Br] 1988;70-B:465-7.

measured in 27 successive patients suffering from severe arterial occlusive disease of the lower limb for whom reconstructive vascular procedures were not possible or had failed. In one patient a vascular operation was performed during the follow-up period, but this patient was excluded from the study. Of the remaining 26 patients, 23 had gangrene and three suffered from ischaemic pain at rest. The mean duration of the disease at the time of the initial examination was 37.9 months (range 2 to 96 months). There were 13 males and 13 females, 16 diabetics and 12 smokers, and their mean age was 74.3 years (44 to 88 years).

Hypertension was defined according to WHO criteria for blood pressure in the arm: it was diagnosed with a systolic pressure above 160 mmHg and/or a diastolic pressure above 95 mmHg. By these criteria, 12 of our 26 patients suffered from hypertension. The median SBP measured 100 mmHg (range 0 to 190 mmHg) at the ankle and 10 mmHg (0 to 60 mmHg) at the great toe; the median pedal $tcPO_2$ measured 10 mmHg (2 to 45 mmHg) and increased after oxygen inhalation by 9 mmHg (0 to 50 mmHg). Information about amputations or deaths was collected by letter or phone calls to the patients or their families, or from the hospital records. The follow-up period lasted till death, amputation or review; the median period was 7 months (range 10 days to 13 months). On completion of data collection, all the measurements were analysed in order to estimate their prognostic value for the patient's limb. **Statistical methods.** Mean and standard deviations were calculated for data with Gaussian distribution, and median and range for the others. Student's *t*-test, chi-square and Mann-Whitney tests were used for the statistical analysis when appropriate. Sensitivity, specificity, and positive and negative predicting values (PPV and NPV) were calculated using a double-entry contingency table (Green 1983).

RESULTS

During the period of follow-up, 13 patients underwent an amputation (50%): four at the forefoot, seven below the knee and two at thigh level. Nine patients died during the same period: five had been amputated and four not. The median period between inclusion in the study and death was 3 months (range 1 to 12 months) in amputated patients and 5.5 months (range 1 to 10 months) in non-amputated patients. There was no significant difference between amputated and non-amputated patients with regard to age, sex, diabetes, smoking habit, duration of the disease, follow-up period and number of deaths. There was significantly more hypertension among patients who underwent an amputation ($p < 0.02$). The great toe SBP, pedal $tcPO_2$ and increase in the $tcPO_2$ after oxygen inhalation were significantly lower in amputated patients (Table I).

Four patients in whom the ankle SBP was below

45 mmHg were amputated, but the negative predictive value of this parameter was only 62%. When the great toe SBP was above 30 mmHg, no patient underwent an amputation, but the positive predictive value of this parameter was only 65%. Both positive and negative predictive values of the resting pedal $tcPO_2$ were 85%, using 10 mmHg as the threshold (Table II). However, a predictive value of 100% was achieved when consideration was given to the increase in $tcPO_2$ that occurred with oxygen inhalation: all patients with a $tcPO_2$ increase of less than 10 mmHg during oxygen inhalation were amputated, and conversely, no patient underwent amputation when the pedal $tcPO_2$ increased by more than 10 mmHg.

DISCUSSION

The poor short-term prognosis of patients suffering from severe arterial occlusive disease of the lower limbs (50% amputations and 35% deaths) is in good agreement with the literature (Holstein et al. 1976; Coopermann et al. 1978). Hypertension was the only risk factor with a significantly higher prevalence in our amputated patients. Smoking habits and diabetes did not seem to play an important role at this stage of severe arterial insufficiency.

Our data show that a pedal $tcPO_2$ increase of less than 10 mmHg during oxygen inhalation allows us to predict an amputation within a few months. Conversely, the negative predictive value of this parameter is 100%. Although the pedal $tcPO_2$ increase during oxygen

Table I. Distal systolic blood pressure (SBP) and $tcPO_2$ values in patients who later had amputations compared with those who were not amputated. Values are given as median (range) in millimetres of mercury

	Amputation	No amputation	p value
Ankle SBP	100 (0-110)	100 (46-190)	NS
Great toe SBP	10 (0- 20)	24 (0- 60)	<0.02
Pedal $tcPO_2$	3 (2- 45)	24 (6- 45)	<0.005
$tcPO_2$ increase after oxygen inhalation	0 (0- 8)	16 (10- 50)	<0.001

Table II. The amputation-prediction value of various criteria (in percentages)

Criteria	Sensitivity	Specificity	PPV	NPV
Ankle SBP <45 mmHg	38	100	100	62
Great toe SBP <30 mmHg	100	46	65	100
Resting pedal $tcPO_2$ <10 mmHg	85	85	85	85
$tcPO_2$ increase <10 mmHg after oxygen inhalation	100	100	100	100

PPV and NPV represent the positive and negative predictive values

inhalation appears to be the best predictor, the distal systolic blood pressure also seems valuable: when ankle systolic blood pressure is below 45 mmHg, the probability of an amputation is 100%, but some patients have been amputated despite a higher pressure. The systolic blood pressure in the great toe also gives valuable information: no amputation had to be performed when the pressure was above 30 mmHg. The resting $tcPO_2$ does not represent the best predictive parameter: limb survival is possible even when the pedal $tcPO_2$ is below 10 mmHg.

The increase of $tcPO_2$ during oxygen inhalation may be explained by the greater concentration of oxygen in the blood plus an increase of the local blood flow under the probe secondary to the vasodilatation induced by the heating system (Huch et al. 1981). The lack of $tcPO_2$ increase may mean an absence of local circulation in this area or ischaemia which is so severe that the additional arterial oxygen is negligible and cannot be detected.

In conclusion, although distal systolic blood pressure gives a valuable estimation of ischaemia, the pedal $tcPO_2$ increase during oxygen inhalation seems the best parameter for predicting the prognosis of an ischaemic limb.

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