

## The Toe Pole Test for Evaluation of Arterial Insufficiency in Diabetic Patients\*

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**Objectives:** to evaluate if the pole test at the toe level can be used for assessment of arterial insufficiency in diabetic patients.

**Methods:** twenty-five legs in 23 diabetic patients suffering from leg ischaemia were examined prospectively. A laser Doppler probe was attached to the pulp of the first toe to monitor perfusion continuously before and after occluding the arterial inflow with a cuff and during elevation of the leg until perfusion disappeared (the pole test). At ankle level the examinations were made similarly but with an ankle cuff and a hand-held Doppler.

**Results:** in the 44% (11/25) of the legs where it was possible to compare cuff blood pressure at ankle level with the pole test, the cuff measurements were significantly higher ( $p < 0.01$ ). In 13 of the remaining 14, maximal elevation did not result in disappearance of the Doppler signal. At toe level where 76% (19/25) of the legs could be compared, there was no significant difference between the two methods.

**Conclusion:** the pole test can be used at the toe level to evaluate arterial insufficiency in diabetes. When used in the toe, the pole test can assess pressures below 55–70 mmHg, while only pressures below 45 mmHg can be determined at the ankle level. Falsely elevated blood pressure in diabetics is probably of less importance in digital arteries than in ankle arteries, which makes cuff pressure at toe level a more acceptable approximation.

**Key Words:** Ankle blood pressure; Toe blood pressure; Limb ischaemia; Pole test; Diabetes.

### Introduction

In patients with peripheral arterial occlusive disease (PAOD), accurate assessment of the severity of disease is necessary for adequate treatment and selection for surgery. To make this evaluation objectively, quantitative blood-pressure estimations are needed. Ankle blood pressure (ABP) determination, using a cuff and a hand-held Doppler is therefore an integral part of the evaluation of limb ischaemia. This is also true for diabetic patients, who are particularly in need of objective methods to assess limb ischaemia, since they lack pain as a sign of critical ischaemia. However, a major disadvantage with ABP is its inability to accurately evaluate arterial insufficiency in patients with arteries that resist compression due to wall stiffness. This is a common problem, reported to occur in up to

18% of all insulin-dependent diabetic patients.<sup>1</sup> Moreover, disease located distally may be missed by ABP, because it will only be affected by lesions located proximal to the cuff. The optimal method for evaluation of limb ischaemia in diabetic patients is therefore to measure the blood pressure as distally as possible with a method which is independent of vascular wall stiffness. Toe blood pressure (TBP) is consequently considered the method of choice, as it can predict healing of ischaemic ulcers better than ABP. However, it is unknown if stiff arteries are a problem at the toe level,<sup>2–4</sup> but it is possible that smaller vessels are easier to compress.

It has been suggested that ABP can be measured without a cuff, using the hydrostatic pressure induced by leg elevation, and by recording the height above the heart with a scale on a pole, the pole test.<sup>5</sup> Using laser Doppler fluxmetry, a non-invasive method for continuous skin perfusion measurements, the pole test can also be used at the toe level.<sup>6–9</sup> The aim of the study was to evaluate the ability of the toe pole test for evaluation of arterial insufficiency in diabetic

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**Table 1. Patient characteristics (*n* = 25 legs). The values are number or median and range.**

Sex M/F	n/n	17/8
Age (years)	median	76 (52–90)
Diabetes type I/II	n/n	2/23
Diabetes duration (years)	median	20 (5–61)
Diabetes treatment: oral/insulin	n/n	3/22
Brachial blood pressure (mmHg)	median	140 (120–190)
Ischaemic symptoms:		
Claudication as single symptom	n	1
Rest pain	n	16
Foot ulcer digital/other	n/n	13/9

patients with foot ulcers, by comparing it with cuff measurements.

### Material and Methods

Twenty-five limbs in twenty-three consecutive patients with diabetes were recruited from a group of 25 patients who were referred for evaluation of foot ulcers to the vascular surgical clinic. Two patients with previous hallux amputations or gangrene, which made TBP measurements impossible, were excluded. Of the 23 patients, all but nine still had foot ulcers. Twenty-two were insulin-dependent. The patient's characteristics are shown in Table 1. Brachial pressures were derived from the brachial artery by placing a 15-cm-wide pneumatic cuff around the arm 5 cm above the elbow. Korotkoff's sounds were detected with a stethoscope placed in the cubital region. The cuff was inflated to 250 mmHg and the pressure was recorded when the sounds reappeared during slow deflation. The procedure was repeated and the mean value used for analysis.

ABP with cuff (ABP-cuff) was measured by insonating the dorsal pedal, posterior tibial and, if possible, the peroneal artery at ankle level with a hand-held Doppler (ultrasonic Doppler flow-detector model 811-B, Parks Medical Electronics Inc. Aloha, OR, U.S.A.). A 15-cm-wide cuff was placed just proximal to the malleoli and inflated until the Doppler signal disappeared. The cuff was slowly deflated (2–3 mmHg per 5 seconds) and the pressure in the cuff when the signal reappeared was named ABP-cuff. When ABP with the pole test (ABP-pole) was measured, the patient's leg was slowly elevated to a level where the Doppler signal vanished during insonation of one of the arteries and then lowered until an audible Doppler signal reappeared. The height over the left ventricle of the heart at which the signal reappeared was the

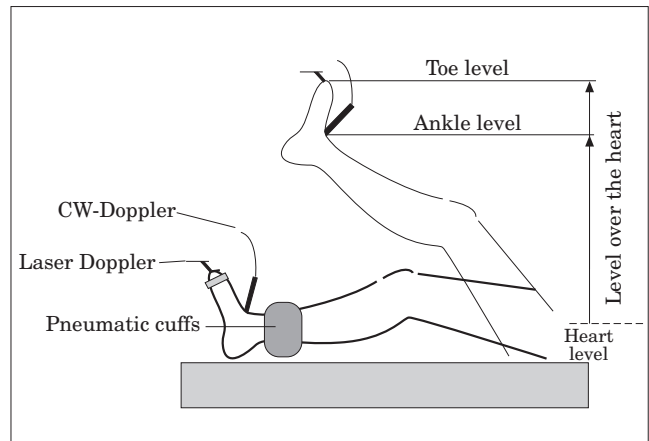


Fig. 1. Schematic drawing of the study set up.

ABP-pole (Fig. 1). The artery with the highest value was used for the analysis of both ABP-cuff and ABP-pole pressures.

Measurements of TBP were made using a laser Doppler (laser blood-flow monitor, MBF 3D, Moor Instruments, Axminster, England) probe placed at the toe pulp skin and monitoring skin perfusion during inflation of a 2 cm-wide cuff located at the base of the toe. The cuff was deflated (2–3 mmHg per 5 seconds) and the value when the flux signal reappeared or increased more than 10% above the occlusion value was named TBP-cuff.<sup>10</sup> The pole test at toe level (TBP-pole) was measured by elevating the leg until the LD signal dropped to biological zero.<sup>11</sup> The leg was then lowered again, recording the level above the heart where the flux signal reappeared or increased to more than 10% above the biological zero value (Fig. 1). The distance in cm obtained from the pole-test measurements was converted to mmHg by assuming the density of blood to be 1.055 g/cm<sup>3</sup> and of mercury 13.54 g/cm<sup>3</sup>. Accordingly, the pressure unit 1 cm blood above the heart corresponds to 0.78 mmHg (10 mm · 1.055 / 13.54 = 0.78 mmHg).<sup>12</sup>

Patients rested in supine position for fifteen minutes in a room with a temperature of 20–22 °C. The brachial blood pressure in the right arm with the patient lying flat and the distance between the left ventricle of the heart and the bed were measured (Fig. 1). ABP-cuff and TBP-cuff measurements were performed in sequence, followed by ABP-cuff and the pole at ankle level for all three ankle arteries. All pressures were recorded twice and the mean value used for comparisons. Comparison between the methods were made with Wilcoxon signed-rank test for paired observations and Mann-Whitney *U*-test for unpaired data. Values were considered significant when *p* values were less than 5%.

**Table 2. Blood pressures and indices as median and range in the legs where it was possible to compare the cuff and pole methods.**

Pressure method	n	mmHg	Arm-pressure index
Ankle-cuff	11	70 (50–125)	0.50 (0.12–0.85)
Ankle-pole	11	30 (3–45)	0.23 (0.02–0.34)
Toe-cuff	19	30 (5–110)	0.23 (0.04–0.69)
Toe-pole	19	23 (5–69)	0.17 (0.04–0.43)

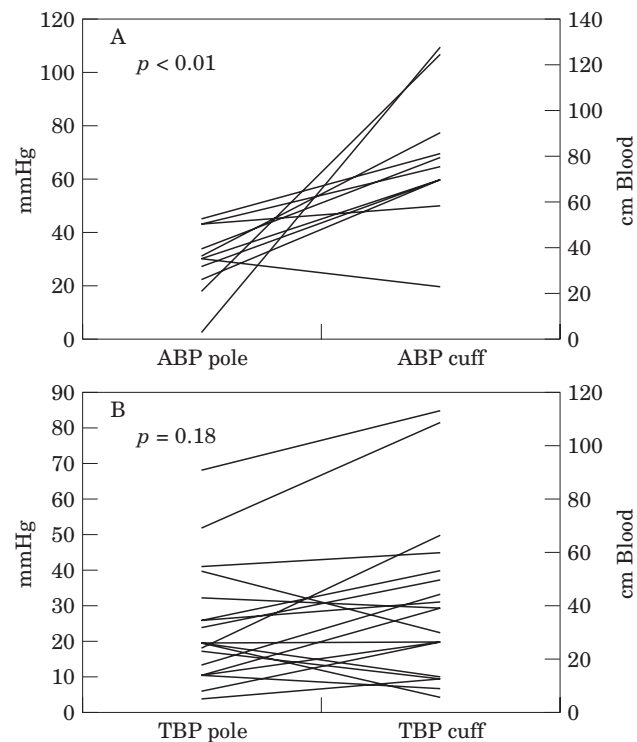
**Results**

It was not possible to measure ankle or toe blood pressure in all patients. At ankle level one leg had an incompressible artery (>300 mmHg) and in 13 legs it was impossible to use the pole test because the flow signal was still present at maximal leg elevation. Pressure determination with both cuff and pole test at ankle level was possible in 11 legs (Table 2, Fig. 2a). The median level over the heart at which the flow signal was still present when the leg was maximally raised during ABP-pole examination was 58 cm (43–75 cm). This converts to 45 (32–55) mmHg. The highest pressure that was actually measured was

45 mmHg, implying that, because of anatomical limitations, the highest measurable ABP-pole is 45 mmHg for these patients. The height tended to be lower for females (n=5, median 57 cm, 43–71) than for males (n=8, median 63 cm, 51–75), but was not significantly different.

At toe level four lacked any detectable perfusion and in two the laser Doppler signal still persisted at maximal leg elevation. Both cuff and the pole test could be performed in 19 toes (Table 2, Fig. 2b). In the two legs with persistent blood flow at maximal leg elevation during TBP-pole determination, the height above the heart was 69.5 (65 and 74) cm corresponding to 54 mmHg. The highest recorded TBP-pole was 69 mmHg, suggesting that the highest measurable pressure is 55–70 mmHg.

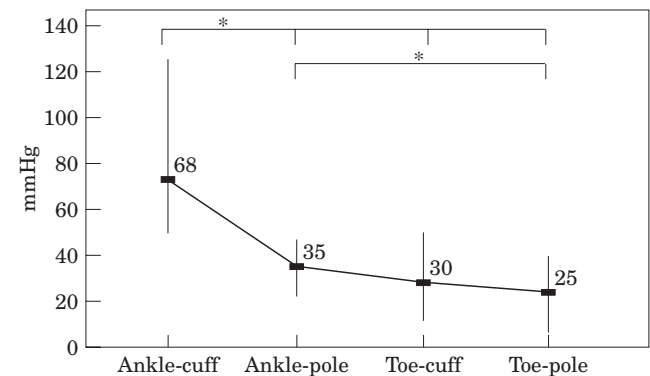
In the eleven legs where ABP-pole and ABP-cuff could be compared, ABP-cuff values were significantly (p<0.01) higher than ABP-pole, with a 40 mmHg difference between the median values (Fig. 2a). The corresponding difference at toe level where 19 legs could be compared was 7 mmHg, which was not significant (p=0.18, Fig. 2b). Similar results were found when comparing ankle-brachial and toe-brachial indices (Table 2). All four pressures could be determined in eight legs. In these ABP-cuff was significantly (p=0.012) higher than the other methods and ABP-pole higher (p=0.049) than TBP-pole (Fig. 3).



**Fig. 2.** Blood pressures that could be measured with cuff and pole test: (A) at ankle level (n=11) and (B) at toe level (n=19). Individual values and median values for each method. Probabilities according to Wilcoxon signed-rank test.

**Discussion**

There is no ideal method available to objectively evaluate PAOD in diabetes. Several methods have been tried, but with a possible exception of TcPO<sub>2</sub>, none



**Fig. 3.** Blood pressures that could be measured with cuff and pole test at both ankle and toe level (n=8). Individual values and median values. Significances according to Wilcoxon signed-rank test where \* equals p<0.05.

have yet entirely replaced simple ABP measurements with a cuff.<sup>13</sup> This is quite surprising, since there is no significant difference in ABP-cuff values between healing and non-healing limbs of diabetic patients with gangrene or foot ulcers.<sup>4</sup> The two most important reasons for this observation is the vessel wall calcification, creating erroneously high pressures, and the predominance of arterial lesions in the distal leg rather than in the thigh.

Incompressible arteries affecting blood pressure measurements is common.<sup>13,14</sup> Not only diabetic patients with severe leg ischaemia, but also 1% of diabetic patients without clinically evident PAOD, have stiff arteries in the lower limb and a blood pressure measurement exceeding 300 mmHg in one or more of the ankle arteries. The corresponding frequency in diabetic patients with PAOD varies between 2–18%.<sup>1,14</sup> There is a positive correlation between a high ankle–arm index and the amount of calcification seen in the tibial vessels on plain X-rays.<sup>15</sup> Accordingly, the higher the ABP-cuff values, the more calcification is likely to be present. In this study, only one leg out of twenty-five had completely incompressible arteries, but the difference of 40 mmHg between ABP-cuff and ABP-pole values is probably partly explained by varying degrees of stiffness in the arteries. Contributing to this finding is also the location of disease. As shown in Fig. 3, ABP-cuff was much higher than the other pressures. The other three values recorded, ABP-pole and TBP-cuff and TBP-pole, are all affected by lesions distal to the malleoli, while ABP-cuff is only determined by lesion above the cuff, its upper edge being 15 cm above the malleoli. While the foot arteries are usually spared in diabetic PAOD, the distal calf arteries are often diseased.

The stiff arteries and the distal disease location are also the reasons for using the TBP instead of ABP to evaluate patients with diabetes and PAOD.<sup>16</sup> So far, measuring TBP-cuff has required rather large and expensive equipment, restricting its use to vascular laboratories in hospitals. In the near future recent innovations may facilitate the TBP recordings in the outpatient clinic and GP's offices.<sup>8,10</sup> TBP-cuff is significantly higher in healing legs with foot ulcers than in non-healing,<sup>4</sup> and a TBP-cuff pressure less than 45 mmHg provides a primary healing rate of 85%.<sup>17</sup> The present results show that the concordance between cuff and the pole test values were much greater at toe level than in the ankle, supporting the clinical value of TBP. It is possible, however, that not even TBP-cuff reflects the true perfusion pressure. Though not significant in our patients, there was tendency towards higher pressures with the cuff than with the pole test also at toe level.

Although the principle of the pole test has been used, particularly in diabetic patients, for decades as a clinical test to diagnose the severity of ischaemia by just inspecting the skin during leg elevation, the concept of the objective method was introduced by Smith *et al.* in 1994.<sup>5</sup> In that study the pole test was compared with a blood pressure index measured with cuff at the ankle level and direct intra-arterial blood pressure recorded in distal calf arteries during bypass surgery. While there was no significant difference between the pole test and the intra-arterial pressure in that study, the cuff method overestimated the blood pressure both compared to the pole test and the direct method. This is supported by the present results where the median ABP-cuff was 40 mmHg higher than if measured with the pole test. In the study by Smith, all patients investigated were measurable with the pole test at the ankle level and no patient had incompressible arteries or a persistent Doppler signal at maximal leg elevation. This finding is in contrast to our results, where only 42% of the legs allowed the pole test at ankle level. The reason for this discrepancy may be that we performed measurements strictly on diabetic patients, in whom symptoms are difficult to evaluate by medical history. Patients with milder disease than in the study by Smith were included, who only measured patients with critical limb ischaemia (CLI). Accordingly, the clinical value of the pole test at the ankle level is limited to severe disease and may not be so helpful in identifying patients with subcritical ischaemia. Assuming that the patients in the study by Smith met the criteria in the Second European Consensus Document, having an ABP  $\leq 50$  mmHg, their findings are somewhat more in agreement with the present ones, where only pressures less than 45 mmHg could be measured by the pole test at the ankle level.<sup>5,13</sup>

At the toe level, however, higher pressures can be measured with the pole test simply because the distance from the hip joint to the toe is longer than to the ankle arteries. Even though we could not determine the upper limit for TBP-pole measurements (only two legs could not be assessed due to persistent signal), it is probable that this is 55–65 mmHg, corresponding to an elevation to 75–90 cm above heart level. This would include all pressures  $\leq 30$  mmHg, suggested by the Second European Consensus Document as the limit for CLI in diabetes, as well as patients with pressures just above that limit who may be subjected to follow-up.<sup>13</sup> Hypothetically, if we based our treatment decision on TBP-cuff to determine CLI, 37% (7/19) of our patients would meet the criterion of a pressure  $\leq 30$  mmHg and be revascularised, while 58% (11/19) of the legs had a TBP-pole  $\leq 30$  mmHg. The corresponding figures, using criterion of ABP  $\leq 50$  mmHg,

give more dramatic differences between cuff and pole test. Only 18% (2/11) had ankle pressure  $\leq 50$  mmHg using cuff, compared to 100% (11/11) with ABP-pole. Many of our patients would be subjected to surgery just by using ABP-pole instead of ABP-cuff to assess CLI. This emphasises the problem with distal pressures to select diabetic patients with PAOD for surgery, and strongly supports the use of TBP (or ABP-pole) in favour of ABP-cuff in this patient group.<sup>2-4</sup>

In conclusion, this study shows that the pole test can be used at the toe level to evaluate arterial insufficiency in diabetes. When used in the toe, the pole test can assess pressures below 55–70 mmHg, while only pressures below 45 mmHg can be determined at the ankle level. Falsely elevated blood pressures in diabetics are probably of less importance in digital arteries than in ankle arteries, which makes cuff pressure at toe level an acceptable approximation.

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