

Dialysis Fistulae Patency and Preoperative Diameter Ultrasound Measurements

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Background. This study was designed to investigate the possibility of defining a vascular diameter with a practical cut-off point, which predicts a successful patency for radiocephalic arteriovenous fistulae in dialysis patients.

Methods. This is a retrospective analysis of prospectively gathered data. Consecutive patients (n = 148) with chronic renal failure, needing vascular access for haemodialysis, were included if they underwent duplex ultrasound examination to evaluate preoperatively the vascular status and diameters for radiocephalic arteriovenous fistulae (RCAVF) construction. The associations between the diameter of the radial artery and cephalic vein and primary failure at six weeks, primary and secondary patency at one year were investigated.

Results. There was no significant association between either radial artery diameter or dilated cephalic vein diameter and primary failure. There was an association between radial artery diameter and primary patency (Overall P = 0.042). Males had a significantly larger mean radial artery diameter than females (P = 0.005). Gender did not influence primary patency.

Conclusion. We recommend using radial artery diameters of ≥ 2.1 mm and ≤ 2.5 mm for RCAVF construction, this diameter category having the highest patency at 1 year. A single cut-off guideline cannot be recommended.

Keywords: Arteriovenous fistulae; Duplex ultrasound; Vascular diameters.

Introduction

Duplex ultrasound is recommended in the preoperative strategy for placement of an arteriovenous haemodialysis fistula. Both the K-DOQI and European guidelines recommend a primary radiocephalic arteriovenous fistula (RCAVF) for haemodialysis as best practice. However, duplex ultrasound criteria of vascular diameters predicting good outcome vary.^{1–3}

Duplex ultrasound examination has been described as a valid, accurate and useful diagnostic tool in the evaluation of blood vessels of the upper extremities. Duplex ultrasound examination has been compared to angiography with respect to visualisation, detection and quantification of stenotic lesions and occlusions in both native arterial- and venous segments as well as arteriovenous fistulae in upper extremities. From the subclavian artery down to the distal lower arm

arteries, a sensitivity of 90% and a specificity of 99% have been reported. For the detection of vascular alterations in access fistulae a sensitivity of 89% and a specificity of 95% is reported.⁴ Blood vessels and their diameters are assessed during preoperative duplex ultrasound prior to construction of an autogenous RCAVF.^{5,6} The suggested minimum radial artery diameter varies from 1.6 mm to 2.0 mm or more and for the cephalic vein 1.7 mm to 2.5 mm or more is advocated.^{3,5–9} Publications have suggested that small artery and vein diameters may be responsible for primary failure.^{7,10,11} A recently published meta-analysis described a mean primary failure rate of 15.3% (6%–34%).¹⁰

The primary aim of this study was to explore whether there was a significant association between the pre-operative arterial and venous diameter values determined by duplex ultrasound and the patency and failure of RCAVFs. Another goal was to find an optimal range of arterial and/or venous diameter values for the successful construction of RCAVFs for haemodialysis patients.

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Subjects and Methods

Patients. The study group comprised 148 patients, 81 (55%) male and 67 (45%) female, with chronic renal failure. The mean age at operation was 65 years (range 23-85). Diabetes Mellitus was present in 31% of the patients. 134 (91%) of the RCAVFs were created in the left arm and 14 (9%) in the right arm. The arm of choice was based on manual dexterity and the quality of the vessels as a result of clinical and ultrasound examination: preference was given to the least dexterous arm.

Study design. A retrospective analysis of prospectively gathered data, collected from January 2000 until December 2003. 148 RCAVFs were created in this four-year period. Outcome parameters were primary failure, primary patency and secondary patency. The follow-up for primary and secondary patency was based at 1 year post-operatively. Duplex diameter measurements of the radial artery and cephalic vein were carried out at wrist level and were related to the outcome parameters. Primary failure was defined as thrombosis of the RCAVF or inadequate maturation, which resulted in inadequate dialysis access at 6 weeks after surgery. Primary patency was defined as the interval between the date of operation and the first intervention irrespective whether this involved surgery or percutaneous transluminal angioplasty (PTA). Secondary patency was defined as the total interval between the date of operation and definite access failure. Interventions for access thrombosis or other complications were admissible during this period.^{3,10,11} A pneumatic cuff inflator (Hokanson E20, Hokanson, Bellvue, USA) was used to accomplish maximal dilatation of the cephalic vein by means of occlusion.

Duplex ultrasound examination. The vascular diameters of the patient population were determined preoperatively using duplex ultrasound performed by experienced and registered vascular technologists. A 10-5 MHz broadband transducer (Aloka, ProSound SSD-5500, Aloka, Tokyo, Japan) and a 12-5 MHz broadband transducer (Philips HDI 5000, Philips, Eindhoven, The Netherlands) were used. Anter-posterior internal diameter measurements of the radial artery and cephalic vein were made in the transverse plane in close proximity to the wrist.

Physical properties of arm arteries such as vascular wall irregularities and calibres were examined as well as haemodynamic properties, such as the doppler waveform and the peak systolic velocities measured using an angle correction of 60° or less. (Fig. 1) The examination started with the subclavian artery continuing along the different arm branches terminating at

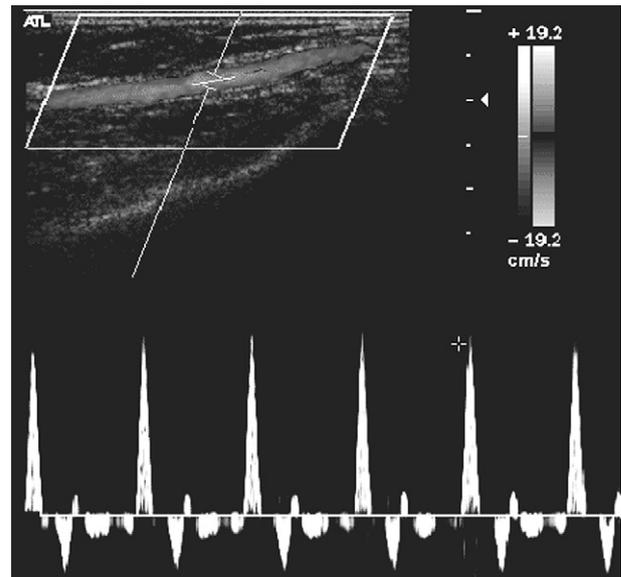


Fig. 1. Radial artery. Longitudinal plane with color-doppler and pulsed-doppler. Peak systolic velocity: 52 cm/sec. The bone structure in B-mode is used as an important landmark.

the ulnar and radial artery at wrist level. In cases of pathology such as a stenotic lesion or occlusion, alternative suitable locations were considered for the creation of an arteriovenous fistula.¹⁻³ In accordance with Gardner *et al.* patients were examined in a seated position with extended arm supported on a trolley at heart level. The venous system was occluded using a standard 10 cm cuff placed on the arm as proximal as possible. The occlusion cuff was inflated to 80 mmHg, preventing venous outflow.¹² Verification of maximal venous dilatation during the proximal venous occlusion was determined by ultrasound.

Once maximum venous dilatation was established, the diameter was measured and noted (Fig. 2). Venous compression was avoided by using ample ultrasound gel between the transducer and skin surface. The

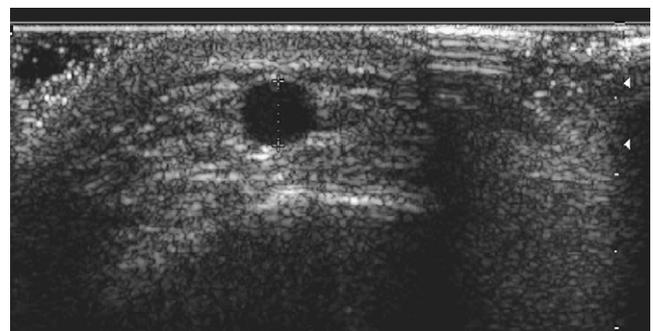


Fig. 2. Cephalic vein. Cross-section. The dilated internal vein diameter is 4.3 mm, in this patient.

complete venous system of the arm was examined taking careful note of diameter variations, continuity and branching. The superficial system was followed from the wrist towards the diverse drainage points in the deep system right up to the subclavian vein as proximal as possible. In order to dismiss the possibility of obstruction through thrombosis, ultrasound compression of the vein was applied. Flow augmentation, during breathing and repetitive fist clenching, was used in the attempt to detect significant central venous lesions.

Surgical procedure. Regional or general anaesthesia was used. A lengthwise incision, between the radial artery and the cephalic vein, just proximal to the wrist, allows for vein and artery preparation according to the well known Brescia and Cimino technique, developed in 1966.¹³ After intravenous injection of 5000 units of heparin, a sterile roll on cuff (Boazul; Hammerplast Medical AB, Lidköping, Sweden) was used to exsanguinate the arm. The cephalic vein then was clipped distally before being cut through and guided towards the more ventral radial artery. An end-to-side anastomosis was made using uninterrupted polypropylene 7.0 suturing (Prolene; Ethicon, Johnson & Johnson, Amersfoort, The Netherlands), with the end of the vein being cut diagonally and sutured into a length incision of the radial artery. After the roll on cuff was removed the anastomosis was checked for blood leakage. The presence of a thrill or bruit, was confirmed by means of auscultation with a sterile stethoscope in the operation room. The skin wound was then closed using Ethilon 3.0.

Statistical analysis. SPSS 11.5 software for Windows (SPSS Inc., Chicago, Illinois, USA) was used for statistical analysis. Levene's test was used to evaluate primary failure in relation to radial artery diameter and cephalic vein diameter. The Chi-square test was used to evaluate primary failure in relation to various characteristics. The Kaplan-Meier life table analysis, including the log rank test, was used to determine the relationship between vascular diameters and other factors regarding primary patency. Cox regression was used to adjust for covariates. Differences were considered to be significant at $P \leq 0.05$.

Results

The mode diameter of the radial artery was 2.0 mm (Fig. 3). Mean radial artery diameter was 2.3 mm (range 1.1–3.7, $n = 139$, 9 missing). Tertiles of radial artery diameter (≤ 2.0 mm ($n = 50$), ≥ 2.1 mm and ≤ 2.5 mm ($n = 47$), and ≥ 2.6 mm ($n = 42$)) were used for analysis. The mode diameter of the maximum

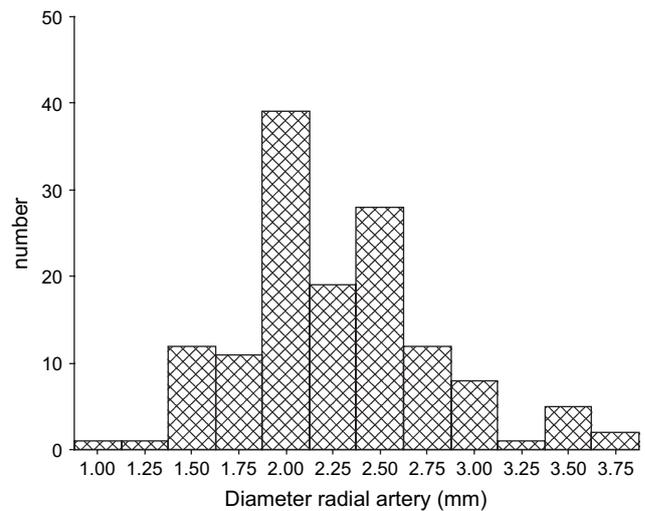


Fig. 3. Frequency distribution of radial artery diameters. Diameters are grouped with an interval size of 0.25 mm. Numbers along horizontal axis represent midpoint of these intervals in mm.

dilated cephalic vein was also 2.0 mm. Mean venous diameter was 2.3 mm (range 0.7–5.9, $n = 148$). Tertiles of dilated cephalic vein diameter (≤ 1.9 mm ($n = 47$), ≥ 2 mm and ≤ 2.6 mm ($n = 56$) and ≥ 2.7 mm ($n = 48$)) were used for analysis.

The primary failure rate was 11% (16/148). There was no significant association between primary failure and either the radial artery diameter ($n = 139$, $P = 0.91$) or the maximum dilated diameter of the cephalic vein diameter ($n = 148$, $P = 0.97$).

Primary patency at 1 year was 57%. Kaplan Meier curves revealed an association between the radial artery diameter and primary patency (Fig. 4, overall $P = 0.042$). Pairwise analysis showed that the middle tertile for radial artery diameter, group B (arterial diameters ≥ 2.1 mm and ≤ 2.5 mm), had better patency than the two other groups, $P = 0.016$ versus group A (diameters < 2 mm) and $P = 0.043$ versus group C (diameters ≥ 2.6 mm). There was no difference between groups A and C ($P = 0.83$). There was no significant association between primary patency and the maximal dilated vein diameter ($P = 0.96$).

Secondary patency at 1 year was 76% with 75 interventions: 22 (29%) PTA and 53 (71%) surgical procedures. Most of the RCAVFs treated by PTA (20, 91%) and 30 (57%) of the fistulae treated surgically remained patent at 1 year.

The diameter of the radial artery was significantly larger in men versus women ($P = 0.005$), but no significant association was established between gender and either the diameter of the cephalic vein ($P = 0.238$) or primary patency ($P = 0.197$) (Table 1). Age and gender did not influence primary patency. Only the diameter

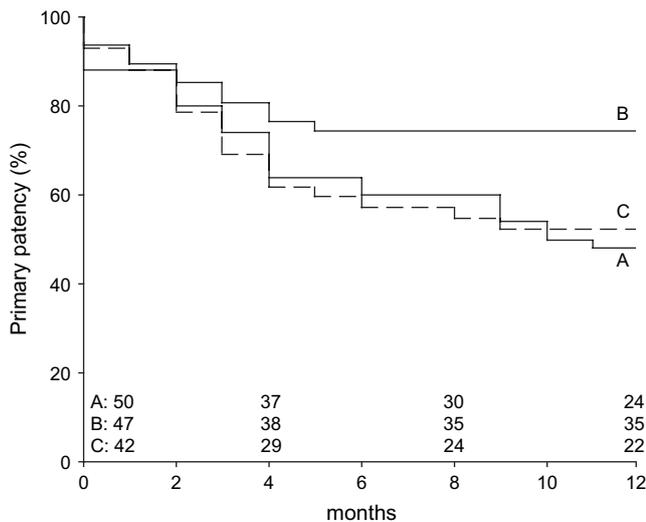


Fig. 4. Primary patency by tertiles of radial artery diameter: Kaplan Meier curves. Curve A: ≤ 2.0 mm, B: ≥ 2.1 mm and ≤ 2.5 mm, C: ≥ 2.6 mm (overall $P = 0.042$). Numbers at risk are given below.

of the radial artery had a significant association with primary patency ($P = 0.037$).

Discussion

The highest primary patency was observed in the group with radial artery diameters ≥ 2.1 mm and ≤ 2.5 mm. A possible explanation for the observation that larger radial artery diameters (>2.5 mm) were associated with a lower patency might be found in the haemodynamic changes, which occur in RCAVFs. Native radial artery shows a high resistance duplex flow pattern which is in the systolic phase a bi- or more phasic doppler waveform (Fig. 1) and zero flow in the diastolic phase. After surgery the radial artery shows a low resistance duplex flow pattern, which is a mono-phasic doppler waveform with a high end

Table 1. Vascular diameters by gender

	Report	Radial artery diameter	Cephalic vein diameter
Male	Mean	2.4	2.4
	<i>n</i>	78	81
	Std. deviation	0.5	1.0
	Median	2.3	2.1
	Minimum	1.4	0.7
	Maximum	3.7	5.9
Female	Mean	2.1	2.2
	<i>n</i>	61	67
	Std. deviation	0.5	0.7
	Median	2	2.1
	Minimum	1.1	0.8
	Maximum	3.7	4.1

diastolic velocity and an increased blood flow volume compared to the native artery. These changes in haemodynamic properties seem to have an impact on the endothelium of the artery. The role of endothelium in vascular remodelling has been documented in experimental studies in large animals. Endothelial cells appear to have the ability to react to tractive forces on the endothelium and keep this within a physiological range by remodelling. Radial artery diameter, flow volume and wall shear stress were calculated with color flow doppler ultrasound *in vivo* in humans, before and after RCAVF creation by Remuzi *et al.*¹⁴ These authors found important increases after surgery. For example: an arterial diameter increased from 2 mm to 2.4 mm, a mean flow volume increased from 11.8 ml/min to 222.9 ml/min and the mean wall shear stress increased from 6.8 dyn/cm² to 73.5 dyn/cm². Another important point to be considered is the maintenance of this wall shear stress during the entire cardiac cycle. This may explain the higher patency found for radial artery diameters range ≥ 2.1 mm and ≤ 2.5 mm. Therefore it can be postulated that the physiological and haemodynamic components seem to be the most favourable in this category. From our results no guidelines for minimum radial artery diameter can be made.

A recent meta-analysis by Rooijens *et al.* showed a pooled estimated primary failure rate of 15% (95 CI: 13%–18%, with 95% of reported rates ranging from 6% to 34%).¹⁰ Our primary failure rate was 11%, this was not significantly different for the mean value of 15% in the meta-analysis, $P = 0.10$. Our primary and secondary patency rates, respectively 57% and 76%, were comparable with the pooled estimated primary and secondary patency rates of respectively 63% and 66%.¹⁰ Our findings differ from a recently published randomised multicentre study in the Netherlands where patients were randomized for construction of a RCAVF or prosthetic forearm loop with radial artery diameters between 1 and 2 mm, and/or cephalic vein diameter ≤ 1.6 mm.¹¹ In the RCAVF category, primary and secondary patencies were respectively 33% and 52%.¹¹ However, in our institution no RCAVFs were constructed when a radial artery diameter was ≤ 1 mm.

High primary failure rates are reported when pre-operative duplex ultrasound is not performed before dialysis fistula construction.^{5–7,15–17} However we did not identify any associations between failure and vascular diameter, perhaps because we assessed maximum internal cephalic vein diameter during pneumatic cuff occlusion. Similarly there was no association between cephalic vein diameter and primary patency in our study, even though 43 (29%) of the

148 patients with a RCAVF had a diameter vein value of <2 mm. This shows that the surgeons did not apply a preoperative venous diameter cut-off point and concurs with findings of Malovrh *et al.* who remarked that the vein's potential distensibility was more important than the diameter.⁹

Non-dilated venous diameters do not seem to predict patency. The optimal value of distensibility (warmth, pharmaceutical) should be further investigated. Van Bemmelen *et al.* used warm water immersion of the arm to further improve distensibility of the arm veins.¹⁸ A prospective study may contribute to further evidence-based standardisation of preoperative duplex ultrasound screening in our hospital and improve the outcome.

Conflict of Interest Statement

We have had no involvements that might raise the question of bias in the work reported or in the conclusions, implication, or opinions stated.

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References

- 1 The Vascular Access Workgroup. NKF-DOQI clinical practice guidelines for vascular access. National Kidney Foundation-Dialysis Outcomes Quality Initiative. *Am J Kidney Dis* 1997; **30**(Suppl. 3):S152–S191.
- 2 National Kidney Foundation. K/DOQI clinical practice guidelines for vascular access. *Am J Kidney Dis* 2000; **37**(Suppl. 1): S137–S181.
- 3 BAKRAN A, MICKLEY V, PASSLICK-DEETJEN J. Management of the renal patient: clinical algorithms on vascular access for haemodialysis. Lengerich: Pabst Science Publishers; 2003.
- 4 WITTENBERG G, SCHINDLER T, TSCHAMMLER A, KENN W, HAHN D. Wertigkeit der farbkodierten duplexsonografie bei der beurteilung von armgefäßen – arterien und hämodialysesesshunts. *Ultraschall in Med* 1998; **19**:22–27.
- 5 SILVA JR MB, HOBSON RW, PAPPAS PJ, JAMIL Z, ARAKI CT, GOLDBERG MC *et al.* A strategy for increasing use of autologous hemodialysis access procedures: impact of preoperative non-invasive evaluation. *J Vasc Surg* 1998; **27**:302–308.
- 6 MALOVRH M. Non-invasive evaluation of vessels by duplex sonography prior to construction of arteriovenous fistulas for haemodialysis. *Nephrol Dial Transplant* 1998; **13**:125–129.
- 7 WONG V, WARD R, TAYLOR J, SELVAKUMAR S, HOW TV, BAKRAN A. Factors associated with early failure of arteriovenous fistulae for haemodialysis access. *Eur J Endovasc Surg* 1996; **12**:207–213.
- 8 ASCHER E, GADE P, HINGORANI A, MAZZARIOL F, GUNDUZ Y, FODERA M *et al.* Changes in the practice of angioaccess surgery: impact of dialysis outcome and quality initiative recommendations. *J Vasc Surg* 2000; **31**:84–92.
- 9 MALOVRH M. Native arteriovenous fistula: preoperative evaluation. *Am J Kidney Dis* 2002; Vol 39(No 6 (june)):1218–1225.
- 10 ROOIJENS PPGM, TORDOIR JHM, STIJNEN T, BURGMANS JJP, SMET DE AAEA, YO TI. Radiocephalic wrist arteriovenous fistula for hemodialysis: meta-analysis indicates a high primary failure rate. *Eur J Vasc Endovasc Surg* 2004; **18**:583–589.
- 11 ROOIJENS PPGM, BURGMANS JJP, YO TI, HOP WCJ, SMET DE AAEA, VAN DEN DORPEL MA *et al.* Autogenous radial-cephalic or prosthetic brachial-antecubital forearm loop avf in patients with compromised vessels? A randomized, multicentre study of patency of primary hemodialysis access. *J Vasc Surg* 2005; **42**: 481–487.
- 12 GARDNER GP, CORDIS PR, GILLESPIE DL, LAMORTE W, WOODSON J, MENZOIAN JO. Can air plethysmography accurately identify upper extremity deep venous thrombosis? *J Vasc Surg* 1993; **18**: 808–813.
- 13 BRESCIA M, CIMINO J, APPEL K, HURWICH B. Chronic hemodialysis using venipuncture and a surgically created arteriovenous fistula. *N Engl J Med* 1996; **275**:1089–1092.
- 14 REMUZZI A, ENE-IORDACHE B, MOSCONI L, BRUNO S, ANGHILERI A, ANTIGA L *et al.* Radial artery wall shear stress evaluation in patients with arteriovenous fistula for hemodialysis access. *Biorheology* 2003; **40**:423–430.
- 15 MIHMANLI I, BESIRLI K, KURUGOGLU S, ATAKIR K, HAIDER S, OGUT G *et al.* Cephalic vein and hemodialysis fistula: surgeon's observation versus color doppler ultrasonographic findings. *J Ultrasound Med* 2001; **20**:217–222.
- 16 ROBBIN ML, GALLICCHIO MH, DEIERHOI MH, YOUNG CJ, WEBER TM, ALLON M. US vascular mapping before hemodialysis access placement. *Radiology* 2000; **217**:83–88.
- 17 LEMSON MS, LEUNISSEN KM, TORDOIR JH. Does pre-operative duplex examination improve patency rates of Brescia-Cimino fistulas? *Nephrol Dial Transplant* 1998; **13**:1360–1361.
- 18 VAN BEMMELEN PS, KELLY P, BLEBEA J. Improvement in the visualization of superficial arm veins being evaluated for access and bypass. *J Vasc Surg* 2005; **42**:957–962.

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