

*Original Article*

## **Prospective evaluation of failure modes in autogenous radiocephalic wrist access for haemodialysis**

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### **Abstract**

**Introduction.** Radiocephalic wrist arteriovenous fistulae (RCAVF) are the primary and best option for vascular access for haemodialysis treatment. However, 10–24% of these AVFs fail due directly to thrombosis and non-maturation. In a prospective study, the failure modes of radiocephalic AVFs and the impact of surgical and interventional treatment on fistula outcome were investigated.

**Methods.** The rate of thrombosis and non-maturation was evaluated in 43 RCAVFs. The selection of RCAVF creation was made on preoperatively determined duplex parameters. Fistula function was evaluated post-operatively by clinical examination and non-invasively measured AVF blood flow. A policy of a liberal use of radiological and/or surgical revision of non-functioning RCAVFs was made on the basis of duplex measured blood flow and angiographically detected vessel stenosis.

**Results.** Primary fistula function was achieved in 26 of 43 patients (60%). Non-maturation and thrombosis occurred in 14 (33%) and three (7%) patients, respectively. A total of 12 interventions (PTA 6; surgery 6) were needed, resulting in salvage of eight RCAVFs (47%). The blood flow in functioning AVFs was significantly higher compared to non-functioning AVFs at 1 (754 vs 440 cc/min), 7 (799 vs 524 cc/min) and 42 days (946 vs 532 cc/min) post-operatively. At the end, 34 RCAVFs (79%) became functional as vascular access for haemodialysis treatment.

**Conclusion.** Primary RCAVFs have a high rate of failure. An aggressive approach towards early interventional treatment of these non-functional AVFs is worthwhile and leads to a considerable salvage rate. Early post-operative AVF flow measurement indicates the chance of successful maturation of RCAVF.

**Keywords:** fistulae; haemodialysis; intervention; non-maturation; radiocephalic vascular access

### **Introduction**

Autogenous radiocephalic arteriovenous fistulae (AVF) have been regarded for the past 35 years as the primary and best choice for vascular access in haemodialysis patients. In Europe, an overall 80% of prevalent patients have autogenous AVFs as a vascular access, while only 24% of patients in the United States use an AVF [1]. When a radiocephalic wrist arteriovenous fistula (RCAVF) successfully matures after the surgical creation, it may function for years with a low risk of complications and low incidence of revisions. However, 10–24% of RCAVFs thrombose directly after operation or do not function adequately due to failure of maturation [2–6]. Usually, AVF thrombosis and non-maturation depend on the quality and size of the vessels used for the arteriovenous anastomosis and the ability of vessel adaptation induced by the augmented blood flow volumes. A preoperative assessment of upper extremity vessel characteristics seems therefore worthwhile to define arteries and veins suitable for autogenous AVF creation. Recently, several duplex-derived criteria have been developed that show a beneficial effect on RCAVFs of using well-sized radial arteries and cephalic veins [7–9]. However, AVF failure and non-maturation may still occur despite anastomosing adequate vessels, and in a high percentage of these patients, anatomical abnormalities like stenoses are correlated with non-functioning accesses. An aggressive approach to the treatment of these lesions by surgical or radiological intervention has been advocated in recent years, with a favourable outcome on fistula function [10].

Therefore, we performed a prospective study to obtain insight into the failure modes of autogenous

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radiocephalic wrist accesses and the impact of interventions on fistula function.

## Subjects and methods

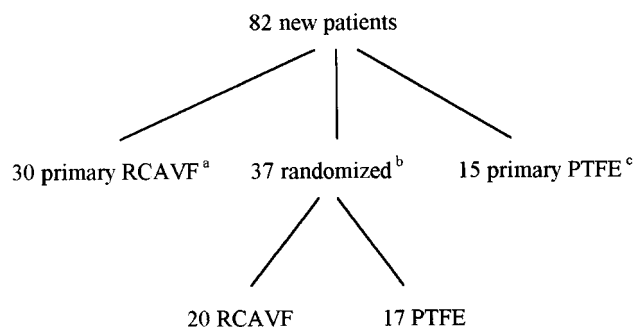
Of the 82 AVFs performed in new patients at our institution between January 1999 and June 2002, 43 autogenous radiocephalic wrist accesses were created. During the same period 141 secondary procedures were performed. The patients were operated on by a single vascular surgeon or senior resident supervised by this surgeon. All patients underwent preoperative duplex ultrasonography of the arteries and superficial veins of the upper extremity. Vessel diameters, arterial obstructions, vein compressibility and vessel continuity were registered. Based on this preoperative duplex examination, patients were allocated to receive a primary RCAVF (non-randomization group), a primary prosthetic graft implantation or randomization between primary RCAVF (randomization group) and prosthetic graft implantation. The criteria for this algorithm are outlined in Figure 1.

### Operative procedure

The construction of the RCAVF was performed under regional axillary block or general anaesthesia with the use of antibiotic prophylaxis. The radial artery and cephalic vein were exposed through a longitudinal or transverse incision 4–5 cm proximal of the radial styloid process. After sufficient vein mobilization an end-to-side vein-to-artery anastomosis was performed with a running 7×0 polypropylene (Prolene) suture. The length of the arteriotomy was 10–15 mm and vessel diameters were measured with coronary probes. AVF patency was confirmed peroperatively by palpation and Doppler examination. Postoperative evaluation was done by palpation and auscultation. Patients were regularly seen by the nephrologist and the decision to start dialysis treatment was made on the severity of deterioration of renal function. First cannulation was performed when the vessels had matured adequately, usually after 4–6 weeks. When cannulation was not possible due to non-maturation, dialysis was started by means of central-vein catheters.

### Follow-up

All patients were followed with duplex ultrasound scanning including measurement of the amount of blood flow through



**Fig. 1.** Algorithm for the creation of vascular access in new patients. <sup>a</sup>Radial artery  $\geq 2$  mm and cephalic vein  $\geq 1.6$  mm; <sup>b</sup>radial artery  $\geq 1$ / $< 2$  mm or cephalic vein  $< 1.6$  mm; <sup>c</sup>radial artery  $< 1$  mm or cephalic vein occlusion.

the radial artery, 1, 7 and 42 days after operation. Patency was defined as functional patency with adequate dialysis.

Clinical criteria were used for detection of AVF thrombosis and non-maturation. Inability to cannulate the AVF or to obtain sufficient dialysis blood flow ( $> 250$  cc/min) within 6 weeks after fistula creation were indicators of a poorly functioning AVF. All patients with non-maturing RCAVFs underwent angiography, visualizing the proximal arterial inflow by retrograde contrast filling initiated through a proximal occluding cuff. Venous outflow vessels were imaged by contrast injection after the release of the proximal cuff.

### Revisions

Short segmental stenotic lesions ( $< 1$  cm) in the cephalic vein underwent balloon angioplasty, while anastomotic stenoses were surgically revised by creating a more proximal anastomosis between the radial artery and the cephalic vein. RCAVFs without demonstrable stenoses, usually indicating poor vessel remodelling, were abandoned and replaced by new accesses. Failed balloon angioplasties underwent open surgical revision whenever possible.

### Statistical analysis

Patient characteristics and duplex parameters of non-functioning and functioning AVFs were compared with the Student's *t*-test and the Fisher exact test when appropriate. Functional patencies were determined by the Kaplan–Meier survival analysis and compared with the Log-rank method. A *P*-value  $< 0.05$  was considered statistically significant.

## Results

During a 3½-year period, 82 consecutive new patients needing primary vascular access were enrolled in a prospective randomized study. According to defined vessel criteria from the preoperative duplex scanning, 30 patients were allocated to primary placement of a RCAVF, of which two patients received PTFE grafts because vessels unsuitable for a direct anastomosis were found. Fifteen patients underwent primary prosthetic graft implantation and 37 patients were randomized to receive either an RCAVF ( $n=20$ ) or prosthetic graft AVF ( $n=17$ ). Of the patients randomized for a RCAVF, five exhibited insufficient wrist vessels, and received PTFE graft AVFs. A total of 28 and 15 RCAVFs in the non-randomization and randomization groups, respectively, were subjected to further analysis (Figure 1).

### Non-randomization group

Primary thrombotic occlusion occurred within a week in one patient (4%). No attempt at revision was made and this patient received a new AVF. A primary function for dialysis was achieved in 20 patients (71%) with a mean time to first cannulation of 52 days (range 28–114 days). Seven RCAVFs (25%) failed to mature and underwent four procedures after a mean period of 79 days (range 47–112 days). Subclavian-artery and

cephalic-vein stenosis in two patients were successfully treated by PTA, and anastomotic stenoses in two patients by surgical revision, performing a more proximal radiocephalic anastomosis. Three patients received new AVFs, while no evident cause for non-maturation was detected by angiography. At the end of the study, the total number of functioning AVFs was 24 of 28 initially created RCAVFs (86%). Primary functional patencies were 71 and 64% after 90 and 180 days, respectively.

#### Randomization group

In the randomization group there were two patients (13%) with a thrombosed RCAVF, and in these patients new AVFs were created. Primary function was observed in only six patients (40%) and these fistulae could be used for dialysis after a mean period of 86 days (range 54–123 days). Non-maturation occurred in seven patients (47%) and eight interventions (PTA 4, new proximal anastomosis 3, graft interposition 1) were needed, resulting in functional accesses in four patients. In one patient surgical revision failed and in this subject a prosthetic graft was implanted. Two patients received a new AVF, although no correctable lesions could be detected on the angiogram. A total of 10 RCAVFs (67%) became functional in the randomization group. The primary patencies were 40 and 36% after 90 and 180 days, respectively. These patencies were significantly different from the non-randomization group.

#### Clinical variables

Patient characteristics in the non-functioning and functioning RCAVFs are shown in Table 1. Female gender and cardiac disease were significantly correlated to failure of AVF maturation. The use of antiplatelet or anticoagulant drugs showed no relationship with AVF malfunctioning.

#### Duplex parameters

In Figure 2 the radial-artery and cephalic-vein diameters, measured preoperatively by duplex scanning in the functional and failed RCAVFs, are outlined. The mean radial-artery diameters in both groups were similar (2.3 vs 2.5 mm); however, cephalic-vein diameters were significantly smaller in the non-functioning AVFs (1.8 vs 2.2 mm;  $P=0.04$ ). Post-operative radial-artery blood flow, measured by duplex scanning, is outlined in Figure 3. All patients, including those with non-maturing AVFs, had a complete duplex follow-up to 42 days. The thrombosed AVFs ( $n=3$ ) had only one flow measurement the first postoperative day. After 1, 7 and 42 days a significant increase in blood flow was observed in the functional RCAVFs. However, in non-maturing AVFs the radial artery flow remained significantly lower compared to the functioning AVFs at 1, 7 and 42 days

**Table 1.** Clinical variables and duplex-derived vessel diameters in non-functioning and functioning RCAVF

	Non-functioning	Functioning	P-value
<i>n</i>	17	26	
Male	7 (41)	19 (73)	0.045
Age (years)	67.4 ± 10.7	65.8 ± 10.3	0.623
Medical history			
diabetes	4 (23)	6 (23)	0.711
hypertension	9 (53)	14 (54)	0.988
ischaemic cardiac disease	12 (71)	7 (27)	0.005
peripheral vascular disease	4 (23)	4 (15)	0.863
cerebrovascular disease	2 (12)	3 (11)	0.663
anticoagulation	5 (29)	9 (35)	0.937
Causes of ESRD			
arteriosclerosis	6 (35)	12 (46)	0.856
diabetic nephropathy	2 (12)	2 (8)	0.505
pyelo-/glomerulo-nephritis	3 (18)	3 (11)	0.460
polycystic kidney disease	4 (23)	2 (8)	0.078
unknown	1 (6)	2 (8)	0.746
others <sup>a</sup>	1 (6)	5 (19)	0.014
Preoperative diameter			
radial artery (mm)	2.3 ± 0.4	2.5 ± 0.7	0.186
cephalic vein (mm)	1.8 ± 0.4	2.2 ± 0.6	0.039

<sup>a</sup>Cyclosporin-induced nephropathy, IgA nephropathy, bilateral nephrectomy (kidney tumour), haemolytic-uraemic syndrome and hydronephrosis.

(mean flows in cc/min, 440 vs 754, 524 vs 799 and 532 vs 946;  $P < 0.05$ ).

#### Discussion

Compared to patients with prosthetic AVFs, patients with autogenous AVFs need significantly fewer interventions and hospital admissions to maintain functional vascular access. Therefore it seems vital to obtain autogenous fistulae in all new dialysis patients. However, with this 'all autogenous' policy, it may be anticipated that in a considerable number of patients there will be failure to create a functioning access because of thrombosis or non-maturation of the fistula. Until now it has not been clear which type of patients are at risk of these problems, and in recent years some authors have attempted to develop objective criteria for selecting patients who would benefit from autogenous AVFs. Certain duplex-derived parameters may predict the risk on failure or dysmaturation. The internal radial artery diameter has been used in several studies to predict the outcome of radiocephalic AVFs or to plan strategies for vascular access. Wong *et al.* [11] observed primary failure of RCAVFs in patients with a radial artery and/or cephalic vein diameter of <1.6 mm. In another study, successful AVFs had a preoperatively measured radial artery diameter of 2.7 mm vs 1.9 mm in failed AVFs [7]. Malovrh [12] discriminated between patients who received an RCAVF with a radial artery diameter >1.5 mm and those with a radial artery diameter ≤1.5 mm. The success rate in the >1.5 mm group was 92% vs 45% in the ≤1.5 mm group.

Although the importance of using well-sized radial arteries for creating radiocephalic AVFs is well

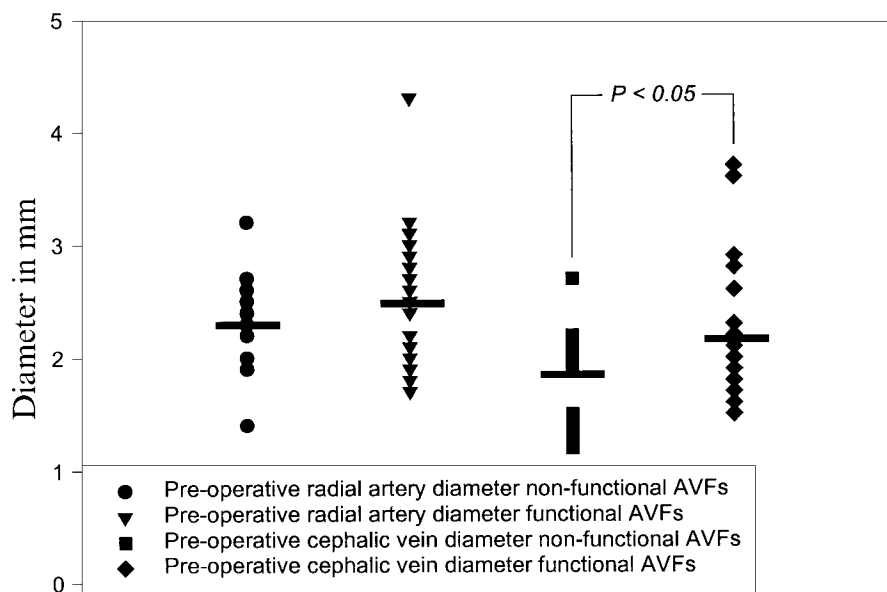


Fig. 2. Preoperative radial artery and cephalic vein diameter (in mm) in non-functioning and functioning RCAVF.

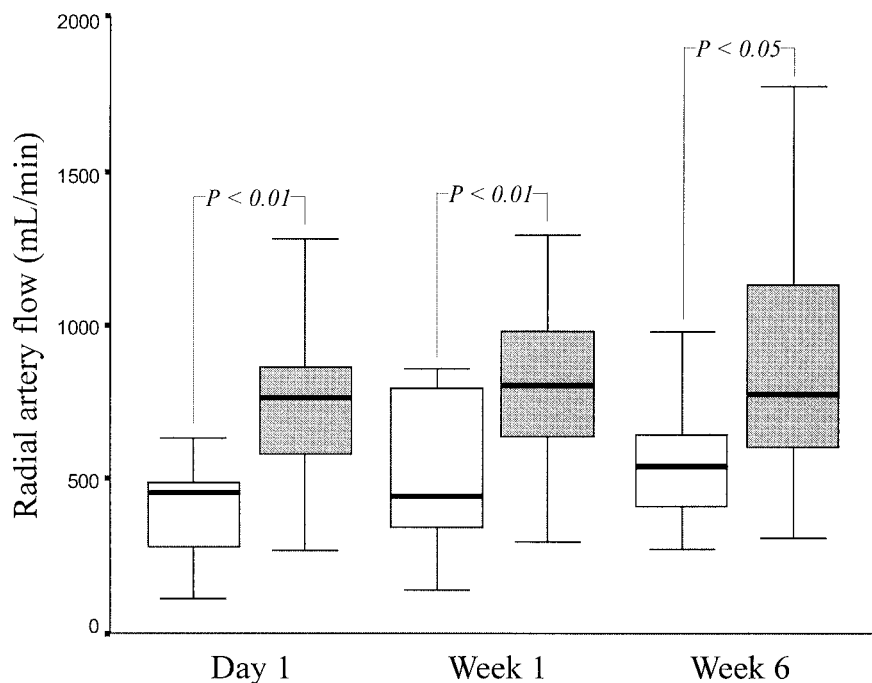


Fig. 3. Postoperative radial artery blood flow (ml/min) in non-functioning RCAVF (white box) and functioning RCAVF (grey box).

established in the literature, we could not detect a significant impact of arterial diameters on fistula outcome. Small variations of arterial diameters in the patients studied may be the explanation for this. Cephalic-vein diameters were significantly associated with non-maturation, and this finding agrees well with the few data from the literature. An increase in the number of RCAVFs from 14 to 63% after the institution of a standard preoperative workup was observed in the study of Silva *et al.* [8]. Strategies for vascular access creation in this study were based on preoperative duplex scanning. Patients with a radial-artery

diameter of  $\geq 2$  mm and a cephalic vein diameter of  $\geq 2.5$  mm received RCAVFs, while graft AVFs were placed in patients with smaller diameter radial arteries and cephalic veins, with an outflow vein in the elbow with a diameter of  $\geq 4$  mm. However, from these studies it appeared that 8–10% of patients who were adjudged to have adequate vessels, still developed non-functioning AVFs.

From the published data, we have adapted the preoperative vessel criteria used in the present study. With this policy of selecting patients with ‘good’ vessels (radial artery  $\geq 2$  mm, cephalic vein  $> 1.6$  mm)

for RCAVF creation, a high percentage of functioning fistulae could be established. However, 14% of these fistulae did not function at all and another 14% needed additional measures such as PTA and surgery to get them working. On the other hand, the risk of early failure of RCAVFs when small vessels are selected for the arteriovenous anastomosis is much higher. In particular, small-calibre cephalic veins were significantly associated with access failure, while radial artery diameters were not. Only 40% in the group with small veins had an initial function for dialysis, while 27% could be salvaged by multiple interventions. From our data, we conclude that preoperative vessel evaluation can help in the decision to choose autogenous vascular access that has a greater chance of functioning (86% of patients with 'good' vessels had a functioning radiocephalic AVF). However, 14% of patients encountered RCAVF failure, and one might wonder if the accepted vessel diameters for RCAVF creation in this study were possibly too small. In patients with small arteries and veins it is probably wise to create primarily an AVF at another site in the upper extremity using large-calibre vessels. Only 43 RCAVFs out of 82 new vascular accesses could be established in this study. We decided to randomize patients with small vessels for an RCAVF or prosthetic graft implantation. Patients with occluded forearm vessels were directly allocated a prosthetic graft AVF. This policy is different from some European studies in which mainly autogenous elbow or upper arm AVFs were created when an RCAVF was not possible [1]. This means that in these studies a high percentage of autogenous AVFs have been reported. In addition the percentage of functioning RCAVFs from the present study was lower compared with other studies. This might be explained by the fact that RCAVFs were also created with the use of small vessels, resulting in a high failure rate.

Anastomotic and cephalic-vein stenoses were angiographically diagnosed in most patients and were eligible for intervention; however, in five patients no anatomical abnormalities could be detected. Inability of vessel adaptation (remodelling) in response to an increase in flow may be responsible for non-maturation in these patients [13]. To what extent vessel-wall stiffness or calcification, for example in diabetic or arteriosclerotic patients, may influence non-maturation is still unknown. In a published series, controversial influences of diabetes mellitus on fistula outcome were reported [14]. We were not able to show a significant negative effect of diabetes mellitus on fistula outcome. Surprisingly, cardiac co-morbidity did result in higher non-maturation rates. It is well known that patients with coronary-artery sclerosis may also exhibit peripheral vascular disease. This feature may be the reason for non-maturation in these patients. On the other hand, it remains puzzling that diabetics, with usually inherent coronary-artery disease, showed no increased risk of AVF failure in our study. Probably, smaller vessels are the reason for significantly higher percentages of non-maturation in

females. No data on the accuracy of imaging superficial veins in the forearm are known. In this respect, we did find a discrepancy between operative findings and duplex measurements in two patients in the group with 'good' vessels, and in five patients in the randomization group. The outcome of duplex scanning depends on the experience of the vascular technician and is therefore a purely subjective method of investigation. More objective techniques such as magnetic resonance angiography or computer-tomographic angiography may possibly increase the accuracy of preoperative imaging [15].

Blood flow in the radial artery, measured by duplex ultrasound 1 and 7 days after the operation may predict maturation [11]. Low blood-flow rates and velocities in the fistula within the first 2 weeks usually result in fistula failure. A radial-artery cross-sectional area of  $>8.5 \text{ mm}^2$  and venous flow of  $>425 \text{ ml/min}$ , measured postoperatively, have a positive predictive value of 0.95 and 0.97, respectively, for the outcome of radiocephalic AVFs [16]. This predictive value of postoperative flow measurement was also shown in the present study. Failed RCAVFs had lower blood flows through the radial artery compared to successful fistulae 1, 7 and 42 days after operation. Also, insufficient augmentation of blood flow after 42 days was observed in non-maturing AVFs and on the basis of these measurements, angiography was indicated.

In the current study a prospective analysis of failure modes of autogenous RCAVFs was performed from duplex parameters and angiographic findings. In 64% of the patients an anatomical lesion at or near the AV anastomosis, amenable to radiological or surgical intervention, was visualized. Similar observations were reported in 52 patients with non-maturing AVFs [10]. All fistulae showed significant stenoses, half of which were located in the anastomotic area. Interventional treatment by means of PTA and stent placement resulted in maturation in 97% of patients. The impact of re-intervention on fistula maturation and maintenance was recently published by two American studies [17,18]. In these series, not only radiocephalic but also a significant number of brachiocephalic and brachio-basilic AVFs were included. A 10% improvement in accomplishing a functional autogenous access was achieved by either PTA or surgical procedures. Balloon angioplasty, vein patch, interposition or transposition and new proximal radial-artery-cephalic-vein anastomoses were employed. The authors suggest that simple and extended salvage procedures may allow maturation with an advantage for surgical revision as compared with percutaneous techniques, in terms of requiring fewer subsequent procedures.

Patients with non-matured AVFs due to insufficient augmentation of blood flow because of remodelling failure of the radial artery (inability to dilate in anatomically small or atherosclerotic vessels), are not cured by AVF revision, but by the construction of a new AVF anastomosing large vessels, usually near the elbow.

In summary, we have investigated the failure modes of radiocephalic wrist accesses and the impact of radiological and surgical intervention on fistula outcome. Non-maturation occurred in 33% of RCAVFs, and in 64% of patients, anatomical abnormalities were found with angiography. The liberal use of interventions resulted in a salvage rate of 47% for non-matured AVFs.

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