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Value of Duplex Scanning in Evaluation of Crural and Foot Arteries in Limbs with Severe Lower Limb Ischaemia — A Prospective Comparison with Angiography*

S. Karacagil†[1], A.M. Löfberg[2], A. Granbo[3], L.E. Lörelius[2], D. Bergqvist[1]

Departments of [1]Surgery, [2]Diagnostic Radiology and [3]Clinical Physiology, University Hospital, Uppsala, Sweden

Objectives: *To compare Duplex scanning with angiography for evaluation of crural and pedal arteries in limbs with lower limb ischaemia.*
Design: *The findings obtained during Duplex scanning and angiography were prospectively compared in a blinded manner.*
Setting: *Departments of Surgery, Diagnostic Radiology and Clinical Physiology, University Hospital.*
Materials: *Duplex scanning and selective angiography of femoropopliteal, crural and foot arteries were performed in 40 limbs (38 patients, 480 segments) with intermittent claudication (n = 6), rest pain (n = 13) and ulcer/gangrene (n = 19). Each arterial segment were graded into four categories: normal, ≤ 50% diameter reduction, > 50% diameter reduction and occlusion. Pedal arteries were evaluated as patency or occlusion of dorsal pedal artery and plantar arch. Chief outcome measures: Accuracy (AC), sensitivity (SE), specificity (SP), positive predictive (PPV), negative predictive (NPV) and kappa values.*
Main results: *The Duplex scanning of the tibioperoneal trunk, crural and pedal arteries had an accuracy of 80% (kappa = 0.6). The SE, SP, PPV and NPV values were 83%, 77%, 79% and 81%, respectively. The SP was relatively low for the peroneal artery (58%) compared to the others.*
Conclusions: *The results demonstrate the feasibility and reliability of Duplex scanning in detecting crural and pedal artery lesions in lower limbs with severe ischaemia.*

Introduction

Duplex scanning of the aortoiliac and femoropopliteal arteries in patients with atherosclerotic occlusive disease has been proved to be a reliable non-invasive diagnostic modality.[1–3] It is possible to distinguish significant stenoses and occlusions from non-significant atherosclerotic changes which in turn provides clinically relevant information to formulate optimal treatment strategy. The application of this method for crural and especially for foot arteries has not been studied extensively.[2] The aim of this prospective study was to compare Duplex scanning with selective femoral angiography for evaluation of crural and pedal arteries in limbs with severe lower limb ischaemia.

Material and Methods

Duplex scanning and selective angiography of femoropopliteal, crural and foot arteries were performed in 40 limbs (38 patients) with intermittent claudiation ($n = 6$), rest pain ($n = 13$) and ulcer/gangrene ($n = 19$). There were 17 men and 21 women with a mean age of 71 years (range 43–87). Seventeen were diabetics, 14 had hypertension, 20 had coronary artery disease and 10 were smokers. Ten patients, of whom eight were diabetics, had falsely elevated ankle pressures (> 200 mm Hg). In the remaining 30 limbs, mean ankle pressure was 70 mm Hg (S.E. = 6 range 30–100). The mean ankle-brachial pressure index was 0.32 (S.E. = 0.037 range 0–0.6). All patients underwent angiography within 2 weeks after Duplex scanning.

Duplex scanning was performed using an Acuson 128 XP model with a 5 Mhz linear array probe (Acuson, Mountainview, CA, U.S.A.). Duplex studies were performed with the patient in supine position, starting from the infrarenal aorta. The popliteal and tibioperoneal segments were studied with the knee

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†Please address all correspondence to: Sadettin Karacagil, Department of Surgery, University Hospital, S-751 85, Uppsala, Sweden.

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slightly flexed. In some patients the popliteal artery and the tibioperoneal trunk were examined with subjects in prone position. Each arterial segment was examined over its entire length searching for colour changes which suggest the presence of an arterial lesion. Peak systolic velocities (PSV) from these areas were compared with the normal segment immediately proximal to the stenosis. In brief, a focal increase of PSV greater than 100% of that in the normal segment was considered as indicative of a 50% or greater stenosis when the Doppler angle was $\leq 60°$.[4] Each of the three crural arteries was evaluated at three positions (proximal, mid and distal). This means a total of 480 segments (tibioperoneal trunk, 40 segments; proximal, mid and distal crural arteries, 360 segments; dorsal pedal, 40 segments and plantar arch, 40 segments) to be compared with angiography. Crural artery lesions were graded into four categories: normal, $\leq 50\%$ diameter reduction, $> 50\%$ diameter reduction (significant stenosis) and occlusion. If the arterial segment demonstrated both stenosis and occlusion, it was considered as occluded. The foot vessel anatomy was evaluated with regard to the anterior and posterior foot arches.[5,6] Visualisation of the dorsal pedal artery from its origin at the ankle level to the deep plantar artery was defined as patent. Segmental occlusion or non-visualisation of this artery was classified as occluded. The plantar arch is composed of the lateral and medial plantar arteries. Plantar arch was categorised as patent if at least one of these arteries was patent from the origin to at least 5 cm distally. No attempt was made to differentiate between medial and lateral plantar arteries. A complete Duplex scanning of the affected leg required approximately 45 min (30–60 min) and all examinations were performed by AG or SK, who have at least 3 years experience with Duplex scanning.

Selective femoral angiography was performed either with antegrade puncture of the femoral artery in 21 or with a cross-over technique from the contralateral side in 19 cases. Standard uniplanar digital subtraction angiography was performed and oblique views were obtained at the discretion of the radiologist. The foot films were obtained with a lateral view. From the angiograms the percentage diameter reduction was calculated by dividing the diameter of the residual lumen by the diameter of the "normal" artery proximal to the stenosis. Duplex scans and angiographic results were evaluated in a blinded manner.

Accuracy (AC), sensitivity (SE), specificity (SP), positive predictive value (PPV), negative predictive value (NPV) and kappa values were calculated from two-way contingency tables. Kappa statistic is a method to relate the found agreement between Duplex scanning and angiography to the proportion of agreement expected by chance. A kappa value of 1.0 means a perfect correlation whereas 0 means a total lack of correlation.[7]

Results

Among 19 angiographies where information on iliac segments were available, only two demonstrated significant angiographic stenosis which correlated well with Duplex scanning.

Four normal femoral or popliteal segments (one distal femoral, two above-knee popliteal and one below-knee popliteal) on angiography could not be visualised with Duplex scanning. Thirty-three limbs demonstrated significant stenosis or occlusion of the common femoral or superficial femoral arteries on angiography. Duplex scanning underestimated significant stenosis or occlusion of femoral and/or popliteal arteries in four cases. Among the 33 limbs with femoral artery lesions, there was occlusion of the popliteal artery over its entire length in eight and segmental occlusion or significant stenosis in nine on angiography. Four of these 17 lesions with greater than 50% stenosis on angiography were misdiagnosed by Duplex scanning as occlusion in two and as normal or nonsignificant stenosis in two cases. Three limbs with patent femoral artery and segmental occlusion or significant stenosis of the popliteal artery were correctly diagnosed by Duplex scanning.

Among 480 infrapopliteal segments (tibioperoneal trunk, proximal, mid, distal crural arteries, dorsal pedal and plantar arch), it was possible to obtain satisfactory visualisation and velocity signals in 465 (97%). The overall correlation between angiography and Duplex scanning for crural and foot arteries is presented in Table 1. Among those 44 normal segments on angiography which were diagnosed as occluded with Duplex scanning, 21 were at the peroneal artery. Twenty-five occlusions which were

Table 1. Two way contingency table for comparing results of Duplex scanning and angiography of the crural and pedal arteries

Angiography (stenosis %)	Duplex (stenosis %)			
	Normal	≤ 50	>50	Occlusion
Normal	184	1	1	44
≤50	1	0	2	0
>50	7	1	6	0
Occlusion	27	1	6	199

Table 2. Duplex scanning *vs.* angiography

Segment	*n*	Accuracy (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Kappa
Poplitea/ below knee	40	88	79	92	85	83	0.76
TP trunk/crural/pedal	240	80	83	77	79	81	0.60
TP trunk/crural	180	80	83	76	78	80	0.59
TP trunk	40	80	71	87	80	80	0.62
Tibialis anterior	40	80	73	86	80	80	0.64
Tibialis posterior	40	80	84	76	84	74	0.61
Peroneal	40	76	93	58	71	89	0.57
Dorsalis pedis	40	88	85	89	79	92	0.71
Plantar arch	40	78	78	76	82	72	0.53
Pedal arteries	80	83	81	84	81	84	0.64
TP/crural/pedal (50% or occlusion)	200	83	86	80	82	84	0.66

The values were calculated according to the contingency table (Table 1). For the TP/crural/pedal (50% or occlusion) % stenosis was graded into two groups: normal or ≤50%; >50% or occlusion.

missed by Duplex scanning were mainly short segmental occlusions and mainly located at the crural level (four tibioperoneal trunk, nine anterior tibial, six posterior tibial and one peroneal segment). Among 71 proximal crural artery segments with significant stenosis or occlusion, 15 had a patent mid and 13 had also patent distal segments on angiography. Duplex scanning correctly diagnosed nine of the patent mid and eight of the patent distal segments. Seven crural arteries had proximal and mid occlusion but patent distal segments. Three of these patent distal segments could be visualised with Duplex scanning. The status of foot vessels in five of these seven limbs were correctly diagnosed with Duplex scanning.

The Duplex scanning of the tibioperoneal trunk, crural and pedal arteries had an accuracy of 80% with a kappa value of 0.6 (Table 2). The sensitivity, specificity, positive predictive and negative predictive values were 83%, 77%, 79% and 81%, respectively. The specificity was relatively low for the peroneal artery (58%) compared to anterior tibial (86%), posterior tibial (76%) and foot arteries (81%). The overall accuracy of Duplex scanning for detection of significant stenosis or occlusion of the crural and foot arteries was 83%, Kappa values for various segments varied between 0.53 and 0.71, with the highest value for dorsal pedal artery and the lowest for the peroneal artery and the plantar arch (Table 2).

Discussion

The rationale behind noninvasive vascular diagnosis with Duplex scanning is eventually to replace angiography which has been considered the "gold standard" for diagnosis of peripheral vascular disease. Angiography provides the necessary information for strategical planning for surgical treatment but, on the other hand, it is invasive and is not without complications. Satisfactory and reliable arterial mapping of the lower extremity with Duplex scanning might provide the necessary information for selection of patients for endovascular interventions or surgical reconstructions without the need for diagnostic angiography.

It has been demonstrated that Duplex scanning produces satisfactory agreement with angiography for the diagnosis of aortoiliac and femoropopliteal atherosclerotic lesions.[1,3] The experience with Duplex scanning for diagnosis of crural artery lesions is limited.[2] Duplex scanning for evaluation of pedal arteries has not been studied previously. The aim of the present study was to evaluate the feasibility and accuracy of Duplex scanning for assessment of crural and pedal arteries in a group of patients with severe lower limb ischaemia (85% with critical ischaemia).

The overall accuracy of cruropedal artery Duplex scanning in comparison with selective angiography in this study was 80% with a kappa value of 0.6. The accuracy of Duplex scanning was similar for the crural and pedal arteries. The relatively low specificity for the peroneal artery (58%) is probably due to difficulties in obtaining satisfactory visualisation of this artery which is located at a deeper plane. This study also demonstrates the feasibility of obtaining reliable evaluation of very distal run-off vessels such as dorsal pedal artery and plantar arch, especially in patients with severe lower limb ischaemia and low ankle pressures. The status of foot vessels as judged at intraoperative completion angiography has been suggested as an important prognostic factor for successful outcome of infrainguinal bypass grafting.[5,6] The noninvasive reliable assessment of foot run-off in the preoperative period offers valuable clinical information to plan strategy of surgical or endovascular intervention. One important research task is to evalu-

ate whether or not this information makes it possible to preoperatively identify patients with a low probability of successful limb salvage.

In conclusion, Duplex scanning of the crural and pedal arteries is feasible and produces satisfactory agreement with angiography in detecting significant lesions in limbs with severe atherosclerotic changes. Thus, these findings would indicate that with the limitations of Duplex scanning at some levels in mind, especially in distal crural segments with proximal and mid occlusion, distal arterial reconstructions would be possible without the need for a preoperative angiogram.

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