Angiographic Evaluation of Peripheral Arterial Occlusive Disease and Its Role as a Prognostic Determinant for Major Amputation in Diabetic Subjects With Foot Ulcers

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OBJECTIVE — To evaluate in diabetic patients with foot ulcers the angiographic findings of peripheral occlusive arterial disease and their role as a prognostic determinant for major amputation.

RESEARCH DESIGN AND METHODS — From 1993 to 1995, 104 diabetic inpatients with foot ulcers underwent arteriography on the ulcerated limb. Stenoses in the iliac trunk, the superficial femoral artery, the profunda femoral artery, the popliteal artery, the anterior tibial artery, the posterior tibial artery, and the peroneal artery were scored on the basis of vessel lumen reduction: 0 if stenoses involved a reduction in the vessel lumen of <50%, 1 if stenoses involved 50 to <75% reduction, 2 if stenoses involved 75 to <100% reduction, and 3 if total occlusion was present. The sum of the points assigned to each of these arteries was called the angiographic score.

RESULTS — Stenoses causing a vessel lumen reduction ≥50% were detected in 103 patients (99%). Stenoses were also detected in subjects with palpable foot pulses, ankle-brachial indexes ≥1, or transcutaneous oxygen tension ≥50 mmHg. The risk of major amputation was increased significantly when total occlusion was present in the popliteal and infrapopliteal arteries (χ^2 for trend = 50.57, $P < 0.001$). No major amputation was carried out in patients with angiographic scores <10; major amputation was carried out in all the patients with scores >14. Multivariate analysis indicated a high angiographic score as an independent risk factor for major amputation (odds ratio 2.32, $P = 0.001$, CI 1.40–3.84).

CONCLUSIONS — Angiography permits an exact detection of occlusive arterial disease in subjects with normal results for noninvasive vascular procedures. A score that has a relevant prognostic value for major amputation can be obtained from the evaluation of the extent and diffusion of the stenoses.

Various factors may influence the outcome of foot ulcers in diabetic subjects, but the severity of lower-extremity arterial disease is the main independent risk factor for major amputation (1). Many studies have used noninvasive methods to assess peripheral arterial disease (2,3), but few studies (4) have used angiography in case histories exclusively involving diabetic subjects with foot ulcers. Available angiographic data have mostly been acquired from heterogeneous groups of diabetic subjects with critical limb ischemia with or without foot ulcers (5) or subjects selected for vascular procedures (6). The prognostic value for major amputation has also been investigated for the results of noninvasive vascular laboratory procedures (7,8) but not for those of angiographic evaluation. The aim of this study is to evaluate the angiographic picture of arterial occlusive disease in diabetic subjects with severe foot ulcers and the value of angiographic findings as a prognostic determinant for major amputation.

RESEARCH DESIGN AND METHODS

— From 1993 to 1995, 121 diabetic subjects were consecutively admitted to the hospital in our Diabetology Center for foot ulceration. On admission to the hospital, lesions were classified according to Wagner (9). In our clinical practice, diabetic subjects with full-thickness gangrene (Wagner grade 4) or abscess (Wagner grade 3) were admitted to the hospital. Subjects with less deep ulceration (Wagner grade 2) were also admitted if the ulcer was large and infected and showed defective healing in a month of outpatient therapy. In all subjects without a contraindication, digital subtraction angiography (DSA) of the subaortic vessels was carried out. Contraindications for DSA were creatinine values >221 μmol/l or the presence of the m-component of hypergammaglobulinemia. Because of the risk of nephrotoxicity from contrast material, the day before and the day of the test a protocol including adequate hydration and the administration of mannitol and furosemide was carried out based on the cardiac ejection fraction and creatinine and plasmatic electrolytes. Creatinine, blood urea nitrogen, plasmatic electrolytes, and albumin excretion rate were monitored. Arteriograms were performed by means of a biplanar method using a transfemoral

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Abbreviations: ABI, ankle-brachial index; BPG, peripheral bypass graft; DSA, digital subtraction angiography; PTA, percutaneous transluminal balloon angioplasty; $TcPO_2$, transcutaneous oxygen tension.

approach. Stenoses causing a vessel lumen reduction of ≥50% were considered hemodynamically significant. The angiographic study took into consideration in the ulcerated limb the iliac trunk and common femoral artery, the superficial femoral artery, the profunda femoral artery, the popliteal artery, the anterior tibial artery, the posterior tibial artery, and the peroneal artery. Stenoses in these seven segments were scored on the basis of vessel lumen reduction: 0 if stenoses involved a vessel lumen reduction of <50%, 1 if stenoses involved 50 to <75% reduction, 2 if stenoses involved 75 to <100% reduction, and 3 if total occlusion was present. In the case of multiple stenoses in the same segment, only the stenosis with the highest lumen reduction was scored. For each patient, an angiographic score derived from the sum of the points assigned to each of seven segments in the ulcerated limb was evaluated using a range from 0 to 21. The presence of hemodynamically significant stenoses in the proximal axis only (iliac trunk and femoral arteries), in the distal axis only (popliteal artery and its branches), or in both the axes was then evaluated. Each angiographic exam was evaluated according to the necessity and possibility of carrying out a percutaneous transluminal balloon angioplasty (PTA) or a peripheral bypass graft (BPG). The presence of focal stenoses involving >50% of vessel lumen was considered an indication of PTA. Stenoses completely occluding the lumen or with length >10 cm were considered an impossibility or a contraindication for PTA, respectively. When there was an impossibility of performing PTA, the arteriogram was evaluated by vascular surgeons to carry out a BPG. Based on angiographic criteria, bypasses were performed when a patent vessel in continuity with the foot was present. Each patient undergoing DSA, PTA, or BPG gave his informed consent.

All patients were examined for diabetic retinopathy (fundus oculi by ophthalmologist), albumin excretion rate (milligrams per 24 h, the average of three 24-h collections [nephelometry]), renal impairment (creatinine >133 μmol/l), arterial hypertension (systolic blood pressure >160 mmHg and/or diastolic blood pressure >95 mmHg or antihypertensive therapy), obesity (BMI >24 for women and >25 for men), and dyslipidemia (total cholesterol >6.20 mmol/l [colorimetry] and/or HDL cholesterol <0.90 mmol/l for men and <1.16 mmol/l for women [Polyethylene Glycol 6000] and/or triglycerides >2.25 mmol/l [colorimetry] or hypolipidemic therapy). Sensorimotor neuropathy (10) was investigated with electromyography in all subjects (considered present when showing abnormalities of nerve conduction velocity and sensory action potential in at least two nerves). Autonomic neuropathy (11) (present if the score was >4 in the five standard autonomic cardiovascular tests) and vibration sense (12) (impaired if the vibration perception threshold measured on the malleoulus with a biothesiometer was >25 V) were investigated when technically possible in collaborative patients. Diabetic neuropathy was considered present when at least one of the described tests was abnormal. Specimens of the foot lesion, after decontamination and debridement followed by curettage, were collected for aerobic and anaerobic culture and for antimicrobial susceptibility testing for antibiotics. X-rays were taken of both feet and legs to discover arterial media calcifications and bone abnormalities. In the ulcerated limb, the transcutaneous oxygen tension ($TcPo_2$) (normal value: ≥50 mmHg) on the dorsum of the foot and the ankle-brachial index (ABI) (i.e., the ankle-brachial blood pressure ratio measured by continuous wave Doppler technique) (normal value: ≥1) were measured. During these tests, foot pulses—tibial posterior and dorsalis pedis pulses—were recorded as either palpable or not using a dichotomous classification.

An aggressive and radical debridement was performed: abscesses were immediately incised and drained, necrotic and nonviable tissue was removed, and toe amputation and ray resection were carried out when required to reach the viable tissue. After surgical curettage, the wound was cleaned with uncolored antiseptic and wadded with wet or dry gauze or covered with occlusive dressing. On admission to the hospital and after collection of a specimen of the ulcer for culture examination, all patients were given broad-spectrum antibiotic therapy. Initial empirical antibiotic therapy was modified according to susceptibility testing results as necessary. The antibiotic therapy was continued during the hospital stay until the culture examination, repeated each week, was negative. After discontinuation of antibiotic therapy, reculturing to assess the cure was performed three times every 2 days. An optimized metabolic control was pursued either through subcutaneous insulin administrations or oral hypoglycemic agents seven times a day according to blood glucose determinations. For blood glucose levels >22 mmol/l, a procedure of intravenous insulin infusion was administrated, according to an algorithm based on the assessment of blood glucose levels every 2 h, until blood glucose values of <9.9 mmol/l were reached. On admission and discharge, HbA_{1c} levels (determined through high-performance liquid chromatography; normal values: 4.4–6.0%) were measured.

Table 1—*Clinical characteristics of patients with diabetic foot ulcer undergoing peripheral angiographic evaluation*

n	104
Men	75 (72.1)
Women	29 (27.9)
Age (years)	64 ± 10
Diabetes duration (years)	18 ± 9
Insulin therapy	64 (61.5)
Oral therapy	40 (38.5)
Total hospital stay (days)	54 ± 29
HbA_{1c} at admission (% Hb)	8.9 ± 2.2
HbA_{1c} at discharge (% Hb)	6.9 ± 1.4
Glycemia at admission (mmol/l)	18.2 ± 7.4
Glycemia at discharge (mmol/l)	7.8 ± 2.4
Wagner grade	
2	14 (13.5)
3	31 (29.8)
4	59 (56.7)
Prior major amputation	3 (2.9)
Prior lesion	28 (26.9)
Neuropathy*	90 (86.5)
Retinopathy	76 (73.1)
Microalbuminuria†	24 (23)
Proteinuria‡	19 (18.3)
Renal impairment§	18 (17.3)
Hypertension‖	55 (52.9)
Hyperlipidemia¶	30 (28.8)
Obesity#	32 (30.8)
Smoking habit	33 (31.7)
Infection	96 (92.3)
Infection recovery	76 (73.1)
Arterial media calcification	69 (66.3)

Data are *n* (%) or means ± SD. *Abnormalities in at least one nerve at electromyography and/or equal to score >4 at five standard cardiovascular tests and/or vibration perception threshold >25 V at biothesiometry. †Albumin excretion rate 20 to <200 mg/24 h. ‡Albumin excretion rate >200 mg/24 h. §Creatinine value ≥133 μmol/l. ‖According to World Health Organization criteria or antihypertensive treatment. ¶Total cholesterol >6.20 mmol/l and/or HDL cholesterol <0.90 mmol/l for men and <1.16 mmol/l for women and/or triglycerides >2.26 mmol/l and/or hypolipidemic treatment. #BMI >24 for women and >25 for men.

Table 2—*Results of noninvasive vascular laboratory procedures for patients with diabetic foot ulcers undergoing peripheral angiographic evaluation*

Intermittent claudication	27 (25.9)
Palpable foot pulses	24 (23.1)
ABI*	0.6 ± 0.2
ABI ≥1	17 (16.3)
$TcPO_2$† (mmHg)	28 ± 14
$TcPO_2$ ≥50 mmHg	8 (7.7)

Data are *n* (%) or means ± SD. *ABI is the ankle-brachial blood pressure ratio measured with the Doppler technique. †$TcPO_2$ on the dorsum of the foot.

Statistical analysis

Univariate summary statistics were calculated for all the data collected (13). For the continuous variables, the mean values (±1 SD) were computed, and for the discrete variables, percentages of occurrences were counted. For the ABI and $TcPO_2$ variables, the values are reported both in continuous and in discrete scale (cut point: ABI ≥1, $TcPO_2$ ≥50 mmHg). For comparison of the angiographic score before and after the interventions, the paired Student's *t* test was used. The difference in the major amputation rate in different groups with increasing numbers of total occlusion were tested for trends by the χ^2 test. Major amputation (above the ankle) was considered the response variable, assuming the value 1 when a major amputation was carried out and 0 when it was not. Correlation between major amputation and the characteristics of the studied population was tested using univariate logistic regression. A *P* value of 0.05 was considered sufficient to reject the null hypothesis. The same analysis was carried out with multivariate logistic regression and stepwise selection of independent variables to elucidate the independent factors associated with major amputation (14). For dichotomous independent variables, the constants estimated by the model are the log odds ratio for major amputation in the classes identified by the variables. For continuous independent variables, the odds ratio expresses the increment of risk for major amputation per unit increase of age and diabetes duration and per decrease in the values for ABI (0.1 U) and $TcPO_2$ (1 mmHg). Goodness-of-fit was computed with the Hosmer-Lemeshow test.

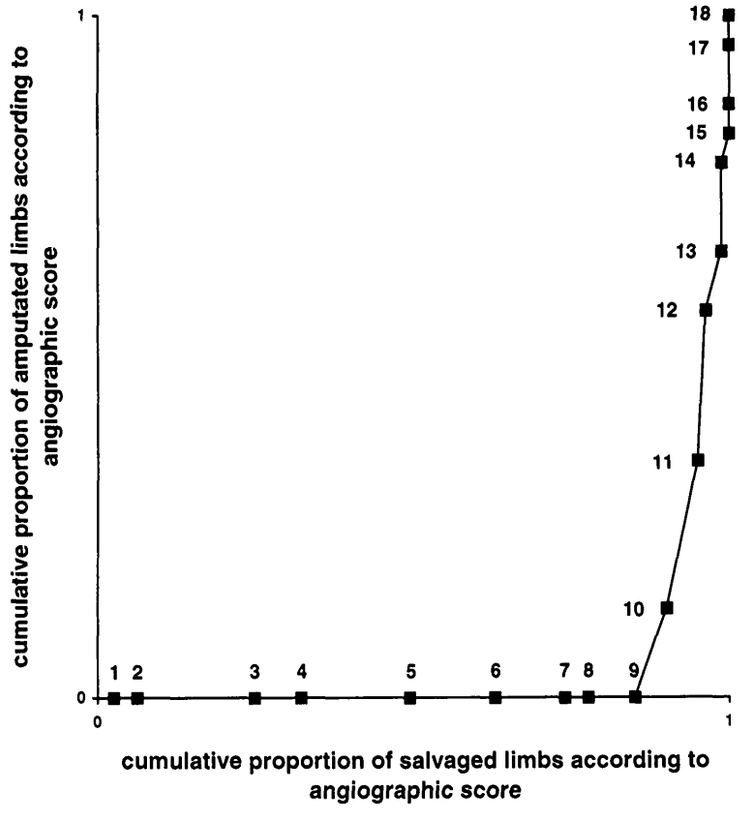

Figure 1—*Relationship between the angiographic score and major amputation in the study population (n = 104). The angiographic score was obtained from the sum of the score of each of seven segments of peripheral vascular tree of ulcerated limb according to the following scheme: 0 if stenoses were absent or involved <50% of the vessel lumen, 1 if stenoses involved 50 to <75% of the vessel lumen, 2 if stenoses involved 75 to <100% of the vessel lumen, and 3 if total occlusion was present. The score range is 0–21.*

RESULTS — From 1993 to 1995, 121 diabetic subjects were consecutively admitted to our diabetologic unit for foot ulceration. In 104 subjects out of 121 (86.0%), DSA was carried out. Seventeen subjects did not undergo DSA: two because of refusal, four because of presence of the m-component of hypergammaglobulinemia, and eleven because of creatinine >221 μmol/l. There were no adverse reactions or deterioration of blood-urea nitrogen, creatinine, and albumin excretion rate in any of the patients (data not shown). The clinical data for the study population are detailed in Table 1. Results of the noninvasive vascular laboratory procedures are shown in Table 2. Stenoses involving ≥50% of the vessel lumen were found in 103 (99%) of the 104 subjects undergoing DSA. In 9 subjects (8.7%), stenoses were present in the iliofemoral axis only; in 51 subjects (49.5%), they were present in the popliteal and infrapopliteal axis only; and in 43 subjects (41.7%), stenoses were present in both axes. Stenoses were detected in 23 of 24 subjects with palpable foot pulses: 13 subjects had one stenosis, 10 subjects had two stenoses. Stenoses have been detected in 16 of 17 subjects with ABI ≥1: 10 subjects had one stenosis, and 6 subjects had two stenoses. Of eight subjects with a $TcPO_2$ value ≥50 mmHg, DSA showed one stenosis in two subjects and two stenoses in five subjects.

The major amputation rate in relation to the angiographic score is reported in Fig. 1. In Table 3, healing rate without amputation, with minor amputation, and with major amputation and the angiographic score are reported. No major amputation was performed in subjects with palpable foot pulses, ABI ≥1, or $TcPO_2$ ≥50 mmHg. Of 104 subjects, 38 (36.5%) underwent vascular procedures: 26 underwent PTA and 12 BPG. Of the PTAs, 8 were performed in the iliofemoral axis and 18 in the popliteal or infrapopliteal axis. Angiographic evaluation proved that PTA was technically effective in 22 subjects (84.6%) and ineffective in 4 subjects (15.4%). These four subjects underwent a major amputation. One PTA was carried out on a subject

Table 3—*Healing rate without amputation, with minor amputation, or with major amputation and angiographic score of the study population* (n = 104)

Outcome	Patients	Angiographic score	*P*
No amputation	35 (33.7)	5.02 ± 3.08	—
Toe (*n* = 35) or forefoot (*n* = 11) amputation	46 (44.2)	6.71 ± 2.81	0.02*
Major amputation	23 (22.1)	13.00 ± 2.37	<0.001†

Data are *n* (%) or means ± SD. **P* versus no amputation. †*P* versus no amputation and toe or forefoot amputation. Angiographic scores were obtained from the sum of the score for each vessel of the ulcerated limb according to the following scheme: 0 if stenoses were absent or involved <50% of the vessel lumen, 1 if stenoses involved 50 to <75% of the vessel lumen, 2 if stenoses involved 75 to <100% of the vessel lumen, and 3 if total occlusion was present.

with palpable pulses and ABI = 1, one on a subject with palpable pulses and ABI <1, and three in subjects without palpable pulses and ABI ≥1. In all of these subjects, $TcPO_2$ was >30 to <50 mmHg. Furthermore, PTA was effective in all of these subjects, and a major amputation was not performed in any of them. Of the 12 BPGs, six were femoralpopliteal and six pedal. No BPG was performed on subjects with palpable pulses, ABI ≥1, or $TcPO_2$ ≥50 mmHg. Of the 12 subjects who underwent BPG, major amputation was carried out in 3 (25%): one for hemorrhage of the graft, one for necrosis of dorsal foot wound, and one for vein graft thrombosis. In subjects undergoing PTA successfully, the angiographic score was 6.0 ± 2.2 before PTA and 3.5 ± 2.2 after PTA ($P < 0.001$). In subjects undergoing BPG successfully and considering the stenoses of the bypassed arteries annulled, the angiographic score was 9 ± 2.60 before BPG and 5.22 ± 2.33 after BPG ($P < 0.001$). In Table 4, the trend for major amputation according to presence of total occlusion in the popliteal and infrapopliteal arteries is reported. In Table 5, results of the univariate analysis are shown. Results of the multivariate analysis carried out on the variables found associated with major amputation in the univariate analysis are shown in Table 6. The goodness-of-fit of the proposed model, computed by the Hosmer-Lemeshow test, is $\chi^2 = 42.96$, with 83 degrees of freedom and $P = 0.999$.

CONCLUSIONS — In diabetic patients, the most significant occlusive lesions occur in the popliteal and infrapopliteal arteries (15,16). In our study, which involved only subjects with foot ulcers, these data were particularly evident: nearly half of our patients had stenoses in the popliteal and infrapopliteal axis only. In our opinion, the most interesting data is the very high rate of occlusive arterial disease: only 1 of 104 subjects did not have hemodynamically significant stenoses. Our study was made up only of inpatients with ulcers of severe grade, and the assessment of the ischemia was based on angiographic study. One could conclude that in diabetic subjects, when the ulcer grade is severe and the assessment of ischemia is based on angiography, peripheral occlusive arterial disease is the most common finding. Because neuropathy also is very common (90 subjects, 86.5%) under these conditions, the prevalent clinical picture is the neuroischemic foot. Therefore the assessment of peripheral ischemia requires some special consideration in diabetic people (17). The absence of symptoms of ischemia does not exclude this diagnosis: diabetic neuropathy can prevent the sensation of exercise or rest ischemic pain in the legs. Of the 103 subjects of our study population in whom DSA had detected hemodynamically significant stenoses, ischemic pain was present in only 27 subjects (26.2%), and in 76 subjects (73.8%) this pain was completely absent. Stenoses ≥50% of vessel lumen were also detected in subjects with normal ABIs or reassuring values of $TcPO_2$. These results are not surprising: it is common knowledge that the Doppler-derived ABI can be unreliable because of arterial media calcification (18), and that the transcutaneous oximetry values may be influenced by various systemic and local factors (e.g., blood oxygenation, thickness of the skin, and the presence of inflammation or local edema) (19). These conditions are particularly frequent in diabetic subjects with foot ulcers (3). One of the limits of our study was that we did not evaluate the duplex scanning that is considered by some to be as effective as angiography (20). However, the arterial media calcification can give confounding findings even when this method is used (21). The accuracy of duplex scanning is very high in the aortofemoral segment but lower in the distal arteries (22). This seems to be a particularly important limit in diabetic subjects with foot ulcers, in whom stenoses are prevalently distal and, in many cases, exclusively distal.

In our study, even the presence of palpable foot pulses did not exclude occlusive arterial disease. This finding has been described by other authors as well (23,24). Our data confirm these reports and show that even the absence of intermittent claudication or ischemic pain, a normal ABI, and a reassuring $TcPO_2$ value do not exclude the presence of an arterial occlusive disease. Angiography draws attention to occlusive arterial disease that is not detectable with noninvasive laboratory procedures. If angiography had not carried out, they could have been considered to have neuropathic foot. On the basis of the angiography, however, they were considered to have neuroischemic foot. It is true that this classification is irrelevant as far as major amputation is concerned. A major amputation was not performed in any of the subjects with normal results for noninvasive vascular procedures. It is also true that in these subjects, we were able to administer medication for the arterial disease, some PTAs, and an accurate follow-up. We believe that all of these are useful for slowing down the progression of arterial disease (25) and that this fact is particularly meaningful in diabetic subjects with foot ulcers (26,27). Alarm (28) concerning an adverse reaction in regard to renal func-

Table 4—*Trend for major amputation according to presence of total occlusion in popliteal and infrapopliteal arteries*

Number of arteries with total occlusion	Cases	Number amputated
One	28	1 (3.57)
Two	11	6 (54.54)
Three	10	10 (100.00)
Four	6	5 (83.33)

Data are *n* or *n* (%). χ^2 for trend = 50.57. $P < 0.001$.

Table 5—*Association between major amputation and characteristics of study population* (n = *104*)

Variable	*P* value	Odds ratio	CI
Sex	0.405	—	—
Age	0.001	1.09	1.03–1.15
Diabetes duration	0.073	—	—
Insulin therapy	0.130	—	—
Oral therapy	0.126	—	—
HbA_{1c} at admission (% Hb)	0.943	—	—
HbA_{1c} at discharge (% Hb)	0.458	—	—
Glycemia at admission	0.893	—	—
Glycemia at discharge	0.428	—	—
Wagner grade	0.014	3.23	1.29–8.22
Prior major amputation	0.004	2.48	1.40–4.60
Prior lesion	0.047	1.10	1.01–7.15
Neuropathy*	0.103	—	—
Retinopathy	0.753	—	—
Microalbuminuria†	0.809	—	—
Proteinuria‡	0.760	—	—
Renal impairment§	0.047	3.40	1.02–11.37
Hypertension‖	0.938	—	—
Hyperlipidemia¶	0.150	—	—
Obesity#	0.149	—	—
Smoking habit	0.193	—	—
Infection	0.995	—	—
Infection recovery	0.016	2.35	1.17–4.69
Arterial media calcification	0.013	3.69	1.31–10.40
Intermittent claudication	0.602	—	—
Palpable foot pulses	0.003	**	**
ABI††	0.000	2.40	1.61–3.55
$TcPo_2$ (mmHg)	0.002	1.06	1.02–1.11
Angiographic score‡‡	0.000	2.24	1.55–3.25

*Abnormalities in at least one nerve at electromyography and/or equal to score >4 at five standard cardiovascular tests and/or vibration perception threshold >25 V at biothesiometry. †Albumin excretion rate 20 to <200 mg/24 h. ‡Albumin excretion rate >200 mg/24 h. §Creatinine value ≥133 μmol/l. ‖According to World Health Organization criteria or antihypertensive treatment. ¶Total cholesterol >6.20 mmol/l and/or HDL cholesterol <0.90 mmol/l for men and <1.16 mmol/l for women and/or triglycerides >2.26 mmol/l and/or hypolipidemic treatment. #BMI >24 for women and >25 for men. **None of these subjects has had a limb amputated. ††ABI is the ankle-brachial blood pressure ratio measured with the Doppler technique. ‡‡Angiographic scores were obtained from the sum of the score of each vessel of ulcerated limb according to the following scheme: 0 if stenoses were absent or involved <50% of the vessel lumen, 1 if stenoses involved 50 to <75% of the vessel lumen, 2 if stenoses involved 75 to <100% of the vessel lumen, and 3 if total occlusion was present.

Table 6—*Multivariate analysis of the association between major amputation and variables significantly associated in the univariate analysis*

Variables	*P* value	Odds ratio	CI
Angiographic score	0.001	2.32	1.40–3.84
ABI	0.019	1.84	1.10–3.06
Prior amputation	0.035	2.69	1.07–6.77

ABI is the ankle-brachial blood pressure ratio measured with the Doppler technique. Angiographic scores were obtained from the sum of the score of each vessel of the ulcerated limb according to the following scheme: 0 if stenoses were absent or involved <50% of the vessel lumen, 1 if stenoses involved 50 to <75% of the vessel lumen, 2 if stenoses involved 75 to <100% of the vessel lumen, and 3 if total occlusion was present.

tion (29) has probably limited the use of angiography. Our study also demonstrates that by using adequate precautions (30), this diagnostic procedure does not attack renal function. On the basis of our data, we believe that ulcer grade—Wagner grade 2 with defective healing over a month of outpatient treatment and Wagner grade >2—can be an indication for angiographic study in diabetic patients with foot ulcers.

The angiographic evaluation can also provide prognostic information. By assigning to the stenoses found through angiography a score that takes into consideration their extent (percentage of vessel lumen reduction) and diffusion (involved segments of vascular tree), it is possible to obtain a numerical index, our angiographic score, that evaluates the severity of the peripheral occlusive arterial disease and its prognostic value. Multivariate analysis has indicated the angiographic score to be an independent variable associated with major amputation. In clinical practice, this score could give a useful indication of whether the ulcer will heal with or without major amputation. In our study, no patient with a score <10 underwent a major amputation, and all patients with a score >14 underwent a major amputation. There is also a statistically significant difference in angiographic score between subjects healed with or without a minor amputation. Nevertheless, the overlapping between the two groups does not allow the indication of precise cutoffs. The evaluation of the extent of the stenoses in the popliteal and infrapopliteal arteries is particularly important: when there is a total occlusion of >2 of each of the arteries, the probability of major amputation is very high.

It is remarkable that all of this diagnostic and prognostic information was derived from a procedure that is highly reliable in diabetic subjects despite the distal pattern of occlusive arterial disease and the presence of local and vascular abnormalities caused by ulcer and diabetes.

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