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ORIGINAL ARTICLE

Morphologic and functional vessels characteristics assessed by ultrasonography for prediction of radiocephalic fistula maturation

Tamara K. Jemcov

Clinic of Nephrology, Clinical Center of Serbia, Belgrade - Serbia

ABSTRACT

Purpose: **Although native radiocephalic arteriovenous fistula (RCAVF) is the best vascular access for hemodialysis (HD), a major obstacle to increase its use is high frequency of fistulas that fail to mature. The aim of this study was to investigate and define cut-off values of morphologic and functional vessel parameters influencing successful RCAVF maturation using ultrasound.**

Methods: **A prospective, observational study was performed on 122 patients (66 men) who underwent primary RCAVF creation. Internal diameters of cephalic vein (CVd) and radial artery (ARd), venous distensibility (VD), resistance index (RI) and endothelial function by flow mediated dilatation (FMD) were determined by ultrasound examination before AVF placement. AVF maturation was observed by measuring blood flow (Qa) and CVd 0, 14 and 28 days after creation. Depending on the time when AVFs attained maturity (Qa ≥500 mL/min, CVd ≥5 mm), patients were divided into three groups: (i) successful maturation (after four weeks), (ii) prolonged maturation (within eight weeks) and (iii) failure to mature.**

Results: **Only 11% of patients failed to achieve a mature RCAVF. Successful AVF maturation occurred in 53% of patients and prolonged maturation in 36% of patients. ROC analysis defined the limits of variables relevant for RCAVF success (CVd >1.8 mm, ARd >1.6 mm, VD >0.4 mm). Female sex was associated with prolonged maturation (OR 0.35, 95% CI=0.17-0.72; P=0.005) having a significantly smaller ARd (1.83 vs. 2.01 mm, P=0.01) but better FMD (2981.5 vs. 2689.5, P=0.02) compared to men.**

Conclusions: **ARd ≤1.6 mm, CVd ≤1.8 mm and VD ≤0.4 mm are exact cut-off points, which best predict nonmaturation of RCAVF. Women need extended time for adequately matured AVF.**

Key words: **Blood vessels diameters, Endothelial function, Hemodialysis, Radiocephalic arteriovenous fistula, Ultrasonography, Vein distensibility**

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INTRODUCTION

A prerequisite for successful hemodialysis is the existence of adequate access to the systemic circulation, which allows sufficient blood flow in the extracorporal system. A native, radiocephalic arteriovenous fistula (RCAVF) is the preferred option for hemodialysis (HD) and the desired vascular access of vascular surgeons and nephrologists. Nevertheless, a significant failure-to-mature rate is a barrier to overcome.

Several studies have assessed factors associated with AVF failure. Older age, female sex, diabetes, race, preexisting cerebrovascular or peripheral vascular diseases are some of the predictive factors (1-4). However, optimal vessel size for successful AVF creation is still a key question. Different authors suggest different cut-off values for prediction of AVF failure to mature (5, 6). In addition, data from the literature also indicate that some functional blood vessel parameters (arterial response to reactive hyperemia, vein dilatation under tourniquet and endothelial function) appear to play additional roles in maturation (6, 7). Ultrasound can give us valuable information about vessel diameters, their functional characteristics and AVF readiness for use, although disparities in AVF outcome persist despite pre-operative ultrasound mapping (5, 6, 8, 9). The time from AVF creation to the moment of the first cannulation is called the period of maturation. There are different opinions regarding the timing of the first AVF cannulation (10-12). The optimal time is when the period of maturation is completed,

which means that access is ready for use, and can provide adequate dialysis dose (Kt/V) with minimum risk of damage.

For the above reason, the aim of this study was to investigate the influence of morphologic and functional vessel parameters on AVF maturation by ultrasound examination.

MATERIALS AND METHODS

The study included 122 consecutive end-stage kidney disease patients, who commenced hemodialysis between October 2008 and April 2010. All patients were hospitalized at the Clinic of Nephrology, Clinical Center of Serbia to create a primary native AVF, in order to be prepared for the chronic hemodialysis programme.

Baseline patient data are shown in Table I.

The average age was 55.54±15.8 (range, 22 to 81 years).

All patients were informed about the planned procedure and gave informed consent. The study was approved by the Clinical Center of Serbia Ethics Committee. Baseline demographic information and clinical data were collected via a computerized database.

An ultrasound TOSHIBA Corevision SSA-350A scanner with high frequency (7-10 MHz) linear 38 mm probe was used for measurements. Ultrasound measurements were taken by a single practitioner, but to ensure consistency, some measurements were randomly double checked by another ultrasonographer.

All patients underwent pre-operative physical and Color Doppler Ultrasound (CDU) assessment of blood vessels of the non-dominant arm. Cephalic vein and radial artery diameter were measured near the wrist. In case of hematoma, absent radial pulse and signs of venous thrombophlebitis, the place of measurement was moved upward but never in the upper half of forearm, or the blood vessels of the dominant hand were examined and then used for AVF creation. Using B mode, the blood vessels caliber and their functional features (compressibility and distensibility) were reviewed. Vein distensibility (VD) was assessed on the basis of differences in the vein diameter before (VD_0) and after (VD_1) application of a tourniquet (at the elbow) for two minutes [VD (mm) = VD_1-VD_0]. Resistance index (RI) was measured in the radial artery after reactive hyperemia induced by opening the clenched fist after two minutes as previously reported (13). Endothelium-dependent flow mediated dilatation (FMD) was determined in a temperature controlled room (22ºC to 25ºC) with the patient in a post-absorptive state in supine position. Vasoactive medications (ACE inhibitors, beta-blockers, calcium channel blockers) were continued without interruption before the study, because no effect on vascular function was observed in comparable patients (14). Patients were asked to refrain from smoking overnight before the measurements.

The brachial artery ipsilateral to fistula placement was measured longitudinally 5 cm proximal to the antecubital fossa. The inner diameter of the arteries was measured three times during the diastolic phase of the cardiac cycle. The mean value was taken as the basal diameter of the brachial artery (AB_0). The same procedure was used to measure the diameter of the brachial artery (AB_1) one minute after induction of reactive hyperemia by five minute inflation of a blood pressure cuff on the upper arm to more than 200 mm Hg. FMD was calculated as: FMD (%)=AB_1/AB_0-1x100 (15). All AVF created were radiocephalic between the side of the radial artery and the end of the vein, as distally as possible.

Flow through the AVF (Qa) was measured over the brachial artery in the mid-upper arm, in the longitudinal plane. During measurement of the Doppler signal, the angle was below 60° (16-18). Qa was calculated by software equipment using the formula: time averaged mean velocity-TAMV (cm x s^{-1}) x cross-sectional area of the vessel (πr^2; cm^2) x 60. Flow size was obtained as the mean of three consecutive measurements and expressed as mL/min.

Measurements of Qa and CVd were repeated within 24h after AVF construction and subsequently after two and four weeks. AVF that did not attain the given criteria continued to be monitored for a total of eight weeks.

Outcome definition

A certain number of AVFs thrombosed immediately or during the first 24h after construction. In a number of cases of immediate failure, a second attempt was successful and those AVFs attained maturity. As repeated successful attempts occurred, those cases of failure were considered as "technical" failure of surgery.

TABLE I - CLINICAL CHARACTERISTICS OF THE STUDY POPULATION

	n (%)
Number of patients	122 (100)
Men	66 (54)
Age >65 y	38 (31)
Diabetes	23 (19)
Hypertension	120 (98)
Central venous catheter	68 (56)
Obesity[a]	12 (10)
Smoker	57 (47)

[a]Body mass index ≥30, consistent with WHO definition.
y = years.

Robbin et al revealed that the following ultrasound criteria for fistula maturation (a diameter of the outflow vein >4 mm and a blood flow of at least 500 mL/min), are predictive for successful maturation and suitability for dialysis (16). Considering that our local criteria are similar (without available data from the literature which would deny the above allegations) the author accepted them as valid.

The accepted ultrasound criteria for successfully (S) matured AVF after four weeks were Qa ≥500 mL/min, CVd ≥5 mm (16). An AVF which attained the given criteria within eight weeks was considered as prolonged successful (PRS) maturation AVF. Those AVFs that failed after repeated surgical attempts or did not attain maturation criteria within the extended period of eight weeks were considered as failed to mature (FTM). In most matured AVFs (86/109), hemodialysis was successfully commenced immediately after the maturation period was attained, with two-needle puncture and blood flow of ≥250 mL/min. In other AVFs, hemodialysis was commenced after three months of maturation.

Statistical Analyses

Pearson's correlation was used for parametric and Spearman's for non-parametric variables to detect associations among predictor variables and AVF outcome. The cut-off point for statistical significance was 0.05.

Receiver operating characteristic (ROC) analysis was performed in order to define the limits of morphologic parameters influencing the outcome of AVF. Considering the fact that ROC analysis is a binary classifier, its implementation required a re-categorization outcome (Tab. II).

The proposed binary variable aimed to clearly separate limit values of parameters by comparing two extreme outcomes: success and failure of AVF, and to further define the limits of some parameters affecting prolonged-successful AVF. Thus, we took absolute success (AS) and absolute failure (AF) in relation to the variations of relative success (RS) and relative failure (RF). For these reasons two ROC curves were formed for each parameter. The ROC curve with greater accuracy was selected.

TABLE II - RE-CATEGORIZATION OF AVF OUTCOME TO BINARY OUTCOME

	success - [S]	vs.	prolonged-success and failure to mature - [PRS+FTM]
1	absolute success - [AS]	vs.	relative failure - [RF]
	failure to mature - [FTM]	vs.	prolonged-success and success - [PRS+S]
2	absolute failure- [AF]	vs.	relative success – [RS]

The results for the limit values obtained from ROC curves, which considered the binary outcome AF vs. RS, should be taken with some caution, because of the distinct asymmetry of the groups (13 vs. 109) in accordance with the recommendations (19).

Univariate logistic regression analysis was performed to determine the association between different factors in relation to AVF outcome. This included factors that were based on previously performed analyses selected as significant for the outcome of AVF.

An independent *t* test and a Mann-Whitney test were used to compare the differences between two independent groups (man vs. woman). A P value of ≤0.05 was considered statistically significant.

Multiple variable logistic regression analysis was used to model which factors (previously selected as significant) were associated with AVF outcome: absolute success (AS) vs. relative failure (RF). Independent variables were entered into the model using the stepwise method to obtain the multivariable equation and then estimate the probability of successful outcome of AVF.

RESULTS

Morphologic and functional vessel characteristics assessed by Duplex Sonography in all patients, men and women are shown in Table III.

TABLE III - MEASUREMENTS OF VESSEL DIAMETERS AND THEIR FUNCTIONAL CHARACTERISTICS USING DUPLEX ULTRASONOGRAPHY IN ALL PATIENTS, MEN AND WOMEN

		ARd	RI	FMD	ABo	CVd	VD
All	Mean	1.93	0.75	2.29	3.56	2.22	0.54
	Minimum	1.30	0.48	-13.64	2.00	1.20	0.20
	Maximum	3.50	1.00	22.27	5.10	3.60	1.50
	SD	0.40	0.15	5.88	0.65	0.45	0.25
Men	Mean	2.02	0.75	1.13	3.89	2.27	0.55
	Minimum	1.30	0.48	-13.64	2.73	1.50	0.20
	Maximum	3.30	1.00	21.98	5.10	3.50	1.50
	SD	0.40	0.16	5.65	0.56	0.44	0.27
Women	Mean	1.84	0.75	3.64	3.16	2.17	0.52
	Minimum	1.30	0.50	-7.63	2.00	1.20	0.20
	Maximum	3.50	1.00	22.27	4.03	3.60	1.20
	SD	0.38	0.15	5.91	0.50	0.46	0.23

ARd = arteria radialis diameter; CVd = cephalic vein diameter; FMD = flow mediated dilatation; RI = resistance index; SD = standard deviation; VD = vein distensibility.

TABLE IV - CORRELATION BETWEEN THE VARIABLES EXAMINED AND THE RADIOCEPHALIC ARTERIOVENOUS FISTULA OUTCOME

Variable	ARd	RI	FMD[a]	AB_0	CVd	VD[a]	VD%[a]*
Correlation coefficient	0.26	-0.06	0.00	0.33	0.30	0.31	0.18

ARd = arteria radialis diameter; CVd = cephalic vein diameter; FMD = flow mediated dilatation; RI = resistance index; VD = vein distensibility. VD% = vein distensibility expressed as % increase in diameter, after proximal vein compression. [a]nonparametric variable (CV >30%).

The overall cumulative success of AVF maturation was 89% (109 of 122 patients). This included successful AVF maturation in four weeks (65 patients [53%]) and prolonged maturation during eight weeks (44 patients [36%]). FTM rate was 11% (13 patients) and did not include immediate failure AVFs. Immediate failure occurred in 35 of 122 patients (28%). A second attempt was successful in 25 (20%) patients.

Statistically significant correlations were found between AVF outcome and ARd, AB_0, CVd and VD (expressed in mm), but there was no statistically significant correlation between AVF outcome and VD expressed as a percentage (Tab. IV). Furthermore, there were slight increases in VD expressed as a percentage increase between outcome groups (success 26.2±11.96; prolonged success 23.3±9.77 and FTM 20.6±10.71)

The ROC curve for the radial artery was formed for the ratio of absolute failure to relative success. Namely, the limit of >1.6 mm obtained for the radial artery was the threshold for failed AVF outcomes in relation to relative successful AVF outcomes: AUC=0.74; 95% CI 0.648-0.811, P=0.003 (Fig. 1A).

The marginal value of CVd >1.8 mm was the absolute criterion for successful AVF outcome as opposed to relative failure of AVF outcome. Based on the analysis obtained, the AUC was 0.67; 95% CI 0.581-0.754, P=0.00004 (Fig. 1B).

The AUC was 0.72. Values of VD >0.4 mm separated the two AVF outcomes (AF vs. RS) with relatively high sensitivity and specificity (62.4% and 76.4% respectively) at P=0.0032 and 95% CI=0.628-0.795 (Fig. 1C).

Univariate logistic regression analysis found the following variables to be associated with different AVF outcomes (Tab. V).

Female sex was associated with relative failure, i.e. for prolonged maturation or failure to mature (OR=0.35; 95% CI=0.17-0.72; P=0.005). The limits obtained for the measured morphologic and functional parameters were significant predictors of successful outcome of AVF. When two extreme outcomes (AS vs. AF) were compared, the highest value of OR was obtained (for ARd=13.26, 95% CI=3.39-51.92; for CVd 10.29, 95% CI=2.48-42.63 and for VD=6.98, 95% CI=1.74-28.07). The OR value

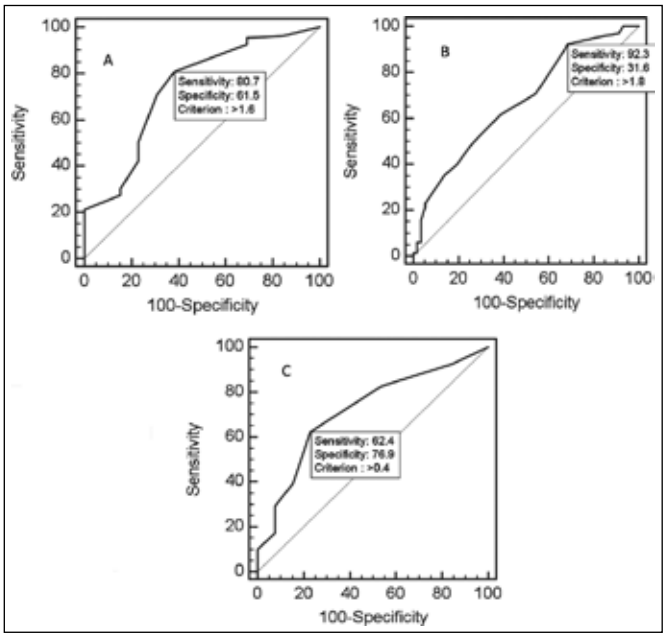

Fig. 1 - *ROC curves for different variables:* ***A)*** *ROC curve for the radial artery (absolute failure versus relative success);* ***B)*** *ROC curve for the cephalic vein diameter (absolute success versus relative failure);* ***C)*** *ROC curve for the vein distensibility (absolute failure versus relative success).*

was lower in the comparison of RS vs. AF and lowest but also statistically significant in the comparison of AS vs. RF (Tab. V).

The pre-operative vascular diameters and functional characteristics, age and smoking status were compared between patient subsets (Tab. VI).

The arterial diameters were significantly lower in women than in men, although venous diameters did not differ. There were no statistically significant differences between the sexes in age (P=0.37), vein distensibility (P=0.57) or smoking habit, although there were more smokers in the male group (P=0.067). Men had more successful matured AVFs (65% vs. 39%) and women had a prolonged AVF outcome more often than men (46% vs. 27%). After an extended period of eight weeks there were no differences in cumulative AVF outcome between the sexes (Fig. 2).

On multiple variable logistic regression modeling, radial artery diameter, cephalic vein diameter and vein distensibility together were the predictive factors of early success AVF vs. relative failure (Tab. II and Tab. VII).

Considering that previously performed analyses singled out radial artery as a parameter depending on biological sex, this was excluded from the modeling equation.

$$\text{Logit}(p) = 1.11 \times (\text{CVd.}) + 1.97 \times (\text{DV}) + 0.61 \times (\text{ARd}) - 4.83$$

P=probability of presence of the characteristics of interest. The logistic transformation is defined as the logged odds.

TABLE V - LOGISTIC REGRESSION OF MATURATION OUTCOME IN FOREARM ARTERIOVENOUS FISTULA

	n (N=78) AS vs. AF		n (N=122) RS vs. AF		n (N=122) AS vs. RF	
Independent variable	OR (CI 95%)	P	OR (CI 95%)	P	OR (CI 95%)	P
Sex F/M	0.3 (0.09-1.09)	0.069	0.49 (0.15-1.60)	0.238	0.35 (0.17 -0. 72)	0.005
Age <65 vs >65	1.76 (0.5-6.13)	0.500	1.44 (0.44-4.73)	0.75	1.65 (0.76 - 3.56)	0.2
ARd >1.6 vs <1.6 mm	13.26 (3.39-51.9)	<0.001	6.70 (1.99-22.59)	0.002	5.21 (2.02-13.45)	<0.001
RI <0.7 vs. >0.7	0.5 (0.12-2.06)	0.508	0.56 (0.14-2.24)	0.53	0.6 (0.32-1.46)	0.328
FMD[a] <0 vs. >0	0.69 (0.18-2.67)	0.72	0.65 (0.41-5.61)	0.73	1.0 (0.43-2.36)	0.841
CVd >1.8 vs. <1.8	10.2 (2.48-42.63)	0.002	4.64 (1.39-15.51)	0.017	5.54 (1.90-16.14)	<0.001
VD >0.4 vs. <0.4	6.98 (1.74-28.07)	0.004	5.53 (1.44-21.3)	0.008	2.33 (1.12-4.86)	0.037

AF = absolute failure; ARd = arteria radialis diameter; AS = absolute success; CVd = cephalic vein diameter; FMD = flow mediated dilatation; OR = odds ratio; RF = relative failure; RI = resistance index; RS = relative success; VD = vein distensibility.
[a]Values obtained by FMD measurement were both negative and positive, depending on the response of the endothelium or whether the AB_1 was greater or less than the AB_0.

TABLE VI - DIFFERENCES IN CONTINUOUS VARIABLES BETWEEN MEN AND WOMEN

	Men (Mean/Rank Sum)	Women (Mean/Rank Sum)	P
Age[b]	4233.000	3270.000	0.371340
Smoking[b]	3703.500	3799.500	0.067781
ARd[a](mm)	2.0167	1.8357	0.012384
AB_0[a] (mm)	3.8934	3.1570	0.000000
CVd[a](mm)	2.2697	2.1661	0.205995
VD[b]	4167.500	3335.500	0.577224
FMD[b]	2689.500	2981.500	0.022537

[a]Independent t test (Mean).
[b]Mann-Whitney test (Rank Sum).
ARd = arteria radialis diameter; CVd = cephalic vein diameter; FMD = flow mediated dilatation; RI = resistance index; VD = vein distensibility.

TABLE VII - MULTIPLE VARIABLE LOGISTIC REGRESSION MODEL OF FACTORS ASSOCIATED WITH FISTULA SUCCESS VS. RELATIVE FAILURE OUTCOME (P=0.0005)

Variable	OR	95% CI
Arteria radialis	1.83	0.65 - 5.18
Cephalic vein	3.05	1.09 - 8.54
Vein distensibility	7.22	1.27 - 41.28

Each of these variables had a different impact on successful AVF maturation, but vein distensibility (OR 7.22, P=0.0005) had a major influence.

DISCUSSION

Maturation and optimal cannulation time have not been well defined and there are significant differences in data from European, American and Asian countries.

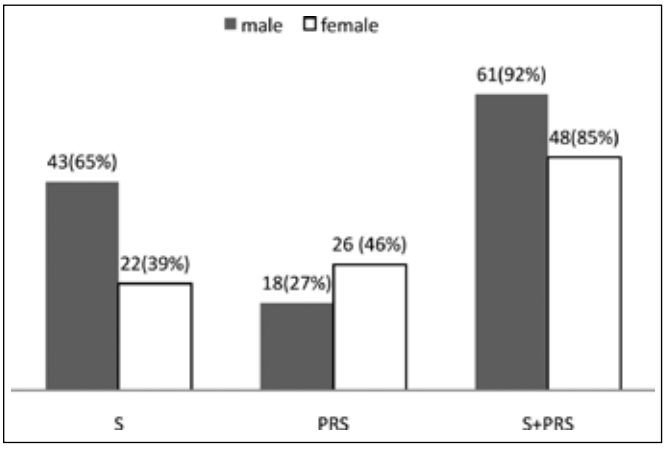

Fig. 2 - *Arteriovenous fistula outcome during the following period of maturation. S = success maturation after 4 weeks; PRS = prolonged success maturation after 8 weeks.*

Data from the DOPPS study revealed that AVF puncture occurred within one month of construction in 74% Japanese hemodialysis centers, 50% in European, and less than 2% in the U.S. (10). Saran et al noted that AVF puncture within one month was not related to poor outcome advising that it is probably safe to cannulate the AVF four weeks after creation (10, 11). They also suggested that decision about AVF suitability for cannulation should be based on clinical examination and objective measurement techniques, such as CDU (11).

Malovrh reported a 80.2% success rate for distal AVF created after a maturation period of 12 weeks (6), while other authors recommended different maturation periods and reported different failure-to-mature rates (3, 4, 16, 20).

Bicarbonate hemodialysis is the standard in most Serbian hemodialysis centers, with duration of 4-5h and

blood flow of 250-350 mL/min. Fistulas are usually left to mature for four weeks prior to their first cannulation, less than four weeks in special cases under supervision of experienced nephrologists or vascular surgeons, but sometimes we left the AVF for six to eight weeks. If they do not attain maturation criteria within eight weeks, there is no doubt that an additional intervention is necessary. CDU is available and used routinely during the pre-operative period and later during follow-up.

In this study, 53% of the patients attained maturation criteria after four weeks, while 36% of the patients had a prolonged course of maturation, and attained the above criteria after eight weeks. The overall cumulative success rate of maturation was 89%. These results confirm previous findings (6, 21).

The influence of sex on the outcome of AVF is currently the subject of many studies. Some authors found that female sex is an independent risk factor for a positive outcome of AVF (2, 8, 16).

There were more men in the successful maturation group after four weeks (43 vs. 22), while in the prolonged maturation group women were in a majority (26 vs. 18). This means that men are more likely to achieve maturation criteria within four weeks and women are more likely to need extended time for RCAVF maturation (Fig. 1A; Tab. IV). However, after eight weeks there was no statistically significant difference in the percentage of matured AVFs between men and women (92% vs. 85%). One of the reasons for prolonged AVF maturation time could be smaller arterial diameters in women. On the other hand, women had better endothelial function, which may have helped them to equal men in the percentage of matured AVFs after the extended period of eight weeks. One possible explanation for impaired endothelial function in men could be a negative influence of testosterone associated with cigarette smoking as was previously observed (22-24).

The recommended minimum artery diameter for successful outcome of forearm AVF differs. Thus, some authors recommend a diameter of 1.5 mm (6, 25), others 1.6 mm (26), while another took the limit of ≥ 2.1 mm (27). Certainly, the size of vessels that supply blood to the AVF ("feeding artery") contributes to a favorable outcome. Therefore, it is expected that artery diameter is positively associated with a positive outcome of AVF. However, the data differ. Silva et al reported failure of only 8.3% of primary AVF, using radial artery and cephalic vein diameters of ≥2 mm and ≥2.5 mm, respectively, as criteria (5). With the same criteria, Lockhart et al obtained a significantly lower rate of successful AVF -36% (28). When it comes to minimum vein diameter, some authors achieved greater AVF success in patients with ≥2 mm veins (29), while others reported a marginal diameter of 2.6 mm, but only in women (30). On the other hand, the vein's internal diameter is not always taken as a factor influencing the outcome of AVF, although all AVFs with vein diameters <1.6 mm were unsuccessful (26).

These disparities suggest that vessel diameters are an important but not the only determinant for successful AVF maturation. It appears that functional characteristics of blood vessels also play a role in the process of AVF maturation (6, 7).

The arterial response to reactive hyperemia has been highlighted. Malovrh reported pre-operative RI<0.7 after clenched fist release as helpful and indicative for AVF success (6). Other authors have given various results (20, 28, 31), which are difficult to compare, but indicate that the hyperemic response may be a useful supplementary test in radial arteries of borderline quality or caliber (32). This study showed no influence of the reactive hyperemia test on the outcome of native forearm AVF (Tab. IV).

The results of this study did not reveal any influence of FMD on AVF maturation (with the exception of FMD differences between sexes) as was reported by Owens et al (7).

Furthermore, it appears that vein distensibility (VD) is an important parameter for AVF outcome (6, 33, 34). Merging a vein with an artery leads to increased flow through the vein and consequent dilatation. Vein dilatation depends on the characteristics of its wall, which is affected by previous inflammatory processes and punctures. Different methods have been used to gain insight into the capacity of veins to dilate: hot water (35), proximal venous compression (6), and a supine position (36). Kim et al measured the change in diameter of the cephalic vein using venography with and without a tourniquet. They found that there was a 7.4 times greater chance of successful AVF maturation when diameter increased by >0.35 mm (34).

The results obtained in this study expressed vein distensibility as an important factor for the prediction of successful AVF maturation. A diameter change of >0.4 mm under proximal vein compression (sensitivity 62.4%, specificity 76.4%, P=0.0032) clearly separated the failure-to-mature category (AF) from the categories of relative success (RS) (Fig. 1C).

Patients whose veins dilated >0.4 mm had a nearly seven-fold greater likelihood of a successful outcome than those whose AVF failed to mature (OR 6.98, P=0.004). Thus, VD was singled out as a factor of importance for a positive outcome of AVF, success as well as a prolonged success.

The results obtained are consistent with earlier findings emphasizing the importance of VD as a functional parameter affecting the outcome of AVF (6, 32, 33). In this study VD is expressed in mm, whereas other authors expressed VD as a percentage (6) or as mL/mmHg (31). As the value of 0.4 mm was obtained and confirmed by ROC and univariate regression analysis, it could be considered accurate, in addition to expressing VD in mm.

Furthermore, multiple variable logistic regression analysis singled out VD as the most important predictive factor for successful RCAVF maturation (Tab. VII).

The method of proximal venous compression and measuring vein diameter by ultrasound used in this study differs from that of Kim et al (34). It is easily feasible, reproducible, requires no additional apparatus or contrast exposure, and can be used in small hospital centers. In addition, the number of patients examined was more than double (50 vs. 122) while the value for borderline vein distensibility is similar (0.35 vs. 0.4 mm).

This study has some limitations. First, the observations were obtained in a single dialysis center and may not be generalized to other dialysis centers. Second, our patients were all white and therefore the conclusions should not be applied to the black population. Finally, this study focused on the immediate outcome of maturation and not on long-term survival. The clinical utility of these morphologic and functional parameters in increasing rates of native maturated AVFs and their survival requires further clinical assessment.

In short, vein distensibility is a factor of significant importance for the prediction of successful AVF maturation. The marginal value of CVd >1.8 mm and the limit of >1.6 mm obtained for ARd were the thresholds for failed AVF outcomes in relation to prolonged and successful outcomes. Most RCAVFs in men attain maturation criteria after four weeks but some require an extended period of eight weeks. Women have smaller arterial diameters than men but better endothelial function; the RCAVF outcome was worse after four weeks but after eight weeks they equaled men in achieving maturation. Therefore, they should be considered for RCAVF placement earlier than men.

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Address for correspondence:
Dr. Tamara K. Jemcov
Clinic of Nephrology
Clinical Center of Serbia
Pasterova 2
11000 Belgrade, Serbia
tjemcov@gmail.com

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