Eur J Vasc Endovasc Surg 35, 619–624 (2008)
doi:10.1016/j.ejvs.2007.11.004, available online at http://www.sciencedirect.com on ScienceDirect

Prospective Evaluation of Ischemia in Brachial–Basilic and Forearm Prosthetic Arteriovenous Fistulas for Hemodialysis

X.H.A. Keuter,[1*] A.G.H. Kessels,[2] M.H. de Haan,[3] F.M. van der Sande[4] and J.H.M. Tordoir[1]

Departments of [1]Surgery, [2]Clinical Epidemiology, [3]Radiology, and [4]Nephrology, University Hospital Maastricht, The Netherlands

Ischemia is a devastating complication after arteriovenous fistula (AVF) creation. When not timely corrected, it may lead to amputation. Symptomatic ischemia occurs in 3.7–5% of the hemodialysis population. Upper arm AVFs have a higher incidence of ischemia compared to forearm AVFs. As more patients may need upper arm AVFs in the growing and older hemodialysis population, occurrence of symptomatic ischemia may increase. The purpose of this study is to identify predictors for occurrence of ischemia.
Methods*. A prospective evaluation of ischemia was performed in patients randomised for either a brachial–basilic (BB-) AVF or a prosthetic forearm loop AVF. Clinical parameters, preoperative vessel diameters, access flows, digital blood pressures, digit-to-brachial indices (DBI) and interventions for ischemia were recorded.*
Results*. Sixty-one patients (BB-AVF 28) were studied. Seventeen patients (BB-AVF 8) developed ischemic symptoms. Six patients (BB-AVF 3) needed interventions for severe symptoms. Age, history of peripheral arterial reconstruction and radial artery volume flow were significant predictors for the occurrence of ischemia.*
Conclusion*. Symptomatic ischemia occurred in 28% of patients with brachial–basilic and prosthetic forearm AVFs. Age, history of peripheral arterial reconstruction and radial artery volume flow might be important for prediction of ischemia.*
© 2007 European Society for Vascular Surgery. Published by Elsevier Ltd. All rights reserved.

Keywords: Ischemia; Vascular access; Hemodialysis; Brachial basilic arteriovenous fistula; Prosthetic brachial–antecubital forearm loop.

Introduction

Ischemia in end-stage renal disease (ESRD) patients on hemodialysis is an uncommon but feared complication of vascular access creation, which can lead to finger and hand amputation.[1–3] Upper extremity ischemia is reported to be more frequent in elbow and upper arm fistulas as compared to forearm fistulas.[4] It is estimated that 20–25% of patients with an upper arm fistula will develop hand ischemia.[1,5–7] Due to the growing and older hemodialysis population, an increasing number of patients will rely on upper arm vascular access because of the impossibility of forearm AVF creation (radial–cephalic AVF) or failure of previous accesses. As a result, an increase in the total number and percentage of patients with symptomatic ischemia after vascular access creation might be expected.[8] There still is little information on patient-related and noninvasively measured vessel parameters that may predict the occurrence of ischemia in elbow/upper arm accesses like brachio-basilic and prosthetic forearm loop AVFs.

The primary purpose of this study is therefore to evaluate patient demographics as well as preoperative duplex parameters to identify predictors for occurrence of ischemia in brachio-basilic and prosthetic forearm loop AVFs. The secondary purpose of this study is to compare the occurrence of ischemia in these two types of vascular access.

Methods

Patients at a single dialysis facility with failed vascular access or insufficient arterial and/or venous vessels (distal radial artery and/or forearm/upper arm cephalic vein <2.0 mm in diameter) were included and randomised for creation of a brachio-basilic AVF (BB-AVF) or prosthetic (Polytetrafluoroethylene; Gore

*Corresponding author. X. H. A. Keuter, MD, Department of Surgery, University Hospital Maastricht, P.O. Box 5800, 6202 AZ Maastricht, Limburg, The Netherlands.
E-mail address: xha.keuter@ah.unimaas.nl

1078–5884/000619 + 06 $34.00/0 © 2007 European Society for Vascular Surgery. Published by Elsevier Ltd. All rights reserved.

& Ass, Flagstaff, USA) brachial–antecubital forearm loop (PTFE loop; prosthetic graft AVF). This study was part of a larger randomised trial in which patency rates were compared between these two options for vascular access. Approval of the ethical committee was obtained. All patients gave informed consent. Preoperatively, patients received preoperative upper extremity vessel assessment by means of duplex ultrasound investigation (SSD-2000, Aloka Co Ltd, Tokyo, Japan) as a standard procedure. Fore- and upper arm cephalic and basilic vein diameters and brachial, ulnar and radial artery diameters and flow were measured. Bilateral systolic and diastolic brachial bloodpressure (Riva-Rocci method) and systolic digital pressure were measured. Finger pressures were measured by using a photoplethysmograph and an inflatable cuff (Nicolet Vascular, Madison, WI, USA) and the digit-to-brachial index (DBI) was calculated by dividing systolic digital blood pressure by systolic brachial blood pressure.

Clinical and duplex parameters were recorded preoperatively. Postoperatively, clinical parameters, flow and DBI were recorded at 6, 12, 26 and 52 weeks. Ischemic symptoms were defined as pain during exercise and/or hemodialysis (stage 2–3).[4] The indication for intervention for ischemia was made on clinical symptoms and the outcome of DBI and duplex measurements. In particular the amount of bloodflow through the AV anastomosis was non-invasively measured. All patients underwent pre-intervention angiography with visualisation of the complete arterial inflow, AV anastomosis and outflow veins. In principle all arterial inflow obstructions were treated by radiological intervention, while high bloodflow through the vascular access was surgically revised by flow-reducing techniques.

Statistical analysis

For statistical analysis, SPSS 12.01 program was used. All complications and interventions related to symptomatic ischemia were recorded. Patients who died, were transplanted, had access failure or were lost to follow up were censored for ischemia-free survival analysis. No power calculation was used for this study, as the primary aim of this study is to find predictors for ischemia. The Kaplan–Meier method was used to compare the ischemia-free period for the two groups. Univariate Cox-regression was used to find predictors for the occurrence of ischemia. Parameters with $P < .1$ were included in a multivariate backwards Cox-regression. In this multivariate regression, a P-value of less than .05 was considered statistical significant.

Results

Sixty-one patients were randomised of which 28 had BB-AVF and 33 prosthetic graft AVF creation. Patient characteristics are shown in Tables 1 and 2. Mean follow up time was 282 ± 19.3 (SE) days for the BB-AVF group and 247 ± 22 days for the prosthetic graft group. In one patient, non-maturation of the BB-AVF did occur. There were 14 patients (1 in the BB-AVF group) with 31 thromboses (range: 1–6 per patient).

Ischemia occurred earlier after operation in the PTFE group; however, there was no significant difference in occurrence of ischemic symptoms after one year for both types of access (29% vs 28% for the BB-AVF and prosthetic grafts) (Fig. 1). The mean ischemia-free period was 280 ± 26 and 262 ± 29 days for the BB-AVF and prosthetic graft group, respectively. The percentage of patients who did not need intervention for ischemia after one year was 89% versus 90% for the BB-AVF and PTFE group, respectively. Mean intervention-free period for ischemia was 339 ± 14 and 331 ± 18 days for the BB-AVF and graft AVF. As can be seen in Table 3, brachial artery volume flow was at no time significantly different for the BB-AVF and PTFE group as well for the non-ischemia and ischemia group.

Six patients (3 BB-AVF; 3 prosthetic grafts) needed a total of 12 interventions for salvage of ischemia. The BB-AVF group underwent 4 percutaneous transluminal angioplasties (PTA) with additional stent implantation (one patient) for subclavian artery obstruction. In addition, distal arterial flow enhancement by

Table 1. Patient characteristics of prosthetic graft (PTFE) and BB-AVF group

	PTFE	BB-AVF
N	33	28
M/F	22/11	13/15
Previous RC-AVF	2	10
Previous BC-AVF	1	4
Previous graft AVF	3	6
Dominant hand Left/Right	0/33	1/27
Smoking	8	8
Cardiac disease	4	9
Hypertension	21	15
Diabetes	17	7
PAOD	12	10
Previous vascular surgery	17	18
History of central arterial reconstruction	3	2
History of peripheral arterial reconstruction	2	0
Age (years) (SE)	66.3 (2.1)	64.4 (3.1)
Months on CAPD (SE)	7.0 (2.7)	4.5 (1.9)
Months on Hemodialysis (SE)	6.3 (2.5)	20.9 (6.6)
Mean number of previous accesses (SE)	0.3 (.1)	1.0 (.2)

PTFE = Polytetrafluoroethylene, graft material.
RC-AVF = radial–cephalic arteriovenous fistula.
BC-AVF = brachial–cephalic arteriovenous fistula.
PAOD = peripheral arterial obstructive disease.
CAPD = continuous ambulatory peritoneal dialysis.

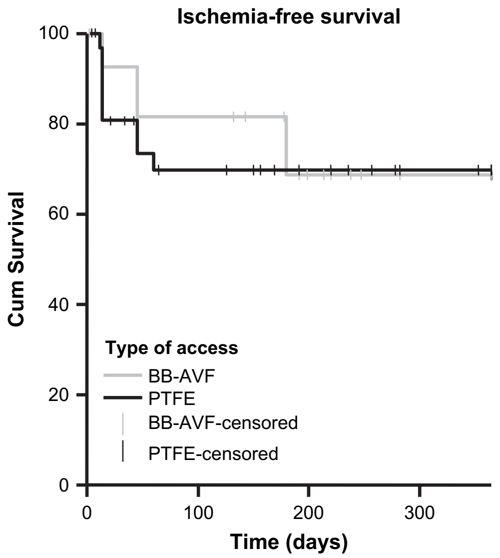
Table 2. Preoperative vessel characteristics for the prosthetic graft (PTFE) and brachial−basilic fistula (BB-AVF)

	PTFE	BB-AVF
Brachial artery diameter (mm) (SE)	4.4 (.2)	4.3 (.2)
Brachial artery volume flow (ml/min) (SE)	83.8 (11.2)	82.2 (12.2)
Radial artery diameter (mm) (SE)	2.3 (.1)	2.4 (.1)
Radial artery volume flow (ml/min) (SE)	22.7 (3.7)	24.0 (4.9)
Ulnar artery diameter (mm) (SE)	1.9 (.1)	2.0 (.1)
Systolic digital pressure (mmHg) (SE)	152 (7)	144 (8)
Systolic brachial pressure (mmHg) (SE)	157 (7)	143 (8)
Digit/Brachial Index (SE)	0.98 (.02)	0.98 (.04)

proximalisation of the arteriovenous anastomosis with graft implantation[9] was needed in 2 patients combined with anastomotic patchplasty in one. In the end, 2 BB-AVFs had to be surgically ligated to resolve ischemia, leaving only one patient successfully treated for ischemia. In the prosthetic graft group, 2 PTAs and 2 banding procedures to reduce high flow were necessary to solve ischemic complications. There was no graft ligation necessary in the prosthetic group.

Patient and vessel characteristics of the non-ischemia and ischemia group are listed in Tables 4 and 5. In an univariate Cox-regression analysis age, previous brachial−cephalic AVF, cardiac disease, hypertension, a history of peripheral arterial reconstruction, preoperative brachial artery diameter and volume flow of the distal radial artery were significant parameters for ischemia ($P < .01$) (Tables 4 and 5). In the backwards multivariate Cox-regression analysis with these parameters, a history of peripheral arterial reconstruction and volume flow of the distal radial artery were independent predictors for ischemic symptoms within one year after operation ($P < .05$) (Table 5). With a *P*-value of .053, age showed a trend to be a predictor for ischemia as well.

The increase in brachial arterial diameter from operation until one year after was significantly lower in the ischemia group compared to the non-ischemia group ($P < .001$), while brachial artery volume flow was not significantly different. The decrease in DBI after access creation was significantly greater in the ischemia group compared to the non-ischemia group ($P = .03$). The decrease in DBI in patients who needed intervention was even greater (Fig. 2).



Number at risk	0 days	100 days	200 days	300 days	365 days
BB-AVF (n)	28	22	14	9	9
PTFE (n)	33	18	13	8	7

Fig. 1. Ischemia-free survival in brachial−basilic (BB-AVF) and prosthetic graft AVF (PTFE).

Table 3. Brachial artery volume flow for the BB-AVF vs. PTFE and non-ischemia vs. ischemia group

Brachial artery volume flow (ml/min)	BB-AVF	PTFE	*P*	Non-ischemia	Ischemia	*P*
6 Weeks	1508	1634	NS	1574	1561	NS
12 Weeks	1569	1561	NS	1490	1761	NS
26 Weeks	1543	1519	NS	1456	1683	NS
52 Weeks	1507	1446	NS	1505	1423	NS

Discussion

In this study, 28% of patients with BB-AVF and forearm grafts developed symptoms of ischemia while 11% needed intervention within one year after access creation. Similar percentages are reported in the literature, with in particular high percentages in brachial-based arteriovenous fistulas. However, when prospectively evaluated with the use of a questionnaire, steal symptoms are experienced on a much larger scale than previously thought.[7] Not all patients with ischemic symptoms need intervention, but a carefully wait and see policy is recommended.

Several clinical predictors for ischemia have been described: age, diabetes, hypertension, peripheral arterial obstructive disease, coronary artery disease, and female gender have been associated with the occurrence of ischemia.[3,10−12] A preoperative prediction of ischemia would be helpful to better outline the strategy for access placement. In the present study a history of peripheral arterial reconstruction and

Table 4. Patient demographics for the non-ischemia and ischemia group

	Non ischemia	Ischemia	*P*-value univariate analysis	*P*-value multi-variate analysis
N	44	17		
M (%)	61	47	.290	
Previous RC-AVF (%)	23	12	.311	
Previous BC-AVF (%)	11	0	.094	1.000
Previous graft AVF (%)	16	12	.674	
Dominant hand right (%)	98	100	.404	
Smoking (%)	30	18	.316	
Cardiac disease (%)	30	0	.003	.986
Hypertension (%)	52	76	.094	.927
Diabetes (%)	43	29	.285	
PAOD (%)	32	47	.238	
Previous vascular surgery (%)	59	53	.633	
History of central arterial reconstruction (%)	9	6	.582	
History of peripheral arterial reconstruction (%)	0	12	.059	**.039**
Age	62.0	74.2	.001	**.053**
Months on CAPD (SE)	6.5 (2.1)	4.5 (3.4)	.659	
Months on Hemodialysis (SE)	14.4 (4.4)	9.1 (4.2)	.446	
Number of previous accesses (SE)	0.7 (.2)	0.4 (.2)	.375	
BB-AVF (%)	46	47	.736	
AVF placed in left arm (%)	77	88	.419	
AVF placed in non-dominant arm (%)	80	88	.554	

Patient demographics for the non-ischemia vs. the ischemia group. The values in the fourth column represent the *p*-value found in a univariate Cox-regression analysis for ischemia. Variables with a *p*-value smaller then .1 were put in a multivariate Cox-regression for ischemia. Last column represent the *p*-value found in the multivariate backward regression. When *P*-value is <.05, the parameter is considered a statistically significant predictor for ischemia. Bold numbers indicate (borderline) statistical significance.

radial artery volume flow are found to be independent predictors of ischemia. Furthermore, age shows a tendency to significance. It is well appreciated that the aging dialysis population has poor peripheral vessels due to associated cardiovascular morbidities and therefore a priori at risk for deteriorated peripheral hand circulation, in particular when high flow brachial artery-based accesses may induce steal.

Yeager *et al.* found ischemia of the hand in ESRD patients with primarily distal atherosclerotic arteries.[13] These poor atherosclerotic arteries have less ability to adapt to higher flows than healthy arteries. Taken this theory into account, in these fistulas less flow will go through the fistula and to the already impaired atherosclerotic peripheral circulation. Thus,

Table 5. Preoperative vessel parameters for the non-ischemia and ischemia group

	Non ischemia	Ischemia	*P*-value	*P*-value multivariate analysis
Brachial artery diameter (mm) (SE)	4.2 (.1)	4.7 (.2)	.063	.359
Brachial artery volume flow (ml/min) (SE)	78.3 (9.2)	95.4 (17.2)	.417	
Radial artery diameter (mm) (SE)	2.3 (.1)	2.5 (.1)	.197	
Radial artery volume flow (ml/min) (SE)	19.3 (2.6)	31.9 (7.2)	.078	**.034**
Ulnar artery diameter (mm) (SE)	1.9 (.1)	2.0 (.2)	.871	
Systolic finger blood pressure (mmHg) (SE)	146 (6)	154 (8)	.710	
Systolic blood pressure (mmHg) (SE)	149 (7)	154 (8)	.835	
Digit/Brachial Index (SE)	0.97 (.02)	1.00 (.03)	.594	

Preoperative duplex parameters. The values in the fourth column represent the *p*-value found in an univariate Cox-regression analysis for ischemia. Variables with a *P*-value smaller then .1 were put in a multivariate Cox-regression for ischemia. Last column represent the *p*-value found in the multivariate backward regression. When *P*-value is <.05, the parameter is considered a statistically significant predictor for ischemia. Bold number indicates the statistical significant parameter.

a history of peripheral arterial reconstruction of the legs indicates also a poor peripheral circulation in the upper extremity and therefore a higher risk for ischemia of the hand.

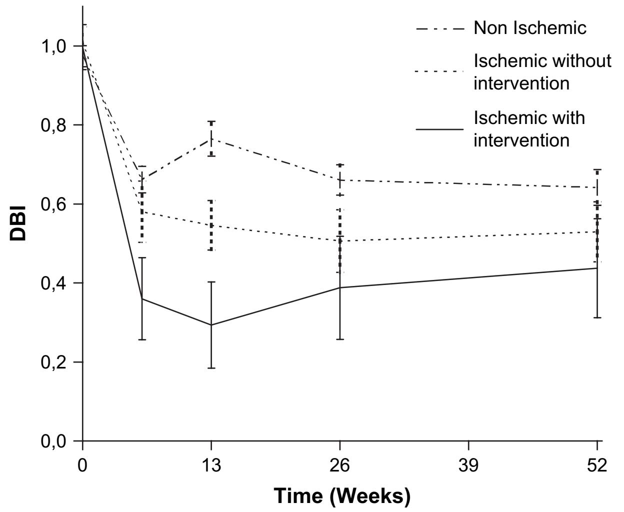


Fig. 2. Digit-to-brachial index in brachial–basilic (BB-AVF) and prosthetic graft AVF (PTFE). Digit-to-brachial index (DBI) is shown with standard error bars for the non-ischemia group, the ischemia group without intervention and the ischemia group with intervention. There is a significant difference in DBI between the non-ischemia group and the ischemia group ($P = .03$).

We found volume flows of the distal radial artery to be an independent predictive variable for the occurrence of ischemia. An explanation for this may be a greater impact of steal on the blood flow to the hand. Another explanation could be that patients with low radial artery volume flows already developed collateral blood flow to the hand, which compensates steal phenomenon due to the fistula.

Access volume flows were at no time point different between the ischemia and non-ischemia group. Therefore this parameter is not useful to discriminate between patients with and without distal hypoperfusion. On the other hand, determination of the access flow is of importance to outline the strategy for treatment. Flow reduction procedures for instance by access banding is the primary option in high-flow arteriovenous fistulas,[8,14] whereas in normal/low-flow fistulas the distal revascularisation and interval ligation (DRIL) procedure or proximalisation of the arteriovenous anastomosis are recommended.[9,15,16]

The digit-to-brachial index (DBI) is described to be a predictor for the occurrence of ischemia, although different cut-off values (.60 to 1.00) for ischemia have been proposed.[8,11,12,14,17,18] In this study the DBI at 6 weeks postoperatively was lower compared to preoperative values and remained unchanged during the follow up in most patients. This is in accordance with the findings of Papasavas *et al.*, who reported a significant change in DBI directly after operation, which remained stable from there on.[18] In the univariate Cox-regression analysis we found the preoperative DBI not to be a predictor for the occurrence of ischemia. However a significant decreased DBI was seen six weeks after operation in the ischemia group, with very low values (<.4) in patients who needed interventions. Also, Valentine *et al.* were not able to determine a preoperative DBI threshold that could indicate the development of postoperative ischemia.[12] Others studies reported a DBI of <.6 direct postoperative or <.45 intraoperatively as a predictor for ischemia, but could not indicate when to intervene on basis of these values.[11,18] Therefore, the DBI measurement might possibly be a method for the diagnosis of patients with suspicion on ischemic symptoms and might be helpful to support the decision for intervention, although the clinical symptoms prevail in the final decision to treat the patient. Access preservation and relief of symptoms are the ultimate goals of treatment. The major key for a successful outcome is angiography with visualisation of the in- and outflow arterial tree.

Sixty-six percent of the patients with severe ischemia in this study had an angiographically proven subclavian artery stenosis. After percutaneous dilatation, ischemic symptoms disappeared in only one patient, despite an adequate PTA with no residual stenosis. In the BB-AVF group we performed distal arterial flow enhancement by proximalisation of the arteriovenous anastomosis with graft implantation as described by Zanow *et al*.[9] Although they reported good results with this technique, we had to ligate these two fistulas because of persistent ischemia. Duplex investigation showed steal in the brachial artery distal of the newly created proximal anastomosis.

In summary, steal is a rather common complication after vascular access creation (28% in this population). This study showed, in a multivariate Cox'regression, age, history of peripheral arterial reconstruction and distal radial artery volume flow to be predictors for the development of symptomatic ischemia of the hand after vascular access creation. There is no difference in occurrence of ischemia between brachial–basilic or forearm graft AVF. Furthermore, DBI measurement might be an important surveillance method and can indicate whether a patient will develop ischemia or not. Future studies on the pre- and postoperative forearm vessel hemodynamics may indicate better predictors for the development of ischemia after access creation.

Acknowledgement

This study was supported by a research grant from the Dutch Kidney Foundation.

References

1 Odland MD, Kelly PH, Ney AL, Andersen RC, Bubrick MP. Management of dialysis-associated steal syndrome complicating upper extremity arteriovenous fistulas: use of intraoperative digital photoplethysmography. *Surgery* 1991;**110**:664–669 [discussion 669–670].
2 Levine MP. The hemodialysis patient and hand amputation. *Am J Nephrol* 2001;**21**:498–501.
3 Morsy AH, Kulbaski M, Chen C, Isiklar H, Lumsden AB. Incidence and characteristics of patients with hand ischemia after a hemodialysis access procedure. *J Surg Res* 1998;**74**:8–10.
4 Tordoir JH, Dammers R, van der Sande FM. Upper extremity ischemia and hemodialysis vascular access. *Eur J Vasc Endovasc Surg* 2004;**27**:1–5.
5 Zerbino VR, Tice DA, Katz LA, Nidus BD. A 6 year clinical experience with arteriovenous fistulas and bypass for hemodialysis. *Surgery* 1974;**76**:1018–1023.
6 Zibari GB, Rohr MS, Landreneau MD, Bridges RM, DeVault GA, Petty FH *et al*. Complications from permanent hemodialysis vascular access. *Surgery* 1988;**104**:681–686.
7 van Hoek F, Scheltinga MR, Kouwenberg I, Moret KE, Beerenhout CH, Tordoir JH. Steal in hemodialysis patients depends on type of vascular access. *Eur J Vasc Endovasc Surg* 2006;**32**:710–717.
8 Clinical practice guidelines for vascular access. *Am J Kidney Dis* 2006;**48**(Suppl. 1):S176–S247.
9 Zanow J, Kruger U, Scholz H. Proximalization of the arterial inflow: a new technique to treat access-related ischemia. *J Vasc Surg* 2006;**43**:1216–1221 [discussion 1221].

10 Mattson WJ. Recognition and treatment of vascular steal secondary to hemodialysis prostheses. *Am J Surg* 1987;**154**: 198−201.
11 Tynan-Cuisinier GS, Berman SS. Strategies for predicting and treating access induced ischemic steal syndrome. *Eur J Vasc Endovasc Surg* 2006;**32**:309−315.
12 Valentine RJ, Bouch CW, Scott DJ, Li S, Jackson MR, Modrall JG *et al*. Do preoperative finger pressures predict early arterial steal in hemodialysis access patients? A prospective analysis. *J Vasc Surg* 2002;**36**:351−356.
13 Yeager RA, Moneta GL, Edwards JM, Landry GJ, Taylor Jr LM, McConnell DB *et al*. Relationship of hemodialysis access to finger gangrene in patients with end-stage renal disease. *J Vasc Surg* 2002;**36**:245−249 [discussion 249].
14 Tordoir JH, Mickley V. European guidelines for vascular access: clinical algorithms on vascular access for haemodialysis. *Edtna Erca J* 2003;**29**:131−136.
15 Berman SS, Gentile AT, Glickman MH, Mills JL, Hurwitz RL, Westerband A *et al*. Distal revascularization-interval ligation for limb salvage and maintenance of dialysis access in ischemic steal syndrome. *J Vasc Surg* 1997;**26**:393−402 [discussion 402−404].
16 Knox RC, Berman SS, Hughes JD, Gentile AT, Mills JL. Distal revascularization-interval ligation: a durable and effective treatment for ischemic steal syndrome after hemodialysis access. *J Vasc Surg* 2002;**36**:250−255 [discussion 256].
17 Goff CD, Sato DT, Bloch PH, DeMasi RJ, Gregory RT, Gayle RG *et al*. Steal syndrome complicating hemodialysis access procedures: can it be predicted? *Ann Vasc Surg* 2000;**14**:138−144.
18 Papasavas PK, Reifsnyder T, Birdas TJ, Caushaj PF, Leers S. Prediction of arteriovenous access steal syndrome utilizing digital pressure measurements. *Vasc Endovascular Surg* 2003;**37**:179−184.

Accepted 3 November 2007
Available online 2 January 2008