Value of toe pulse waves in addition to systolic pressures in the assessment of the severity of peripheral arterial disease and critical limb ischemia

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Purpose: **Although pressure measurements are useful in the assessment of the severity of the arterial obstruction, they do not completely identify limbs with and without critical limb ischemia. Our objective was to test whether addition of the measurements of toe pulse waves (PW), which depend on distal perfusion, to pressure measurements could improve the determination of the severity of arterial disease and the presence of critical limb ischemia.**

Methods: **We measured toe pressure (TSP) and ankle/brachial index (ABI) and recorded PW with photoplethysmography in 358 limbs of 182 patients.**

Results: **TSP, ABI, and PW amplitude were lower in 67 limbs with rest pain, skin lesions, or both, with mean differences of 29 mm Hg, 0.12, and 16 mm, respectively ($p < 0.01$). Similarly, in the subgroup of 107 limbs with TSP ≤30 mm Hg, TSP, and PW amplitude, but not ABI, were lower in 53 limbs with rest pain, skin lesions, or both, with mean differences of 10 mm Hg and 7 mm ($p < 0.01$). Multiple logistic regression showed that after controlling was done for TSP and ABI, the odds ratio for the presence of rest pain, skin lesions, or both associated with PW amplitude ≤4 mm was 4.3 (95% confidence interval 1.7, 11.0; $p < 0.01$). In the subgroup with TSP ≤30 mm Hg, this odds ratio was 3.5 (95% confidence interval 1.0, 11.6; $p < 0.05$).**

Conclusions: **The findings indicate that addition of PW recording to pressure measurements is likely to increase the accuracy of assessment for critical limb ischemia. (J Vasc Surg 1996;24:258-65.)**

Measurements of systolic pressures have been applied successfully to the diagnosis and follow-up of individual patients with peripheral arterial disease, to the study of the natural history of the disease, and to the evaluation of results of surgery and of other forms of therapy.[1-7] Both ankle and toe systolic pressures correlate well with the severity of the symptoms and the angiographic findings.[3,8-10] Although pressure measurements are helpful in the estimation of the likelihood of spontaneous healing of skin ulcers and gangrene and the assessment for critical limb ischemia, ankle and toe pressures each provide different information and do not completely identify limbs with and without critical ischemia.

When ankle pressure is less than 50 mm Hg, spontaneous healing of skin lesions is unlikely to occur.[7,11] However, in many limbs in which ankle pressure is higher, healing also does not take place, and amputation is carried out.[3,11] This finding is related to the fact that ankle pressure usually does not detect isolated obstruction of one or even two of the three branches of the popliteal artery between the knee and the ankle nor the obstruction in the vessels of the foot.[3,6,8] Furthermore in many patients, especially those with diabetes mellitus, increased rigidity of the tibial or peroneal arteries results in "incompressibility" of the walls, which gives rise to falsely high pressure values.[3,6,8] Thus low ankle pressure is consistent with the presence of severe arterial obstruction and critical limb ischemia, but higher pressures are not reliable.

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Toe pressure reflects the overall obstruction in the arterial tree proximal to the digits and does not appear to be affected by the arterial incompressibility.[1,3,6,10] If toe pressure exceeds 30 mm Hg, spontaneous healing occurs in a large majority of cases.[3,7,11,12] When toe pressure is less than 30 mm Hg, the chance of healing decreases with the pressure value, but in approximately 25% of the limbs healing does take place.[3,11,12] Also, toe pressure less than 30 mm Hg is found in some limbs without skin lesions or pain at rest, suggesting the absence of critical ischemia.[3,13] Thus high toe pressure is a good predictor of the absence of critical ischemia, but lower pressure is less helpful.

Among limbs with toe pressure less than 30 mm Hg the prognosis in those with skin lesions or rest pain was reported to be considerably worse than in limbs without these manifestations.[13] This finding suggests that among limbs with low toe pressure, subgroups with different distal hemodynamics are present. Therefore the use of another parameter of circulation, which depends on distal blood flow, in combination with measurements of pressure may improve assessment of patients with severe arterial disease. The importance of measurements that reflect distal perfusion and the status of the microcirculation was recognized in the Second European Consensus Document on Critical Leg Ischemia.[7]

Pulse waves recorded from the digits were reported to vary with temperature and blood flow.[6,14] Arterial pressure wave is altered distal to an obstructive lesion, which results in damping of the wave, lower amplitude, and a change in the shape manifested by increased time to peak.[6,15] Parameters of the externally recorded pulse waves over the arteries at the ankle and in the popliteal fossa, as is the case with the ankle and thigh pressures, also correlate with angiographic findings.[15] Similarly, measurements of pulse waves recorded from the toes correlate well with angiographic findings.[16] Recording of digital pulse was recommended in the evaluation for critical leg ischemia[7] and is used empirically to make decisions about treatment of patients with arterial disease.[6]

This study was undertaken to determine the value of the measurement of pulse waves recorded from the toes in the assessment of the severity of peripheral arterial disease. Specifically, our aim was to assess whether digital pulsatility might be helpful in distinguishing limbs with rest pain, skin lesions, or both, the clinical manifestations of critical ischemia, in which there is evidence of severe hemodynamic impairment and likely poor prognosis, from those without critical ischemia, in which spontaneous healing of skin lesions is likely to occur without surgery.

PATIENTS AND METHODS

Patients studied. The study sample consisted of 185 patients (358 extremities) referred to the Vascular Laboratory at St. Boniface General Hospital over a period of 1 year in whom pressures and pulse waves were recorded. The study was approved by The Committee on the Use of Human Subjects in Research of the University of Manitoba. Sixty-seven patients (130 extremities) had diabetes. A total of 107 men and 75 women with the average age of 69 ± SD 11 years and 71 ± SD 11 years, respectively, were evaluated.

In 71 limbs the ankle/brachial systolic pressure index (ABI) and toe/brachial index were greater than 0.90 and 0.50, respectively, indicating either the absence of overt arterial disease or the presence of very mild obstruction.[3,6,10] The remaining 287 limbs were considered to have significant arterial disease. Among these, no symptoms were reported in 96 extremities. The absence of symptoms was related to the presence of relatively mild disease, to more severe obstruction in the contralateral limb, or to the inactivity of the patients. Typical intermittent claudication was the only symptom in 124 limbs. The remaining 67 limbs included 52 with skin lesions (ulcers, gangrene) and 15 with rest pain without lesions. Rest pain was defined as pain in the foot, increased by lying down or waking patient at night, usually relieved by the dependent position and requiring narcotics. Severe obstruction was defined by the presence of toe pressure of ≤30 mm Hg.[3,6,7,13] This subgroup consisted of 107 of the 287 limbs with arterial disease and included 53 of the 67 limbs with rest pain, skin lesions, or both (40 with skin lesions and 13 with rest pain without lesions).

Measurements. Ankle and first toe systolic pressures were measured with the use of the previously described methods.[8,10,17] Brachial systolic pressure was measured at the time of each ankle and toe pressure measurement. The values of the pressure at each site were based on the average of duplicate measurements. The ABI and toe/brachial index were calculated as the ratios of the distal to the brachial systolic pressure.

Ankle pressures were not measured in four limbs, and in 20 limbs they either could not be measured because the flow continued despite the inflation of the blood pressure cuffs to 300 mm Hg or the measurements were clearly unreliable because of "partial arterial wall incompressibility" when high ankle pressures were associated with grossly abnormal monophasic arterial velocity sounds over the ankle arteries. Ankle pressures in these limbs were excluded

from the analysis. In 6 of the 24 limbs without valid ankle pressure measurements, toe/brachial index was greater than 0.50 indicating absence of significant arterial obstruction. Among the 18 remaining limbs, 8 limbs had rest pain, skin lesions, or both.

Pulse waves were recorded from the plantar aspect of the distal phalanx of the hallux with photocell plethysmography. The results are based on the averages of measurements of at least three pulse waves. The amplitude was measured in millimeters of deflection and adjusted to the basic recorder sensitivity (PPG, Medasonics Inc, Mountain View, Calif. - maximum setting in arterial mode; Beckman 611 recorder: Amplifier Type 411 - 0.1 Preamp. multiplier setting; Pressure Coupler Type 9853H - DC setting; Preamplifier Type 461D - basic sensitivity setting of 0.2 mv/mm). The time to peak (crest time) and the width of the pulse wave at half amplitude were measured and expressed as percentage of the cardiac cycle as described previously.[15] In waves with low amplitude the time to peak and the width of the wave could not be measured.

Vasomotor state. The measurements were carried out after the patients rested supine for at least 20 minutes with their body and extremities covered with a heating blanket to buffer the measurement from possible effects of cool outdoor temperatures.[17] The room temperature was approximately 23° C. To assess the potential effect of local temperature, skin temperature of the tip of the hallux was measured with a thermistor.

In addition, preliminary experiments were carried out in 20 limbs of 10 other patients with arterial disease (mean ABI 0.65 ± SD 0.18) in which toe pulse waves were recorded during body heating and cooling induced by the modification of the technique of Gibbon and Landis[18] by Lezack and Carter[19] to assess the relationship of the wave amplitude recorded with photoplethysmography to the changes in the vasomotor state.

Statistical analysis. Data of continuous variables were reported as mean and SEM unless otherwise indicated. Pearson correlation coefficients were used to test the strength of the linear relationship between pairs of continuous variables of wave and pressure. The significance of the differences between means were compared by the two-sample Student's t test. The χ^2 statistic was used to test the significance of the difference of proportions of limbs with and without rest pain, skin lesions, or both.

Logistic regression analysis was used to relate independent variables such as the wave and pressure measurements and the presence of diabetes to the occurrence of rest pain, or skin lesions, or both. A univariate model was used to show the relationship of each variable to these clinical manifestations by itself. The independent effect of each variable after adjustment was done for other variables in the model was determined by the use of multivariate analysis.

Odds ratios for the occurrence of rest pain, skin lesions, or both were calculated both for independent variables in binary form and for changes in continuous variables. For binary variables the odds ratio is interpreted as the odds of rest pain, skin lesions, or both for a subject with the binary factor relative to the odds for a subject without this factor. For a change in a continuous variable such as a 10 mm Hg change in toe systolic pressure, the corresponding odds ratio is interpreted as the factor by which the likelihood of rest pain, skin lesions, or both is increased for a subject with the lower toe pressure relative to the subject with the higher pressure.

The level of significance was set at 0.05 for all analyses.

RESULTS

Correlation between pulse waves and pressures. Table I shows correlations between the parameters of the pulse waves and the toe pressure and ABI. All wave parameters showed highly significant correlations with the pressures in the total sample of all limbs. In the subgroup with severe arterial disease the crest time and the width of the wave often could not be measured because of the low-wave amplitude and when measured did not correlate significantly with the pressures. However, wave amplitude correlated significantly with the pressures both in the group of all limbs and in the subgroup with severe disease. All correlations were higher with toe pressure than with ABI. The magnitude and significance of the correlation coefficients of the absolute value of the ankle pressure with wave variables were very similar to those shown in Table I for ABI.

The relationship of temperature and pulse waves. A highly significant correlation was seen between the temperature and wave amplitude both in the whole sample of 358 limbs and in the subgroup of 107 limbs with severe arterial disease ($r = 0.550$ and 0.445, respectively; $p < 0.001$). Also, in a preliminary study of 10 other patients with arterial disease, the mean amplitude of the pulse wave recorded during body cooling was 15 ± 7 mm, significantly lower than the amplitude of 44 ± 9 mm during body heating ($p = 0.022$).

Pulse waves and pressures in limbs with and without rest pain or skin lesions. Table II shows that

Table I. Correlation coefficients of pulse waves with pressures

	All limbs		*Severe disease*	
Wave parameter	*TSP*	*ABI*	*TSP*	*ABI*
Crest time	−0.649 (291)*	−0.609 (273)*	−0.253 (55)	−0.184 (54)
Width 1/2 amp.	−0.710 (291)*	−0.581 (273)*	−0.205 (55)	−0.102 (54)
Amplitude	0.574 (358)*	0.448 (334)*	0.560 (107)*	0.218 (101)†

TSP, Toe systolic pressure; *width 1/2 amp*, width of the wave at half amplitude.
Number of limbs is shown in brackets. Ankle systolic pressure was not measured or was not reliable in 18 limbs. Crest time and width at half amplitude could not be measured in limbs with low amplitude.
*$p < 0.001$.
†$p < 0.05$.

Table II. Pressures and pulse wave amplitude in limbs with and without rest pain, skin lesions, or both

Variable	*Group*	*Arterial disease*	*Severe disease*
TSP	No RPLS	48.1 ± 1.4 (220)	23.2 ± 0.9 (54)
	RPLS	19.2 ± 1.9 (67)	12.7 ± 1.3 (53)
		$p < 0.001$	$p < 0.001$
ABI	No RPLS	0.68 ± 0.02 (210)	0.51 ± 0.03 (54)
	RPLS	0.56 ± 0.04 (59)	0.49 ± 0.03 (47)
		$p < 0.001$	
Amplitude	No RPLS	22.8 ± 1.3 (220)	11.8 ± 1.6 (53)
	RPLS	6.7 ± 1.2 (67)	4.6 ± 1.1 (53)
		$p < 0.001$	$p < 0.001$

RPLS, Rest pain, skin lesions, or both.
Data expressed as mean ± SE.
Number of limbs is shown in brackets. Ankle systolic pressure was not measured or was not reliable in 18 limbs.

in the group with arterial disease the mean toe pressure, ABI, and wave amplitude were all significantly lower in limbs with rest pain, skin lesions, or both. Similarly, the mean absolute ankle pressure of 77 ± 4 mm Hg in limbs with rest pain, skin lesions, or both was significantly lower than the value of 100 ± 2 mm Hg in those without these manifestations ($p < 0.001$). In the subgroup with severe disease (toe pressure ≤30 mm Hg) mean toe pressure and the wave amplitude were also significantly lower in the limbs with rest pain, skin lesions, or both, but no significant difference was seen in the ABI. Also, no significant difference was seen in the absolute values of the ankle pressure. No significant differences were seen in the pressures, pressure indexes, and wave amplitude between the limbs with rest pain but without skin lesions and the limbs with lesions both in all limbs with arterial disease and in the subgroup with severe disease (data not shown).

Comparison of limbs with arterial disease in patients with and without diabetes. The differences in mean pressures and pulse waves between subgroups with and without rest pain, skin lesions, or both showed similar results to those illustrated in Table II when analysis was carried out separately in the limbs of patients with or without diabetes mellitus. Also, no significant differences were found in the pressures and wave amplitude between the limbs of diabetic and nondiabetic patients in the groups of limbs with or without rest pain, skin lesions, or both, either in the whole group with arterial disease or in the subgroup with severe disease.

Table III shows the distribution of the limbs with and without rest pain, skin lesions, or both among patients with and without diabetes according to systolic pressures. Significantly more limbs with these manifestations were found among the diabetic patients in the subgroup with toe pressure ≤30 mm Hg ($p < 0.01$), but no significant difference was seen in those with higher toe pressures. Also, significantly more limbs with rest pain, skin lesions, or both were seen among diabetic patients in each of the four subgroups defined by ankle pressure less than or greater than 50 mm Hg and 60 mm Hg ($p < 0.05$).

Table IV shows the distribution of the limbs with and without rest pain, skin lesions, or both among those with low pulse wave amplitude defined as ≤4 mm and those with higher amplitude. The value of 4 mm for the definition of low amplitude was selected because it both identified 93% of all limbs with rest

Table III. Number of limbs with and without rest pain, skin lesions, or both according to systolic pressures and the presence of diabetes

	No diabetes		*Diabetes*		
	RPLS	*No RPLS*	*RPLS*	*No RPLS*	*Total*
All limbs	31	147	36	73	287
TSP (mm Hg)					
≤30	25	41	28	13	107
31-40	4	20	3	16	43
>40	2	86	5	44	137
Ankle (mm Hg)*					
≤50	7	9	10	0	26
51-60	4	11	1	5	21
>60	17	127	20	58	222

Abbreviations as in Tables I and II.
*Ankle systolic pressure was not measured or was not reliable in 18 limbs.

Table IV. Number of limbs with and without rest pain, skin lesions, or both according to the pulse wave amplitude

	Arterial disease			*Severe disease*		
	Amplitude			*Amplitude*		
Group	*≤4 mm*	*>4 mm*	*Total*	*≤4 mm*	*>4 mm*	*Total*
No RPLS	22 (35)	198 (88)	220	12 (25)	42 (72)	54
RPLS	40 (65)	27 (12)	67	37 (75)	16 (28)	53
Total	62 (100)	225 (100)	287	49 (100)	58 (100)	107

RPLS, Rest pain, skin lesions, or both.
Percent of limbs with RPLS in each column are given in brackets.

pain, skin lesions, or both (compared with 76% at ≤3 mm and 45% at ≤2 mm) and had a highly significant association with these clinical manifestations. Significantly more limbs with rest pain, skin lesions, or both were seen among those patients with low-wave amplitude both in the whole group with arterial disease and in the subgroup with severe disease ($p < 0.001$).

Logistic regression analysis. The results of the univariate analysis are shown in Table V. The odds for the presence of rest pain, skin lesions, or both in the group with arterial disease increased significantly with decrease in toe pressure, decrease in ABI, with low-wave amplitude, and with the presence of diabetes. In the subgroup with severe disease the odds of rest pain, skin lesions, or both also increased with the decrease in toe pressure, with low pulse wave amplitude, and with the presence of diabetes, but no significant effect of ABI was seen.

Table VI shows the results of the multivariate logistic analysis. The odds for the presence of rest pain, skin lesions, or both increased significantly with the decrease in toe pressure and the presence of low-wave amplitude both in the whole group with arterial disease and in the subgroup with severe disease. The odds also increased with the presence of diabetes, although in the subgroup with severe disease the effect did not reach the 5% statistical significance level. After controlling was done for other variables, a decrease in the ABI was actually associated with lower odds for rest pain, skin lesions, or both. The low pulse wave amplitude was also associated significantly with the presence of these clinical manifestations after controlling was done for toe pressure, ABI, and diabetes in a subgroup of limbs with toe pressure ≤40 mm Hg with the odds ratio of 3.6 (1.3, 9.7; $p < 0.02$). The odds ratios for the presence of rest pain, skin lesions, or both associated with diabetes in the multivariate analysis were similar to those in the univariate analysis.

The results of the logistic regression analysis were very similar when the absolute value of the ankle pressure was used instead of ABI. In the univariate model a decrease in the ankle pressure of 10 mm Hg was associated with the odds ratio for rest pain, skin lesions, or both of 1.3 (1.1, 1.4; $p < 0.001$) in all limbs with arterial disease, but it was not related significantly to these manifestations in the subgroup with severe disease ($p > 0.3$). Also, in similarity to ABI, a decrease of 10 mm Hg in the ankle pressure resulted in a lower odds ratio for rest pain, skin lesions, or both of 0.9 (0.7, 1.0; $p < 0.05$) in the multivariate analysis of all

Table V. Univariate odds ratios and 95% confidence interval for rest pain, skin lesions, or both

Variable	*Change*	*Arterial disease*	*Severe disease*
TSP	10 mm Hg decrease	2.5 (2.0, 3.2)*	4.5 (2.5, 0.8)*
ABI	0.10 decrease	1.3 (1.1, 1.4)†	1.0 (0.9, 1.2)
Amplitude	≤4 mm/>4 mm	13.3 (6.9, 25.7)*	8.1 (3.4, 19.3)*
Diabetes	Present/absent	2.3 (1.3, 4.1)†	3.5 (1.6, 8.1)†

TSP, Toe systolic pressure.
*$p < 0.001$.
†$p < 0.01$.

Table VI. Multivariate odds ratios and 95% confidence interval for rest pain, skin lesions, or both

Variable	*Change*	*Arterial disease*	*Severe disease*
TSP	10 mm Hg decrease	2.8 (1.9, 4.0)*	3.7 (1.7, 7.9)*
ABI	0.10 decrease	0.8 (0.6, 0.9)†	0.8 (0.6, 1.0)‡
Amplitude	≤4 mm/>4 mm	4.3 (1.7, 11.0)†	3.5 (1.0, 11.6)‡
Diabetes	Present/absent	2.3 (1.0, 5.1)†	2.7 (0.9, 8.1)§

*$p < 0.001$.
†$p < 0.01$.
‡$p < 0.05$.
§$p = 0.06$.

limbs with arterial disease. The association of the ankle pressure with rest pain, skin lesions, or both in the multivariate model in the subgroup with severe disease was not significant. Low pulse wave amplitude remained significantly associated with these clinical manifestations after controlling was done for toe pressure, ankle pressure, and diabetes with an odds ratio of 3.9 (1.6, 9.6; $p < 0.01$) in all limbs with arterial disease and 3.3 (1.0, 10.7; $p < 0.05$) in the subgroup with severe disease.

DISCUSSION

Technical considerations. Recording of digital pulse wave with photoplethysmography is a quick and easy technique that provides a semiquantitative method for assessment of digital perfusion. The significant correlation of the wave amplitude with toe temperature and the finding that body cooling resulted in a large and significant decrease in wave amplitude compared with body heating confirm previous experience that wave amplitude reflects skin perfusion.[14] Because temperature has an effect on the results, the protocol of warming the patient and the feet before obtaining routine laboratory measurements is important to eliminate as much as possible the potential effects of excessive vasoconstriction and to obtain reliable results. Although wave amplitude and distal systolic pressures vary with changes in the vasomotor state,[17] which cannot be completely controlled in routine laboratory testing, wave amplitude on repeated measurements remained less than or greater than 4 mm, the discriminant value used in this study, in 25 of 26 extremities with arterial disease (mean ABI 0.64 ± 0.05) when tested on different days within a 2-week period. Sensors must be applied carefully, because otherwise the recorded pulse waves may be altered, and wave records will also vary with the characteristics of the sensors and the recording equipment.

Clinical applications. Recording of digital pulse has been used to assist in clinical decision making[6] and was suggested as one of the tests in the assessment of limbs for critical ischemia in diabetic patients.[7] In this study the hemodynamic characteristics of the limbs of diabetic and nondiabetic patients with rest pain, skin lesions, or both did not differ significantly, but the proportion of limbs with these manifestations was significantly greater among the patients with diabetes. The presence of diabetes increased the odds ratio for rest pain, skin lesions, or both more than twice both in the univariate and the multivariate analysis after controlling was done for systolic pressures and wave amplitude. These results indicate that our findings on pressures and pulse waves apply both to the limbs of patients with and without diabetes and suggest that factors other than the severity of the hemodynamic impairment are responsible for the higher incidence of severe complications in patients with diabetes. These most likely include higher incidence of the initiating trauma in the diabetics because of the presence of neuropathy and increased susceptibility to infection.

This study demonstrates that low toe pulse wave amplitude is significantly related to the occurrence of rest pain, skin breakdown, or both after controlling is

done for the value of the toe pressure and ABI or ankle pressure. The odds for the presence of rest pain, skin lesions, or both associated with low pulse wave amplitude in the multivariate analysis increased more than three times both in all limbs with arterial disease and in those with severe disease manifested by toe pressure ≤30 mm Hg. Because the chances of spontaneous healing of skin lesions are uncertain in limbs with toe pressure ≤30 mm Hg,[3,12,13] our findings suggest that measurements of wave amplitude may help identify those with good prognosis for spontaneous healing among limbs with such low pressure.

A decrease in toe pressure increased significantly the odds for the presence of rest pain, skin lesions, or both in the univariate and multivariate analysis both in the group of all limbs with arterial disease and in those with severe disease. The decrease in ABI or in ankle pressure was associated with a modest increase in the odds for the presence of rest pain, skin lesions, or both in the univariate analysis in all limbs with arterial disease, but no significant effect was seen in the subgroup with severe disease. In the multivariate analysis the decrease in ABI or in the ankle pressure was actually associated with a modest but significant decrease in the occurrence of rest pain, skin lesions, or both while controlling was done for toe pressure, pulse wave amplitude, and diabetes. The latter finding might be related to the presence of some extremities with these manifestations and poor distal hemodynamics (low toe pressure and wave amplitude) but with high ankle pressure and ABI because of the presence of the obstruction primarily in the small distal vessels of the extremities or because the ankle pressures in some limbs might be falsely high because of undetected partial wall incompressibility.[20] The results of this study indicate that toe pressure shows a much stronger association with the presence of rest pain, skin lesions, or both than ABI or ankle pressure both in our sample of all limbs with arterial disease but especially in those with severe disease.

Previous studies demonstrated that spontaneous healing of skin lesions occurs in more than 90% of limbs with toe pressure greater than 30 mm Hg,[3,11,12] suggesting that critical ischemia is infrequent in limbs with such pressures. In this series rest pain, skin lesions, or both were present in approximately 50% of limbs with toe pressure ≤30 mm Hg, in 16% of those with pressure of 31 to 40 mm Hg, and in 5% of limbs with arterial disease and pressure greater than 40 mm Hg (Table III). The presence of some limbs in which there may be critical limb ischemia when toe pressure is greater than 30 mm Hg may be related in part to the variability of the pressure measurements.

The data in Table III also show that the subgroup with toe pressure ≤30 mm Hg and the subgroup with ankle pressure ≤60 mm Hg had similar proportions of limbs with rest pain, skin lesions, or both (50% and 47%, respectively). However, the subgroup with toe pressure ≤30 mm Hg made up 37% (107 of 287) of limbs with arterial disease and included 79% (53 of 67) of limbs with rest pain, skin lesions, or both compared with the subgroup with ankle pressure ≤60 mm Hg, which made up only 17% (47 of 269) of limbs with arterial disease and included 37% (22 of 59) of limbs with rest pain, skin lesions, or both. Thus these toe and ankle pressure cutoff values have similar positive predictive value for rest pain, skin lesions, or both, but toe pressure identifies a larger proportion of limbs with these manifestations than ankle pressure and has a higher sensitivity.

The prognosis to life and limb in patients who have rest pain, skin lesions, or both and toe pressure less than 30 mm Hg was reported to be considerably worse than in those without these manifestations despite the presence of severe obstruction manifested by such pressures.[13] Our data show that in the presence of severe arterial disease low pulse wave amplitude is associated with more than threefold increase in the odds for the presence of rest pain, skin lesions, or both after controlling is done for pressure values. This finding suggests that addition of the wave amplitude to the pressure measurements is likely to improve assessment for the presence of critical limb ischemia and might be useful in determining the prognosis to limb and life in patients with severe arterial disease. Follow-up studies of patient outcomes are needed to determine the potential prognostic value of the combined use of pulse wave and pressure measurements. We are in the process of monitoring our patients with severe disease. Preliminary results of the follow-up of these patients suggest that addition of the wave amplitude to the pressure measurements improves the prediction of prognosis and outcomes.

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