


Eur J Vasc Endovasc Surg 24, 31–36 (2002)

doi:10.1053/ejvs.2002.1623, available online at <http://www.idealibrary.com> on  IDEAL®

Duplex Scanning or Arteriography for Preoperative Planning of Lower Limb Revascularisation

S. Luján*, E. Criado, E. Puras and L. M. Izquierdo

Vascular Surgery Unit, Fundación Hospital Alcorcón, Madrid, Spain

Objective: to compare the accuracy of duplex and angiography for the planning of lower limb revascularisation.

Patients and methods: Sixty limbs (82% with critical limb ischaemia) were assessed by means of duplex by one surgeon and by angiography by another in terms of the optimum inflow and outflow sites for arterial bypass. These data were then compared with the final operation performed which was used as the gold standard. Surgeons were blinded to the determinations of the other.

Results: surgical plans based on duplex scan and angiography were correct in 77% (40/52) and 79% (41/52), respectively and plans based on the one imaging modality was modified by the other in only 1 and 2 instances. The diagnostic agreement between duplex scanning and arteriography was excellent (Kappa value = 0.94, 95% C.I. 0.89–0.98).

Conclusions: the reliability of duplex scanning is comparable to digital angiography in the preoperative planning of lower extremity arterial reconstruction. However neither exam can be considered as the gold standard because intraoperative arteriography needs to be available in a significant number of infrapopliteal procedures.

Key Words: Arterial duplex scanning; Arteriography; Lower limb revascularisation.

Introduction

The relative merits of duplex and angiography in terms of planning lower limb arterial reconstruction remain controversial. The advantage of angiography is that it provides a detailed road-map although it is argued that a great deal of this information may not be necessarily relevant and outflow vessels can sometimes be missed. Duplex may provide less anatomic detail but does provide physiological information and is non-invasive. The attempt to replace angiography with duplex has not been fully accepted perhaps because most studies have focused on the capability of duplex to draw a precise arterial map being this objective cumbersome and time-consuming.¹

The aim of this blinded, prospective study was to compare the accuracy of the operative plan made for patients with chronic arterial occlusive disease on the basis of duplex scanning with that made on the basis of angiography and to investigate whether duplex scanning misses any information relevant to surgical planning.

Patients and Methods

Patients

Sixty limbs of 57 consecutive patients (47 men and 10 women; mean age: (70 [range 35–89] years) with chronic lower extremity ischaemia were studied of which 82% had critical limb ischaemia.² Mean ankle brachial index was 0.36 (range 0–0.8). Of 60 limbs, 17 had predominant aortoiliac disease, 13 femoropopliteal disease and 30 infrapopliteal disease. Thirteen vascular procedures had been previously performed in 9 patients. Associated comorbidities were observed in 56 patients (Table 1).

Table 1.

Comorbidities	n (%)
Diabetes mellitus	27 (47)
Tobacco use	40 (70)
Hyperlipidaemia	32 (57)
Hypertension	22 (38)
Coronary artery disease	12 (21)
Cerebrovascular disease	5 (9)
Lung neoplasm	2 (4)
Prostate cancer	1 (2)

* Please address all correspondence to: S. Luján, Vascular Surgery Unit, Fundación Hospital Alcorcón, C/Budapest no 1, Alcorcón, Madrid 28922, Spain.

Methods

A staff vascular surgeon blinded to the results of arteriography made a medical history, physical exam, arterial duplex scan and ankle brachial index in every patient. Subsequently a surgical plan was formulated. The rest of the staff blinded to the results of arterial duplex scans made a surgical plan based on arteriography. An intraoperative angiogram was performed in cases of discrepancy between both plans or at the discretion of the operating surgeon if a precise segment of an outflow vessel could not be determined by either duplex or arteriography because of diffuse disease or distal vessel calcification. The surgical decisions were compared to address the issue of whether duplex scan missed any relevant information in comparison with arteriography and both surgical plans were again compared with the final operation performed which was considered as the gold standard.

In seven cases duplex scan was done before angiography. The mean difference in days between angiography and duplex scanning was 2 days (range 1–17 days).

Duplex scanning

Duplex scan was performed with an ATL HDI 3500 machine using 2–5 and 4–7 MHz probes by one staff vascular surgeon (S.L.). The median time to complete the duplex study was 40 min (range 15–60 min). The exam started at the femoral region. Based on previous studies,^{3,4} if the common femoral artery (CFA) showed an acceleration time (AT) < 130 ms, or no stenosis greater than 50% stenosis, iliac disease was ruled out and the exam proceeded distally. Acceleration time was measured from the onset of systolic upslope to the point of maximum velocity. A haemodynamically significant stenosis was defined as a greater than 50% stenosis and was diagnosed if the velocity doubled the immediate proximal segment of the artery.⁴ After ruling out iliac disease, superficial femoral, and deep femoral arteries were scanned and classified as occluded, haemodynamically stenotic, or patent and adequate for inflow site. Additionally, morphologic characteristics (calcification, aneurysms, arteriosclerotic plaques) were recorded.

Subsequently an outflow artery was selected. The distal anastomotic site was determined by identifying the most proximal segment of an artery with continuous flow to the foot. If more than one calf vessel was patent, the morphologic quality of the arteries was assessed and the length of a good diameter internal

saphenous vein was measured to select the most proximal vessel. If a distal vessel was patent but no continuous flow to the foot was visualized because of calcification or diffuse disease (patchy flow pattern), an intraoperative angiogram was indicated.

Tibial arteries were scanned from distal to proximal in order to save time because of the easier visualisation of the tibial arteries in the distal calf. If any of these were occluded distally there was no need to visualise the whole length if it had no continuous flow to the foot. Therefore no attempt was made to draw a complete duplex arteriogram but to select the best sites for vascular reconstruction based on the most adequate distal vessel.

In patients with suspicion of aortoiliac disease based on a diminished or absent femoral pulse or with CFA duplex abnormalities (AT > 130 ms, or >50% stenosis), the infrarenal aorta and iliac arteries were evaluated. Vessels were classified as occluded, haemodynamically stenotic, or adequate for inflow anastomosis.

In all patients with suspected aortoiliac disease both iliac axes were examined. The indication for angioplasty was the presence of a single stenotic lesion of less than 5 cm.

The site for outflow anastomosis was searched by insonating the common femoral, deep femoral and superficial femoral arteries. These vessels were imaged looking for occlusion, stenosis, patency, calcification or dilatation based on the above mentioned criteria and a specific segment was chosen for outflow anastomosis. The deep femoral artery was insonated in its full length if this vessel was considered for the outflow anastomosis. The exam was then followed by a study of the rest of the arteries of the limb in order to see whether they were patent or occluded. In case of grade V or VI disease (SVS/ISCVS Classification) and associated infrainguinal disease, the exam was completed as described previously.

Arteriography

All patients underwent intraarterial digital subtraction angiography. The infrarenal aorta and the distal arterial tree to the foot were visualised. Iliac and deep femoral arteries were imaged both antero-posteriorly and obliquely. The vascular surgery team blindly reviewed angiograms and a surgical plan was drawn.

Data analysis

The proportion of correct surgical plans made by duplex scan was compared with those made by

angiography using McNemar's test for a binomial distribution. The final operation performed was considered as the gold standard. A statistically significant difference was defined as a p value of <0.05 . Ninety five percent confidence intervals were calculated for each proportion.

The results of duplex based surgical plans were compared with those based on arteriography using kappa values for overall diagnostic agreement. Excellent, good and moderate agreement was defined when kappa values were 0.81–1.0, 0.61–0.80, 0.41–0.60, respectively.

The estimation of the sample size was done with a 10% accuracy, an estimated diagnostic validity index of 90% and a confidence level of 95% (alfa error = 5%). Assuming a 10% of patients who could not be submitted to the gold standard test, the estimated sample size was 39 patients.

Results

Fifty-two limbs were finally operated. Compared with the final operation performed in the operating room, 77% (40/52) (95% C.I. 65–88%) of the surgical plans made by duplex scan were considered correct. Of those surgical plans made by arteriography 79% (41/52) (95% C.I. 68–90%) were finally carried out in the operating room (Table 2). The difference between these proportions was not statistically significant ($p = 1$).

In three cases both diagnostic tests did not agree (Table 3). In two arteriography was correct and in one duplex scanning was correct. Duplex scanning misclassified an infra renal aorta as inadequate for inflow vessel and in another case a peroneal artery was classified as patent by duplex scan and was occluded both in arteriography and intraoperative angiogram.

In one case duplex scanning was considered correct. A dorsalis pedis artery was selected as appropriate by the preoperative angiogram and discarded by duplex scan. Intraoperative angiogram confirmed the inadequacy of the vessel (Table 3).

In ten cases, the surgical plans formulated by both tests were exactly the same but were not finally carried out for different reasons (Table 4) and therefore were considered as failures.

Eight patients were not operated. Three patients died before surgery and in five patients a non-operative treatment was chosen (Table 5).

Of the surgical plans made by duplex scan 97% (58/60) (C.I. 92–100%) were not changed by additional arteriography. Conversely of the surgical plans made by arteriography 98% (59/60) (96–100%) were not changed by duplex scan. The diagnostic agreement between duplex scanning and arteriography was excellent (Kappa value = 0.94, 95% C.I. 0.89–0.98).

Overall 9 procedures needed an intraoperative angiogram, 2 because of disagreement between both studies and 7 because of questionable distal vessel adequacy. In 26 patients direct bilateral aortoiliac

Table 2. Correct surgical plans made by arteriography and duplex scan in 39 patients.

Surgical plan – Arteriography	Surgical plan – Duplex scan	Operation performed	<i>n</i>
Femoral to PTA bypasses	Femoral to PTA bypasses	Femoral to PTA bypasses	6
Fem-ATA bypasses	Fem-ATA bypasses	Fem-ATA bypasses	6
Fem-peroneal bypasses	Fem-peroneal bypasses	Fem-peroneal bypasses	5
Fem-AK popliteal bypasses	Fem-AK popliteal bypasses	Fem-AK popliteal bypasses	4
Iliac PTAs	Iliac PTAs	Iliac PTAs	4
Fem-femoral bypass	Fem-femoral bypasses	Fem-femoral bypasses	3
Fem-BK popliteal bypass	Fem-BK popliteal bypass	Fem-BK popliteal bypass	2
Amputations	Amputations	Amputations	2
2 Aorto-bifemoral bypasses	2 Aorto-bifemoral bypasses	2 Aorto-bifemoral bypasses	2
Popliteal-PTA bypass	Popliteal-PTA bypass	Popliteal-PTA bypass	1
Femoral-TP trunk bypass	Femoral-TP trunk bypass	Femoral-TP trunk bypass	1
Aorto-femoral bypass	Aorto-femoral bypass	Aorto-femoral bypass	1
Iliac PTA + profundaplasty	Iliac PTA + profundaplasty	Iliac PTA + profundaplasty	1
Saphenous vein arterialisation	Saphenous vein arterialisation	Saphenous vein arterialisation	1
			39

Table 3. Incorrect surgical plans made by either arteriography or duplex scan.

Surgical plan – Arteriography	Surgical plan – Duplex scan	Operation performed	<i>n</i>
Popliteal-dorsalis pedis bypass	No reconstruction	Intraop. angiogram (no reconstruction)	1 Angiogram incorrect
Infrarenal aorta-bifem. bypass	Suprarenal aorta-bifem. bypass	Infrarenal aorta-bifem. bypass	1 Duplex incorrect
Femoro-BK popliteal bypass	Femoro-peroneal bypass	Femoro-BK popliteal bypass	1 Duplex incorrect

Table 4. Patients in whom both tests agreed but in which a different procedure was carried out.

Surgical plan – Arteriography	Surgical plan – Duplex scan	Operation performed	n
Intraop. angiogram (pop. to PTA or ATA bypass)	Intraop. angiogram (pop. to PTA or ATA bypass)	Intraop. angiogram (3 pop. ATA bypass, 1 pop. PTA bypass)	4
Fem-AK popliteal bypass	Fem-AK popliteal bypass	Fem-BK popliteal bypass (calcification)	1
Aorto-iliac bypass	Aorto-iliac bypass	External iliac-external iliac bypass (retroperitoneal fibrosis)	1
Iliac PTA	Iliac PTA	Femoro-femoral bypass because patient denied iliac PTA	1
Iliac PTA + fem-peroneal by pass	Iliac PTA + fem-peroneal by pass	Femoro-peroneal bypass	1
Aorto-bifemoral bypass vs ilio-femoral bypass	Aorto-bifemoral bypass vs ilio-femoral bypass	Ext. Iliac-deep femoral bypass because of high surgical risk	1
Ilio-femoral vs femoro-AK popliteal bypass	Ilio-femoral vs femoro-AK popliteal bypass	Femoro-AK popliteal bypass because of clinical decision	1
			10

Table 5. Patients who were not finally operated.

Surgical plan – Arteriography	Surgical plan – Duplex scan	Result	n
Amputation	Amputation	Exitus	1
Iliac PTA + femoro-BK popliteal bypass	Iliac PTA + femoro-BK popliteal bypass	Exitus	1
Femoro-PTA bypass	Femoro-PTA bypass	Exitus	1
Femoro-BK popliteal bypass	Femoro-BK popliteal bypass	No surgery because patient denied	1
Femoro-ATA bypass	Femoro-ATA bypass	Conservative treatment	1
Iliac PTA	Iliac PTA	Conservative treatment	1
Femoro-AK popliteal bypass	Femoro-AK popliteal bypass	Conservative treatment	1
Iliac PTA	Iliac PTA	Conservative treatment	1
			8

duplex scanning was finally performed. In 16 of them because a prolonged (> 130 ms) acceleration time, in 6 of them because the common femoral artery showed a greater than 50% stenosis and in 4 for personal choice of the examiner. In 6 patients the exam was not considered optimal because of intraabdominal gas or calcification. However these arterial segments did not preclude a correct surgical indication based on the results of the rest of the exam. No iliac stenosis was found in the arteriogram in those patients with a common femoral artery acceleration time of less than 130 ms. No tibial vessel was inaccessible to duplex imaging.

Discussion

Duplex scan has changed the diagnostic approach in vascular surgery in the last two decades. However its application in patients with lower limb ischaemia has been scarce. In this regard several studies have investigated the ability of duplex scanning to produce a complete arterial map, calculating the sensitivity, specificity, PPV and NPV of duplex scan against arteriography.^{1,5} This approach considers arteriography as the gold standard although it must be remembered that it provides a two-dimension image of a three dimensional disease and does not evaluate function.

The aim of this study was to look for the necessary information to perform an adequate vascular reconstruction rather than to obtain a sensitivity and specificity of duplex scanning against arteriography. A similar approach has been used by Ligush *et al.*,⁶ Wain *et al.*⁷ and Mazzariol *et al.*⁸ and we believe it is a more practical one because it compares surgical decisions rather than images after both diagnostic methods.

On the other hand comparing surgical plans and selecting the final operation as the gold standard has important limitations. We, as Ligush and Wain, considered the final operation performed as the gold standard. But in our experience the final surgical procedure can be changed during the operation because the surgeon may get additional intraoperative information as it occurred in one patient in which an aorto-iliac bypass was discarded because of dense retroperitoneal fibrosis.

Another considerable drawback is the fact that different surgical departments have their own surgical traditions and indications. Surgeons working together tend to perform similar operations. Besides different operations may be well indicated for a single patient. In our view this is the reason why each vascular unit should draw its own guidelines and protocols on this issue based on its own surgical strategies for lower limb revascularisation.

Our study reveals that the reliability of duplex scanning is comparable to digital angiography in the preoperative planning of arterial reconstruction in patients with lower limb ischaemia with excellent agreement between both methods in terms of decision-making regarding treatment.

However, compared with other authors,^{6,7} we have found lower proportions of correct operations predicted by both tests. This may be explained because in our series one patient who denied an iliac PTA and four patients in whom no exact surgical plan could be defined have been counted as failures of both tests. This, considered with the fact that preoperative arteriography deemed adequate an inadequate distal vessel, in our view merely reflects that neither duplex scan nor preoperative angiography can be considered the gold standard and consequently intraoperative angiogram needs to be available when an infrapopliteal revascularisation is required.

At the same time, we have found two important limitations, previously mentioned by different authors, namely the iliac system evaluation by duplex⁹⁻¹¹ and the distal vessel adequacy.^{1,12,13}

With regard to the first issue, this study was not specifically designed to validate duplex scan against arteriography and we chose the criteria based on a prolonged common femoral artery acceleration time and an elevated PSV to suspect an iliac stenosis or occlusion.^{3,9}

We did not find any significant angiographic stenosis in patients with an acceleration time of less than 130 ms and therefore in our patients this criteria was reliable enough to rule out iliac disease. However we have found difficulties in three patients who had diffusely diseased but without focal stenoses iliac axes and associated femoro-popliteal disease. The estimation of the degree of iliac disease in these cases could have been resolved by intraarterial pressure measurements with and without papaverine, as has been proposed by Flanigan *et al.*¹⁰ and Legemate *et al.*¹⁴ It is also important to point out that arteriography underestimates the haemodynamic significance of iliac stenosis¹⁴ and therefore what we are comparing is two methods of estimating significant stenosis rather than objectively measuring iliac stenosis. In this regard it is also important to mention that the significance of iliac stenosis depends on the grade or ischaemia being treated. A 50% stenosis in an active claudicant may be significant and need treatment. However a 50% iliac stenosis may not be haemodynamically significant at rest in a sedentary patient being treated for an ischaemic ulceration and therefore may not need correction in order to improve the overall hemodynamic status of the limb.

Some authors have emphasised the need for preoperative angiography in cases of infrapopliteal revascularisation for different reasons, mainly because of difficulties in distal vessel visualisation^{1,12} or because of limitations in diagnosing distal vessel stenoses in the presence of adjacent segment disease.^{5,15} However, this has not been our experience because of the use of intraoperative angiography. Intraoperative arteriography is considered by several authors⁶ as the true gold standard in infrapopliteal revascularisation. In our study, duplex scan considered patent an occluded peroneal artery probably misidentifying a patent anterior tibial artery but on the other hand the preoperative arteriogram considered adequate an inadequate distal vessel showing limitations of both modes of testing.

As mentioned in other studies perhaps the most important advantage of duplex scanning is its ability to visualise both the lumen and the arterial wall of the vessel.^{8,16} This fact, although not specifically addressed in this study, has allowed us to select proximal and distal anastomoses more precisely and therefore limit the length of the surgical incision in infrainguinal revascularisation.

In our experience, patients with lower limb arterial disease can be accurately operated upon with the only preoperative aid of duplex scan. In fact some authors have reported good results after infragenicular,^{8,17,18} and aortoiliac¹⁹ revascularisation based solely on duplex scan. However, bearing in mind that we have to be certain there is no adequate artery for a distal bypass before proceeding with an amputation we perform an intraoperative angiogram in case of visualising an inadequate distal vessel with duplex scan.

Acknowledgements

The authors wish to thank Dr. Rodríguez Caravaca, Investigation Institute, Fundación Hospital Alcorcón, for his statistical advice.

References

- 1 MONETA GL, YEAGER RA, ANTONOVIC R *et al.* Accuracy of lower extremity arterial duplex mapping. *J Vasc Surg* 1992; **15**: 275-284.
- 2 RUTHERFORD RB, BAKER JD, ERNST C *et al.* Recommended standards for reports dealing with lower extremity ischemia: Revised version. *J Vasc Surg* 1997; **26**: 517-538.
- 3 BURNHAM SJ, JAQUES P, BURNHAM CB. Noninvasive detection of iliac artery stenosis in the presence of superficial femoral artery obstruction. *J Vasc Surg* 1992; **16**: 445-452.
- 4 KOHLER TR, NANCE DR, CRAMER MM, VANDERBURGHE N, STRANDNESS DE. Duplex scanning for diagnosis of aortoiliac and femoropopliteal disease: a prospective study. *Circulation* 1987; **76**: 1074-1080.
- 5 ALLARD L, CLOUTIER G, DURAND L-G, ROEDERER GO, LANGLOIS YE. Limitations of ultrasonic duplex scanning for diagnosing

- lower limb arterial stenoses in the presence of adjacent segment disease. *J Vasc Surg* 1994; **19**: 650–657.
- 6 LIGUSH J, REAVIS S, PREISSER JS, HANSEN KJ. Duplex ultrasound scanning defines operative strategies for patients with limb-threatening ischemia. *J Vasc Surg* 1998; **28**: 482–491.
 - 7 WAIN RA, BERDEJO GL, DEL VALLE WN *et al.* Can duplex scan arterial mapping replace contrast arteriography as the test of choice before infrainguinal revascularization? *J Vasc Surg* 1999; **29**: 100–109.
 - 8 MAZZARIOL F, ASCHER E, SALLES-CUNHA SX, GADE P, HIRONGANI A. Values and limitations of duplex ultrasonography as the sole imaging method of preoperative evaluation for popliteal and infrapopliteal bypasses. *Ann Vasc Surg* 1998; **13**: 1–10.
 - 9 SCHNEIDER PA, OGAWA DY. Is routine preoperative aortoiliac arteriography necessary in the treatment of lower extremity ischemia? *J Vasc Surg* 1998; **28**: 28–36.
 - 10 FLANIGAN DP, RYAN TJ, WILLIAMS LR *et al.* Aortofemoral or femoropopliteal revascularization? A prospective evaluation of the papaverine test. *J Vasc Surg* 1984; **1**: 215–223.
 - 11 CURRIE IC, JONES AJ, WAKELEY CJ *et al.* Non-invasive aortoiliac assessment. *Eur J Vasc Endovasc Surg* 1995; **9**: 24–28.
 - 12 KATSAMOURIS AN, GIANNOUKAS AD, TSETIS D *et al.* Can ultrasound replace arteriography in the management of chronic arterial occlusive disease of the lower limb? *Eur J Vasc Endovasc Surg* 2001; **21**: 155–159.
 - 13 ELSMAN BHP, LEGEMATE DA, VAN DER HEIJDEN FHWM *et al.* Impact of ultrasonographic duplex scanning on therapeutic decision making in lower-limb arterial disease. *Br J Surg* 1995; **82**: 630–633.
 - 14 LEGEMATE DA, TEEUWEN C, HOENWELD H, EIKELBOOM BC. Value of Duplex scanning compared with angiography and pressure measurement in the assessment of aortoiliac arterial lesions. *Br J Surg* 1991; **78**: 1003–1008.
 - 15 BERGAMINI TM, TATUM CM, MARSHALL C, HALL-DISSEKAMP B, RICHARSON JD. Effect of multilevel sequential stenosis on lower extremity arterial duplex scanning. *Am J Surg* 1995; **169**: 564–566.
 - 16 PEMBERTON M, LONDON NJM. Colour flow duplex imaging of occlusive arterial disease of the lower limb. *Br J Surg* 1997; **84**: 912–919.
 - 17 PROIA R, WALSH DB, NELSON PR *et al.* Early results of infra-genicular revascularization based solely on duplex arteriography. *J Vasc Surg* 2001; **33**: 1165–1170.
 - 18 MAZZARIOL F, ASCHER E, HIRONGANI A *et al.* Lower extremity revascularization without preoperative contrast arteriography in 185 cases. Lessons learned with with duplex ultrasound arterial mapping. *Eur J Vasc Endovasc Surg* 2000; **19**: 509–515.
 - 19 VAN DER ZAAG ES, LEGEMATE DA, NGUYEN T, BALM R, JACOBS JHM. Aortoiliac reconstructive surgery based upon the results of duplex scanning. *Eur J Vasc Endovasc Surg* 1998; **16**: 383–389.

Accepted 6 February 2002