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'Pole Test' Measurements in Critical Leg Ischaemia

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Background. *For the quantification of critical limb ischaemia (CLI) most vascular surgery units use sphygmo-manometric and transcutaneous oxygen pressure ($TcPO_2$) measurements. However, measurements obtained by cuff-manometry can be overestimated especially in diabetic patients because of medial calcification that makes leg arteries less compressible. $TcPO_2$ measurements present a considerable overlap in the values obtained for patients with different degrees of ischaemia and its reproducibility has been questioned. Arterial wall stiffness has less influence on the pole test, based on hydrostatic pressure derived by leg elevation, and this test seems to provide a reliable index of CLI.*
Objective. *The objective of this study was to evaluate the pole pressure test for detection of critical lower limb ischaemia, correlating results with cuff-manometry and transcutaneous oxygen pressure.*
Design. *University hospital-prospective study.*
Materials and methods. *Seventy-four patients (83 legs) with rest pain or gangrene were evaluated by four methods: pole test, cuff-manometry, $TcPO_2$ and arteriography. CLI was present if the following criteria were met: (a) important arteriographic lesions + rest pain with an ankle systolic pressure (ASP) ≤40 mmHg and/or a $TcPO_2$ ≤30 mmHg, or (b) important arteriographic lesions + tissue loss with an ASP ≤60 mmHg and/or a $TcPO_2$ ≤40 mmHg. Fifty-seven lower limbs met the criteria for CLI.*
Results. *Measurements obtained by cuff-manometry were significantly higher to those obtained by pole test (mean pressure difference: 40 mmHg, $p<0.001$). The difference between the two methods remained statistically significant for both diabetics (50.73, $p<0.001$) and non-diabetics (31.46, $p<0.001$). Mean $TcPO_2$ value was 15.51 mmHg and there was no important difference between patients with and without diabetes. Overall, there was a correlation between sphygmomanometry and pole test ($r=0.481$). The correlation persisted for patients without diabetes ($r=0.581$), but was not evident in patients with diabetes. Correlation between pole test and $TcPO_2$ was observed only for patients with diabetes ($r=0.444$). There was no correlation between cuff-manometry and $TcPO_2$. The pole test offered an accuracy of 88% for the detection of CLI. The sensitivity of this test was 95% and the specificity 73%.*

Keywords: Pole test; Critical leg ischaemia.

Introduction

Accurate assessment of the severity of lower limb ischaemia is necessary for the selection of patients requiring a surgical treatment. This is particularly important in case of critical ischaemia where adequate revascularisation can prevent a major amputation and where unnecessary aggressive treatment can lead to poor prognosis.

The quantification of critical leg ischaemia (CLI) has been discussed widely. The second European consensus document[1] proposed an objective assessment of ankle systolic pressure (ASP) ≤50 mmHg, or a toe pressure (TP) ≤30 mmHg.

Rutherford[2] proposed different cut-off values and in addition recommends the use of the transcutaneous measurement of oxygen tension ($TcPO_2$).[3]

It is recognized that sphygmomanometry measurements can overestimate pressures, especially in diabetics[4,5] because of the medial calcification that makes leg's arteries less compressible. It has been suggested that the systolic pressure at the toe level is more accurate, as smaller vessels are easier to compress[6] but this technique gives poor results at low temperatures[7] and is difficult to use when ulcers and gangrene are present. The measurement of $TcPO_2$ appears reproducible and correlates well with the existence of skin ischaemia and the Fontaine

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classification clinical severity of leg ischaemia.[8–10] It also is useful in predicting the need for amputation in severe ischaemia.[11] However, there is a considerable overlap in the values obtained for patients with different degrees of ischaemia,[12] and the reproducibility of $TcPO_2$ has been questioned.[13,14] Moreover, technical problems with measurements are common.

The introduction of an alternative approach, the pole test,[15] using hydrostatic pressure derived by leg elevation, seems to provide a reliable index of severe leg ischaemia as it is less influenced by the degree of artery compressibility; nevertheless this test is not yet included in any definition of CLI and it is not used routinely in most vascular surgery units, despite of its simplicity.

The aim of this prospective study was to evaluate the pole pressure test by correlating it with cuff-manometry and $TcPO_2$ measurements and to investigate the ability of this test to detect critical lower limb ischaemia.

Materials and Methods

From January 1999 to September 2000, 74 consecutive patients (83 legs) with clinical signs of critical ischaemia were referred to our vascular surgery unit, for evaluation of lower limb arterial disease. All patients were evaluated by four methods: pole test (P), cuff-manometry (S), $TcPO_2$ (T) and arteriography (A).

Critical limb ischaemia (CLI) was diagnosed when the following criteria were met:

Arteriographic evidence of at least two level lesions (stenosis $>70\%$ or occlusion) and/or important lesions of the three calf arteries without important collateral development, together with either (i) persistently recurring ischaemic rest pain requiring regular adequate analgesia for more than 2 weeks, with an ankle systolic pressure ≤ 40 mmHg and/or $TcPO_2$ ≤ 30 mmHg or (ii) ulceration or gangrene of the foot or toes, with an ankle systolic pressure ≤ 60 mmHg and/or $TcPO_2$ ≤ 40 mmHg.

Fifty-seven legs met the inclusion criteria for CLI.

Measurement by $TcPO_2$

This test was performed first, in the supine position. The electrode was placed on the dorsum of the foot (or nearest to an ulcer, if there was one). $TcPO_2$ was measured with a polarographic electrode (Micro Gas 7640, Kontron instruments) heated at 45°. Calibration for atmospheric pressure was made before each measurement. A direct reading in mmHg was taken after a perfect stabilisation of the $TcPO_2$ (mean duration of the procedure was 30 min).

Measurement by pole test

Measurement of pressures after 30 min in the supine position by insonating (8 MHz probe) the three ankle arteries (dorsalis pedis, posterior tibial and peroneal artery) and the hallux collateral artery, with a calibrated pole (zero pressure level being situated at the level of the left ventricle and corresponding to the anterior axillary line in a supine position). The foot was slowly elevated until the disappearance of systolic pressure signal. The height at which the signal disappeared corresponded to the systolic pressure in cmH_2O and was transformed to mmHg (13 cmH_2O = 10 mmHg). This procedure was repeated three times for each artery. The mean value of each artery was noted and the highest mean value was used. Intra-observer variability was good, for highest measurements mean standard deviation was 0.7 mmHg (range 0–5). Inter-observer variability was not assessed.

Measurement by cuff-manometry

After 30 min in the supine position, measurement of arterial systolic pressures of the same four arteries, using a 15 cm wide cuff placed just above the malleoli and a 8 MHz Doppler probe. This procedure also was repeated three times for each artery and the highest mean value was used.

Arteriography

All patients had an arteriographic examination.

Measurements of blood pressures derived from cuff-manometry and pole test were not feasible in some patients' limbs because of incompressibility of arterial walls and limited maximal leg elevation. If ASP was $>$ 200 mmHg and or a persistent Doppler signal at maximal leg elevation occurred in the pole test were, limbs were excluded from statistical analysis (for comparisons and correlations). We also decided to include diabetic and long term renal dialysis patients in a single group, since both have arterial wall stiffness.

Analysis

Comparisons between the three different non-invasive methods were made with rank sum two-sample test

Table 1. Patient characteristic

	All patients	Patients with diabetes	Patients without diabetes
Number of patients	74	Type I: 26 Type II: 13	35
Number of limbs	83	Type I: 27 Type II: 15	41
Sex ratio m/f	58/16	28/11	30/5
Mean age (years)	72.57 (31–92)	75.62	68.93
Smoking	46/74	20/74	26/74
Hypertension	44/74	22/74	22/74
Dyslipidemia	8 patients	4	4
On dialysis	13 patients (16 legs)	7 patients (8 legs)	6 patients (8 legs)
Rest pain	17 legs	4 legs	13 legs
Foot ulcers/gangrene	66 legs	38 legs	28 legs

(Mann–Whitney). Correlations were obtained by linear regression. The r coefficient of linear correlation which is the measurement of the intensity of a linear relation between two diagnostic tests was calculated; p values <0.05 were regarded as significant. Sensitivity, specificity, predictive values and accuracy were carried out for the evaluation of the pole test. ROC curves were used for the optimum cut-off value of the pole test for the detection of CLI. Finally, intra-observer variability of the pole test measurements was assessed.

Results

The demographic details of the patients are shown in Table 1. For the 57 legs considered to have CLI, 51 had cuff-manometry measurements and 54 pole test measurements. $TcPO_2$ was obtained for all limbs. Forty-eight limbs were evaluated by both cuff-manometry and pole test, 51 by cuff-manometry and $TcPO_2$ and 54 by pole test and $TcPO_2$. Forty-eight limbs were evaluated by all three methods.

Comparisons between measurements obtained by sphygmomanometry and pole test are shown in Table 2.

Mean $TcPO_2$ value was 15.51 (SD$\pm$14.18, $n=57$) and there was no difference between patients with diabetes (12.68$\pm$12.43, $n=28$) and those without diabetes (18.24$\pm$15.40, $n=29$), $p=0.210$.

Correlations between the three tests are shown in Table 3. There was a significant correlation between sphygmomanometry and pole test measurements ($r=0.481$).

No correlation was found between cuff-manometry and pole test for patient with diabetes. However, there was a correlation between these two tests for patients without diabetes ($r=0.581$). No correlation was observed between sphygmomanometry measurements and $TcPO_2$. A correlation was found between pole test and $TcPO_2$ measurements only for patients with diabetes ($r=0.444$).

According to our definition of CLI, from the 83 lower limbs assessed in our study, only 57 were classified as having CLI. We used the same definition as a gold standard for the evaluation of the pole test. From ROC curves, the optimum cut-off value of the pole test for the detection of CLI was of 50 mmHg (Fig. 1). The pole test when used alone to detect CLI showed a sensitivity of 94.7%, a specificity of 73.1%, a positive predictive value (PPV) of 88.5% and a negative predictive value (NPV) of 86.4%. The accuracy of the test was of 88.0%. These values are given in Table 4.

Discussion

All pressures measured by sphygmomanometry were higher than those obtained by leg elevation in the pole test. This finding is in keeping with other authors.[15,16]

Pressures measured by both cuff-manometry and pole test were higher in patients with diabetes than in those without diabetes and these differences were statistically significant. The difference between the two methods was significantly greater for those with diabetes than for those without. Although, Smith[15] showed a similar trend, his data did not achieve statistical significance.

In the study by Smith[15] all patients investigated were assessed by pole test at the ankle level and no patient had a persistent Doppler signal at maximal leg elevation. On the contrary, Pahlsson *et al.*[6] found, that

Table 2. Comparison between patients with and without diabetes for cuff-manometry and pole test measurements (legs in CLI)

	All patients (mean$\pm$SD, number)	With diabetes (mean$\pm$SD, number)	Without diabetes (mean$\pm$SD, number)	Pressure difference	p
Cuff-pressure (mmHg)	66.76$\pm$35.51, $n=51$	80$\pm$38.49, $n=23$	55.89$\pm$29.25, $n=28$	24.11	<0.001
Pole pressure (mmHg)	26.76$\pm$12.88, $n=54$	29.27$\pm$12.61, $n=26$	24.43$\pm$12.91, $n=28$	4.84	<0.05
Pressure difference (mmHg)	40	50.73	31.46		
p	<0.001	<0.001	<0.001		

Table 3. Correlations between the three tests (legs in CLI)

	r	*p*	*n*	Excluded
Cuff-pressure and pole test				
All patients	0.481	<0.001	48	9
With diabetes	0.344	0.131	21	7
Without diabetes	0.583	<0.005	27	2
Cuff-pressure and $TcPO_2$				
All patients	0.000	0.999	51	6
With diabetes	0.022	0.921	23	5
Without diabetes	0.118	0.552	28	1
Pole test and $TcPO_2$				
All patients	0.208	0.132	54	3
With diabetes	0.444	<0.05	26	2
Without diabetes	0.09	0.630	28	1

Table 4. Evaluation of the pole test in the detection of CLI

CLI/non-CLI	Pole test ≤50 mmHg
Sensitivity	94.7
Specificity	73.1
False-negatives	5.3
False-positives	26.9
PPV	88.5
NPV	86.4
Accuracy	88.0

at ankle level, the pole test provided a pressure measurement in less than half (42%) of legs: the remaining 58% had a persistent Doppler signal: this was attributed to the varying inclusion criteria. In our study, pole test measurements were possible in 62/83 legs (when we include all stage III and IV limbs). When we considered only limbs with CLI, the pole test measurements were attained from 54/57 legs.

The value of the pole test in the diagnosis of severe ischaemia is limited by lower leg length. The leg length of most patients does not permit pressures greater than 45 mmHg[6]–60 mmHg[15,17] to be measured at the ankle level. At the toe level higher pressures (55–70 mmHg[6,17]) can be measured because the distance from the hip to the toe is longer. In our study, we managed to measure pole test pressures as high as 70 mmHg but in many patients, because of the limited leg length or mobility in the elderly, values greater than 50 mmHg could not be measured.

There was a good correlation between sphygmomanometry and pole test measurements for patients without diabetes but there was no correlation for patients with diabetes. This is similar to the findings of Jachertz[16] who found a better correlation between the two tests for patients without diabetes.

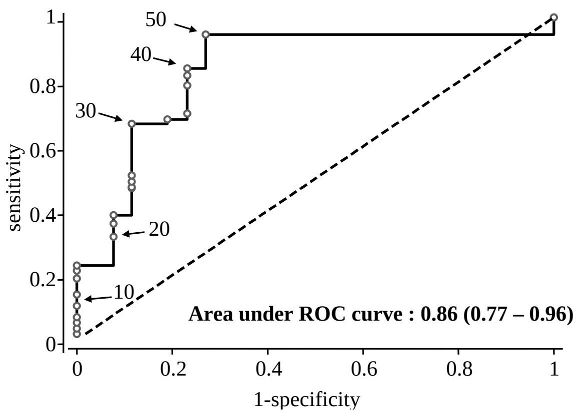

Fig. 1. ROC analysis of different cut-off values of pole test measurements (in mmHg) for the detection of critical limb ischaemia.

There is controversy about the influence of medial calcification on $TcPO_2$ measurements.[18,19] Like Wyss *et al.*[19] we did not find any statistical difference between $TcPO_2$ measurements in patients with and without diabetes. Wyss *et al.*[20] suggested that $TcPO_2$ and Ankle–brachial pressure measurements yield similar results for haemodynamic outcomes in patients without diabetes and in diabetics without important calcification, but our data, like those of Jachertz,[16] did not show a correlation between $TcPO_2$ and cuff-manometry for either group of patients. Nevertheless we found a correlation between pole test measurements and $TcPO_2$ in patients with diabetes. Perhaps this results from the fact that $TcPO_2$ depends on the microcirculation, which is influenced by diabetic microangiopathy.[21,22] However, Jachertz[16] found a good correlation between the two tests for patients without diabetes.

The pole test was evaluated in this study as a diagnostic test for CLI. Our study showed that the pole test was very accurate, with high sensitivity and high NPV for the detection of CLI. It also had good specificity and a high PPV. However, further work remains to assess the inter-observer variability of pole test measurements and the reproducibility of this test in different settings.

It is well-known sphygmomanometry is very specific for the detection of CLI but has a low sensitivity and a large number of false-negatives.[23] This is because critical ischaemia can exist with high ankle pressures especially in patients with stiff arteries (those with diabetes or on renal dialysis).

Transcutaneous oximetry is used regularly for the detection of CLI but its reproducibility[13,14] and accuracy[23] have been questioned. Furthermore, there is a big variation in the cut-off values proposed by different authors.[2,3,23,24]

The assessment of critical ischaemia by means of non-invasive measurements can probably be improved by the combination of several techniques. The pole test could play an important role in the detection of CLI especially in patients presenting calcified incompressible leg arteries.

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References

1 Consensus Document II, European Society of Vascular Surgery. *Eur J Vasc Surg* 1992;**6**(suppl. A):1–32.
2 Rutherford RB, Baker JD, Ernst C, Johnston KW, Porter JM, Ahn S *et al*. Recommended standards for reports dealing with lower extremity ischaemia: revised version. *J Vasc Surg* 1997;**26**: 517–538.
3 Rutherford RB. Ischémie critique des membres inférieurs: définition, advantages et limites. In: Futura publishing company, INC. Ischémie critique des members inférieurs. Marseille: Branchereau A, Jacobs M, 1999, p. 1–10.
4 Goss DE, De Trafford J, Roberts VC, Flynn MD, Edmonds ME, Watkins PJ. Raised ankle/brachial pressure index in insulin-treated diabetic patients. *Diabet Med* 1989;**6**:576–578.
5 Orchard TJ, Strandness Jr DE. Assessment of peripheral vascular disease in diabetes. *Diabetes Care* 1993;**16**:1199–1209.
6 Pahlsson HI, Wahlberg E, Oloffson P, Swedenborg J. The toe pole test for evaluation of arterial insufficiency in diabetic patients. *Eur J Vasc Endovasc Surg* 1999;**18**:133–137.
7 Sawka AM, Carter SA. Effect of temperature on digital systolic pressures in lower limb in arterial disease. *Circulation* 1992;**85**: 1097–1101.
8 Ohgi S, Ito K, Mori T. Quantitative evaluation of the skin circulation in ischaemic legs by transcutaneous measurement of oxygen tension. *Angiology* 1981;**32**:833–839.
9 Hauser CJ, Klein SR, Mehringer CM, Appel P, Shoemaker WC. Superiority of transcutaneous oximetry in noninvasive vascular diagnosis in patients with diabetes. *Arch Surg* 1984;**119**:690–694.
10 Vayssairat M, Mathieu JF, Priollet P, Vellay P, Pines JC, Housset E. Transcutaneous measurement of oxygen partial pressure. A new method for functional study in vascular pathology. *Presse Med* 1984;**13**:1683–1686.
11 Bongard O, Krahenbuhl B. Predicting amputation in severe ischaemia. The value of transcutaneous PO2 measurement. *J Bone Joint Surg Br* 1988;**70**:465–467.
12 Larsen JF, Jensen BV, Christensen KS, Egeblad K. Forefoot transcutaneous oxygen tension at different leg positions in patients with peripherical vascular disease. *Eur J Vasc Surg* 1990;**4**:185–189.
13 Olerud JE, Pecoraro RE, Burgess EM, McKnight B, Wyss CR, Reiber O *et al*. Reliability of transcutaneous oxygen tension (TcPO2) measurements in elderly normal subjects. *Scand J Clin Lab Invest* 1987;**47**:535–541.
14 De Graaff JC, Ubbink DT, Legemate DA, De Haan RJ, Jacobs MJ. Interobserver and intraobserver reproducibility of peripheral blood pressure and oxygen pressure measurements in the assessment of lower extremity arterial disease. *J Vasc Surg* 2001;**33**:1033–1040.
15 Smith FCT, Shearman CP, Simms MH, Gwynn BR. Falsely elevated ankle pressures in severe leg ischemia: the pole test—an alternative approach. *Eur J Vasc Surg* 1994;**8**:408–412.
16 Jachertz G, Stappler T, Do DD, Mahler F. The pole-pressure test: an easy alternative in patients with ischemic legs and incompressible arteries. *VASA* 2000;**29**:59–61.
17 Chantelau E, Sambraus HW. Hydrostatic systolic toe pressure for diagnosis of peripheral ischaemic vessel disease in diabetes mellitus. Correspondence. *Eur J Vasc Endovasc Surg* 1996;**12**:125–128.
18 Rooke TW, Osmundson PJ. The influence of age, sex, smoking, and diabetes on lower limb transcutaneous oxygen tension in patients with arterial occlusive disease. *Arch Intern Med* 1990;**150**: 129–132.
19 Wyss CR, Matsen FA, Simmons CW, Burgess EM. Transcutaneous oxygen tension measurements on limbs of diabetic and non-diabetic patients with peripheral vascular disease. *Surgery* 1984;**95**:339–345.
20 Wyss CR, Robertson C, Love SJ, Harrington RM, Matsen III FA. Relationship between transcutaneous oxygen tension, ankle blood pressure, and clinical outcome of vascular surgery in diabetic and nondiabetic patients. *Surgery* 1987; **101**:56–62.
21 Siperstein MD, Unger RH, Madison LL. Studies of muscle capillary basement membranes in normal subjects, diabetic, and prediabetic patients. *J Clin Invest* 1968;**47**:1973–1999.
22 Brownlee M, Cerami A, Vlassara H. Advanced glygolysation end products in tissue and the biochemical basis of diabetic complications. *N Engl J Med* 1988;**318**:1315–1321.
23 Ubbink DT, Jacobs MJHM, Tangelder GJ, Slaaf DW, Reneman RS. The usefulness of capillary microscopy, transcutaneous oximetry and laser Doppler fluxmetry in the assessment of lower limb ischaemia. *Int J Microcirc* 1994;**14**: 34–44.
24 Scheffler A, Rieger H. Clinical information content of transcutaneous oxymetry (tcpO2) in peripheral arterial occlusive disease (a review of the methodological and clinical literature with a special reference to critical limb ischaemia). *VASA* 1992;**21**: 111–126.

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