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Duplex Scanning as the Sole Preoperative Imaging Method for Infrainguinal Arterial Surgery

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Objective: *to evaluate preoperative duplex as the sole investigation prior to lower limb reconstruction.*
Design: *retrospective analysis.*
Material and methods: *between January 1995 and December 1999, 157 of 329 surgical interventions for chronic infrainguinal arterial or aneurysmal disease were performed without preoperative angiography.*
Results: *in patients undergoing femoral artery endarterectomy, the extent of the stenosis and the status of the distal deep femoral artery were correctly diagnosed with duplex scanning in all but one patient. Duplex scan findings in patients undergoing infrainguinal bypass procedures were in agreement with the findings obtained from on-table angiography in regard to the selection of optimal outflow anastomotic sites in 123 (98%). Duplex scanning correctly evaluated the status of runoff in 113 (90%). There were no significant differences in 30-day occlusion rate and patency at 12 months between reconstructions performed with and without preoperative angiography.*
Conclusion: *in patients with conclusive duplex scan findings there is no need to perform angiography prior to lower limb reconstruction.*

Key Words: Infrainguinal; Surgery; Duplex scanning.

Introduction

Although conventional angiography is still the traditional method for evaluation of inflow and outflow arteries prior to infrainguinal arterial reconstructions, it is associated with a low but significant local and systemic complication rate.[1] Recent experience with duplex scanning suggests that the accuracy of duplex scanning approaches that of angiography and provides, not only anatomic, but also haemodynamic information.[2–8] The aim of the present study was to evaluate preoperative duplex scanning as the sole preoperative diagnostic investigation prior to lower limb reconstruction.

Material and Methods

Patients

From January 1995 through December 1999, 329 surgical interventions were performed for treatment of chronic infrainguinal arterial occlusive ($n=321$) or aneurysmal ($n=8$) disease in our department. The initial decision whether to perform intervention was based on history, clinical investigation and ankle pressure measurements. Potential candidates for intervention underwent duplex scanning. During the study period, there were no strict guidelines for selection of patients for endovascular or surgical treatment, but limbs with stenotic or occlusive femoropopliteal lesions, less than 10 cm in length and patent distal popliteal and/or proximal crural arteries, were preferentially treated by percutaneous transluminal angioplasty (PTA). In limbs with femoropopliteal lesions, unsuitable for PTA, infrainguinal bypass grafting was the treatment of choice. No femorodistal bypass grafting was performed in limbs with claudication. Femoral artery endarterectomy was preferred to bypass grafting only in limbs with claudication, or rest pain, or minor tissue loss, having common femoral and/or deep femoral artery lesions with a patent popliteal artery.

The patient demographics, the type of reconstructions, and the indications for surgery are given in Tables 2 and 3. Critical limb ischaemia (CLI) was defined according to the SVS/ICSVS reporting standards, while limbs with rest pain and/or tissue loss

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Table 1. Surgical reconstructions performed without preoperative angiography during the study period (without angiography/ total) (%).

Reconstruction	Year					
	1995	1996	1997	1998	1999	Total
Endarterectomy	7/12 (58%)	10/17 (59%)	4/10 (40%)	5/9 (56%)	6/12 (50%)	32/60 (54%)
Popliteal bypass	13/28 (46%)	15/36 (42%)	23/33 (70%)	23/34 (68%)	17/28 (61%)	91/159 (57%)
Distal bypass	3/19 (16%)	10/26 (38%)	5/18 (28%)	11/29 (38%)	5/18 (28%)	34/110 (31%)

In total 157/329 reconstructions.

Table 2. Patient demographics.*

Clinical variables	Surgery without angiography ($n=157$)	Surgery with angiography ($n=172$)
Male/Female	1.12/1	1.24/1
Age years (median-range)	74 (14–91)	76 (52–87)
Diabetes mellitus	47 (30%)	58 (34%)
Hypertension	63 (40%)	50 (29%)
CAD	77 (49%)	73 (42%)
CVD	26 (17%)	34 (20%)
Smoking	71 (45%)	70 (41%)
Asymptomatic**	3 (1.9%)	7 (4%)
Claudication	24 (15%)	18 (10%)
Sub-CLI	50 (32%)	41 (24%)
CLI	80 (51%)	106 (62%)

* There were no significant differences between patients undergoing surgery, with and without angiography, with respect to the risk factors and the indications for surgery according to chi-squared test. CAD = Coronary artery disease; CVD = Cerebrovascular disease; Sub-CLI = Subcritical limb ischaemia; CLI = Critical limb ischaemia.
** Patients with popliteal aneurysm or popliteal entrapment syndrome.

Table 3. Type of surgical reconstructions.

Reconstructions	Surgery without angiography ($n=157$)	Surgery with angiography ($n=172$)
Type of reconstruction		
Endarterectomy	32 (20%)	28 (16%)
Popliteal bypass		
above knee	23 (15%)	17 (10%)
below knee	68 (43%)	55 (32%)
Cruropedal bypass	34 (22%)	72 (42%)*
Graft material/bypass grafting		
In-situ vein	45 (36%)	60 (42%)
Reversed vein	28 (22%)	35 (24%)
Vein-PTFE composite	18 (14%)	17 (12%)
PTFE	33 (26%)	32 (22%)
Dacron	1 (<1%)	0

PTFE = Polytetrafluoroethylene.
* 4 were pedal bypass procedures.

and either falsely elevated ankle pressures, or an ankle pressure index (ABPI) below 0.5 and ankle pressures above 40 mmHg, were considered as having subcritical ischaemia (sub-CLI).[9] Patients undergoing infrainguinal bypass graft revisions were not included in the present study.

Duplex scanning

Duplex scanning was performed using an Acuson 128 XP or Seqouia (Acuson, Mountainview, CA, U.S.A.) using 3 MHz (curved array), 4 MHz (vector), or 5 MHz (linear) probes. Patients were not asked to fast prior to the investigation. Examination of the aorta, iliac, femoral, popliteal, and crural arteries was performed with the patient supine. In some cases, the popliteal and the tibial arteries were studied with the patient prone. Each arterial segment was examined over its entire length, with B-mode and colour flow imaging, looking for colour changes indicating increased velocities at stenoses. Spectral Doppler waveforms were obtained from the aorta, common iliac, external iliac, common femoral, deep and superficial femoral, popliteal, and crural arteries, usually at the proximal, mid and distal segments of each artery. The status of dorsal pedal and plantar arteries were investigated routinely in patients scheduled for femoro-crural bypass grafting. The spectral Doppler criteria that were used to grade stenoses were based on the peak systolic velocity (PSV) ratio.[3,4] In summary, the PSV from the areas with colour changes were compared with the normal segment immediately proximal to the stenosis. In cases with proximal stenosis, distal segments were used for comparison. A focal PSV increase, greater than 150% of that normal segment, was considered as indicative of a 50% or greater stenosis, when the Doppler angle was less than or equal to 60°. The arterial segment was considered occluded, if it was clearly visualised by B-mode images, without any detectable Doppler signals (Fig. 1a). In infrapopliteal arteries with low velocity during systole and diastole, spectral Doppler registration and direction of the flow, in the associated veins, were used for the differentiation between patent veins and arteries (Fig. 1b, c). The localisation, and the length of stenoses or occlusions, was noted in detail. The results of the duplex scans were presented both in written and in schematic form. The investigations were interpreted as inconclusive if the artery could not be adequately visualised by B-mode images, or if pulsed Doppler samples could not be obtained with

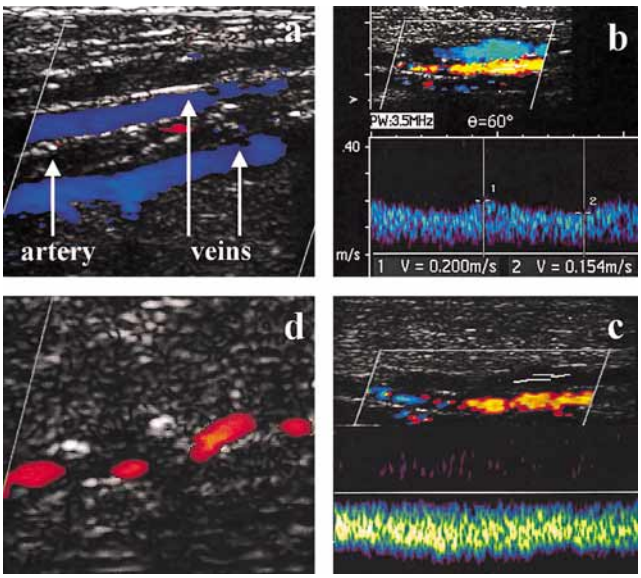

Fig. 1. (a) The posterior tibial artery is clearly visualised with B-mode images, and there is no colour flow visualisation in the artery, indicating occlusion. Note the colour flow imaging of the vein; (b) the posterior tibial artery and the vein are visualised simultaneously, at the distal calf, in a patient with femoro-popliteal occlusion. The spectral Doppler analysis in the artery resembles venous flow, with low peak systolic velocity and continuous forward flow in the diastole due to critical limb ischaemia; (c) the venous flow in the adjacent vein. This patient underwent bypass to the posterior tibial artery; (d) heavily calcified anterior tibial artery with interrupted colour flow.

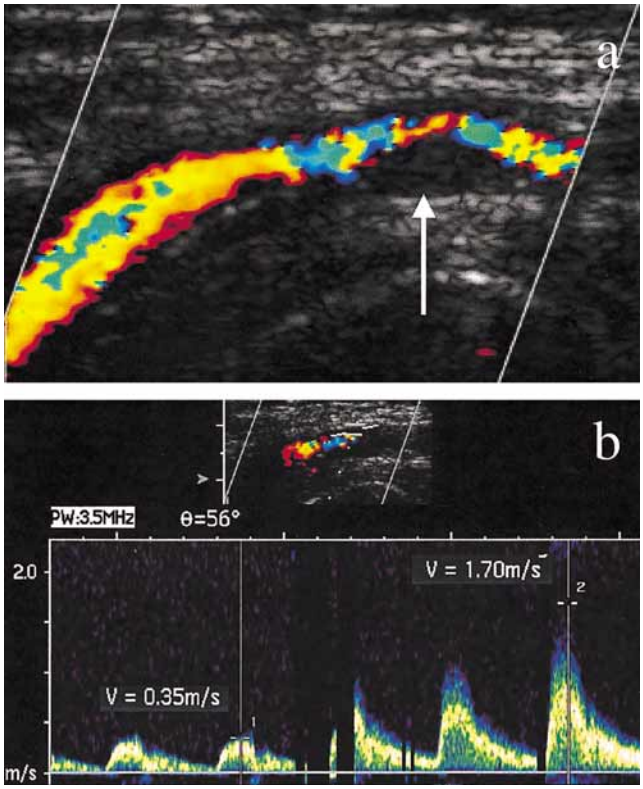

Fig. 2. (a) Colour flow imaging of the common femortal artery, indicating stenosis; (b) peak systolic velocity ratio 5.67 (1.7/0.3) signifying greater than 50% stenosis. The patient underwent common femoral artery endarterectomy.

an angle of insonation less than or equal to 60°. Interrupted colour flow visualisation of the heavily calcified crural arteries was also considered as inconclusive (Fig. 1d). Clearly visualised tortuous vessels, in the vicinity of crural arteries were interpreted as collaterals.

The prerequisite for performing femoral artery endarterectomy was the visualisation of the distal common or deep femoral artery distal to the lesion in limbs with uncompromised inflow to the groin (Fig. 2). The prerequisites for performing infrainguinal bypass grafting, without referring to preoperative angiography were: (1) visualisation of at least one crural artery, in continuity with the popliteal artery, in limbs with superficial femoral artery occlusion and (2) patency of the dorsal pedal and/or plantar artery, in continuity with at least one crural artery, in limbs with superficial femoral and popliteal artery occlusion (Fig. 3). Pedal bypass grafting was not performed without preoperative angiography despite conclusive scans. Duplex scanning was repeated the day before surgery in all patients, undergoing infrainguinal bypass grafting without preoperative angiography, and the site of the distal anastomosis was marked on the skin.

In patients undergoing infrainguinal bypass grafting, without preoperative angiography, the status of

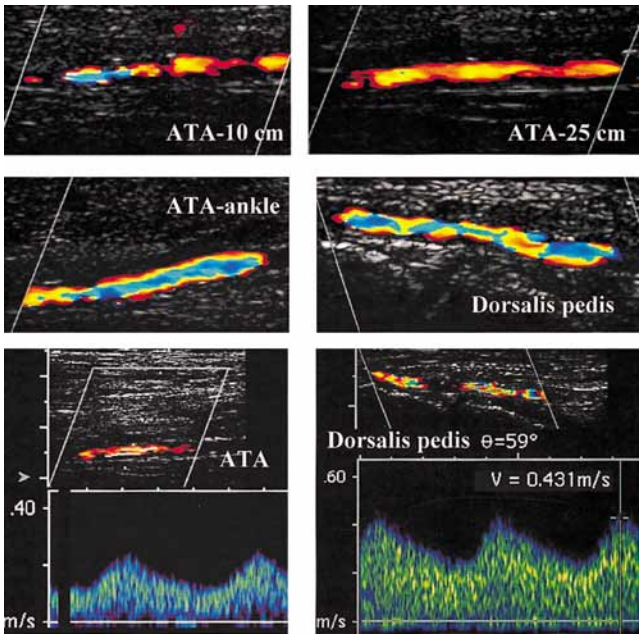

Fig. 3. Visualisation of the entire anterior tibial and dorsal pedal arteries, prior to a bypass procedure to the anterior tibial artery, 25 cm below the origin of the artery.

the iliac arteries were not objectively assessed during surgery. All patients undergoing infrainguinal bypass surgery without preoperative angiography underwent on-table angiography. The decision to perform pre-bypass and/or post-reconstruction on-table angiography was at the discretion of the operating surgeon.

Statistics

The findings obtained from duplex scanning were compared with the findings during surgery (TEA) and the results of on-table angiography; either pre-bypass or post-reconstruction angiography, in patients undergoing infrainguinal bypass surgery. Chi-squared test was used for statistical comparisons between patients undergoing surgery with and without preoperative angiography. Life tables for the patency at 12 months were constructed by the actuarial method according to the SVS/ICSVS reporting standards, and the differences between groups were compared by the log rank test.[9]

Results

Out of 329 reconstructions performed during the study period, 157 reconstructions (140 patients) were performed with duplex scan as the sole preoperative investigation (32 femoral artery endarterectomies, 91 femoropopliteal, and 34 femoro-crural bypass reconstructions). The number of reconstructions performed, with and without preoperative angiography during the study period, is shown in Table 1.

In patients with inconclusive duplex scanning with regard to the visualisation of the inflow or outflow arteries, conventional diagnostic angiography was performed. The reasons for performing preoperative angiography prior to 172 reconstructions were: (1) unavailable duplex scans ($n=38$), (2) inconclusive duplex scan findings of the inflow or outflow arteries ($n=50$), (3) conclusive scans of the inflow, and femoropopliteal segments, but non-available scans of the runoff arteries ($n=28$), (4) conclusive duplex scans in patients with limited or non-visualised runoff vessels ($n=20$), and (5) preference by the responsible vascular surgeon to obtain angiography, despite conclusive scans of the inflow and runoff arteries ($n=36$).

In 32 thromboendarterectomies (30 patients) of the common femoral, and/or deep femoral artery, performed without referring to angiography, the degree (tight stenosis or occlusion) and the extent of lesions were correctly diagnosed in all but one, where duplex scanning underestimated the atherosclerotic changes, and the patient required extended profundaplasty. The primary cumulative life table patency at 12 months following femoral artery endarterectomy with and without preoperative angiography were 80% and 84%, respectively (Table 4).

In 91 femoropopliteal bypass reconstructions, the findings obtained from pre-bypass ($n=21$) or post-reconstruction ($n=73$) on-table angiography, were in agreement with the duplex scan findings, with regard to selection of the distal anastomotic site in all but one patient. In this patient, the distal anastomotic site was selected by duplex scanning to be on the below knee popliteal artery. However, the preoperative on-table angiography revealed a patent popliteal artery above the knee. Duplex scanning misclassified seven patent crural arteries as showing segmental occlusion. These findings did not alter the decision on the site of the distal anastomosis.

In 34 femorodistal bypass grafting, performed without preoperative angiography, the site of the distal anastomosis was onto the anterior tibial artery in 13, posterior tibial artery in 18, tibioperoneal trunk in 2, and the peroneal artery in one patient. In one patient, scheduled for a bypass grafting, duplex scanning demonstrated a patent anterior tibial artery at the distal calf. Patency of the artery was verified by on-table angiography. However, the surgical exploration demonstrated a heavily calcified vessel, and the patient underwent lower leg amputation during the same session. The findings obtained from 10 pre-bypass and 29 post-reconstruction on-table angiographies, were in agreement with duplex scan findings, with respect to the selection of the distal anastomotic site in all but one patient. In this patient, the distal anastomotic site was wrongly selected as the proximal anterior tibial artery instead of the tibioperoneal trunk, according to angiography. The status of the distal runoff vessels were correctly interpreted with duplex scanning in 85% (29/34).

Out of 125 infrainguinal bypass reconstructions in patients without preoperative angiography, 14 grafts (11%) occluded during the initial 30-day period. Occlusion occurred in six patients within 1 month with duplex verified patent grafts at discharge. Four patients with early in-hospital graft occlusion underwent graft thrombectomy, without any other measures in three, and patch angioplasty at the distal anastomosis in one case. The 30-day occlusion rate in limbs undergoing infrainguinal bypass grafting with preoperative angiography was 13% (18/144).

The patients were followed by duplex scanning

Table 4. Cumulative life-table patency at 12 months following infrainguinal reconstructions.*

Reconstruction	No of reconstructions	Primary patency (%)	Primary assisted patency (%)
Surgery without angiography	157		
Femoral endarterectomy	32	84%	84%
Infrainguinal bypass	125	59%	74%
Surgery with angiography	172		
Femoral endarterectomy	28	80%	87%
Infrainguinal bypass	144	64%	78%

* SE at the end of 12 months was <10% for all groups, and there were no significant differences between reconstructions performed, with and without preoperative angiography, according to the log rank test.

during the hospital stay, at 1 month, and thereafter at 3 months intervals, during the first year. There were no significant differences in patency between patients undergoing surgery with and without angiography. The primary cumulative life table patency at 12 months after infrainguinal bypass grafting in limbs with and without preoperative angiography were 64% and 59%, respectively (Table 4). A PSV ratio of ≥ 3 was used to define significant graft stenoses that required intervention.[10] The primary assisted cumulative life table patency after 12 months were 78% and 74%, respectively. The primary assisted patency for infrainguinal vein grafts in limbs with and without preoperative angiography were 80% and 84%, respectively.

Discussion

Our previous experience with duplex scanning of the aorto-iliac, femoropopliteal and cruropedal arteries, in accordance with other previous studies, revealed a satisfactory agreement with conventional angiography.[2–5] These validation studies raised the possibility of using duplex scanning as the sole investigation method, prior to various interventions, in patients with lower limb arterial occlusive disease. Despite wide application of duplex scanning for the selection of patients to percutaneous transluminal angioplasty, reports on surgical reconstructions without preoperative angiography are few.[11–20] However, some authors demonstrated the safety of performing aorto-iliac, as well as infrainguinal reconstructions, without referring to diagnostic angiography by the use of duplex scanning.[14–20]

The basic anatomical principles of infrainguinal arterial surgery are: (1) to assure the adequacy of arterial inflow from the iliac arteries, (2) to appropriately categorise the degree and the extent of the lesions, and (3) to choose the optimal outflow site with regard to the status of runoff. Duplex scanning has the potential to provide satisfactory information on these prerequisites for arterial reconstruction. However, the quality of duplex scanning depends on the experience of the operator and the image interpretation. Further, when using duplex scanning, one has to be aware of the inherent limitations of the method, especially in the crural arteries. In addition, there are no proper guidelines to predict the quality of the artery that is suitable as a recipient vessel. Heavily calcified arteries, especially in diabetics, or in those with renal insufficiency, can be difficult to visualise along their entire length. Collaterals might be misjudged as patent arteries. These technical difficulties are probably the reason for a higher proportion of crural bypass grafting requiring preoperative angiography. Consequently, in cases where duplex scanning is not conclusive, one should not hesitate to perform preoperative conventional diagnostic, or on-table pre-bypass angiography.

During the study period, 19% (50/263) of patients, with available duplex scanning of the entire lower extremity prior to infrainguinal arterial surgery, had inconclusive duplex scans and underwent preoperative conventional angiography. The frequency of inconclusive duplex scans can be reduced with increased laboratory experience. In this retrospective setting, among 193 conclusive duplex scans, 19% (36/193) underwent preoperative angiography at the discretion of the vascular surgeon. Some surgeons do not feel comfortable to perform surgery solely based on duplex scanning, probably due to the lack of a visual display of the duplex scanning, compared to angiography. This is one of the drawbacks with duplex scanning as the only diagnostic imaging prior to infrainguinal surgery, at the present time.

The results of this study demonstrated that infrainguinal surgical reconstructions, either endarterectomy of the femoral artery, or infrainguinal bypass grafting, can safely be performed without preoperative angiography in limbs with conclusive duplex scan findings. The 30-day occlusion rate and patency at 12 months following infrainguinal reconstructions, with and without preoperative angiography, were similar.

The site and the extent of the atherosclerotic lesions were accurately diagnosed by duplex scanning in all but one patient, undergoing femoral artery endarterectomy. In patients undergoing infrainguinal bypass reconstructions, the site of the distal anastomoses, planned according to duplex scan findings, were in agreement with pre-bypass or post-reconstruction on-table angiography in 98%. Duplex scanning correctly evaluated the status of runoff in 90% in patients undergoing femoropopliteal and femorocrural bypass grafting. There were only two femoro-peroneal bypass reconstructions performed without preoperative angiography in the present series. This was mainly due to the limited accuracy of duplex scanning in the evaluation of the entire peroneal artery, including the status of posterior and anterior perforating branches, which are important collaterals to the foot runoff.[3]

In conclusion, this retrospective study demonstrated that it is feasible to perform infrainguinal arterial reconstructions, without preoperative angiography, in patients with conclusive duplex scans. Technical limitations of duplex scanning leading to inaccurate assessment of the inflow and outflow arteries, or non-visualised runoff arteries, should prompt angiographic evaluation.

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