Al-Azhar International Medical Journal

Volume 5 | Issue 1 Article 2

2023
Section: General Surgery

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How to Cite This Article

Elhaig, Omar Mokhtar; Abbas, Reda Osman; and Masoud, Ayoup Salah eldin (2023) "Predicting Dialysis Arteriovenous fistula maturation depending on Rule of six," *Al-Azhar International Medical Journal*: Vol. 5: Iss. 1, Article 2.
DOI: https://doi.org/10.58675/2682-339X.2186

ORIGINAL ARTICLE

Predicting Dialysis Arteriovenous Fistula Maturation Depending on the Rule of Six

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Abstract

Background: **The ideal vascular access is thought to be an arteriovenous fistula (AVF). AVF clinical maturation has been predicted by postoperative ultrasound measures in a few small, single-center studies using measures of the brachial or radial artery or the AVF vein inner diameter and blood flow in various locations along these arteries or the AVF vein, which limits comparability.**

Aim and objectives: **To assess the efficacy of the rule of six (Ro6) in predicting AVF maturation in hemodialysis patients.**

Patients and methods: **This prospective observational research was conducted in the Faculty of Medicine, Al-Azhar University, in the Vascular Surgery Department. Fifty end-stage renal disease patients who underwent AVF formation at Sayed Galal University Hospitals' Vascular Surgery Department were included in the research.**

Results: **Age and BMI were significantly lower in cases with mature AVF. There was substantial variation between mature and failed AVF regarding diabetes and systolic blood pressure ($P < 0.001$). There was highly substantial variation between mature and failed AVF as regards vein diameter, flow rate, and vein depth ($P < 0.001$). Each Ro6 criteria, BMI, and diabetes were separately linked to maturity in a multivariable analysis.**

Conclusion: **The Ro6 are substantially linked with the total maturation of a dialysis AVF when fulfilled utilizing the maximum or lowest values for flow (≥600 ml/min), vein diameter (≥6 mm), and vein depth (≤6 mm). Flow volume and vein depth have much more predictive power than the vein diameter alone.**

Keywords: Arteriovenous fistula, Dialysis, Rule of six

1. Introduction

For end-stage renal disease (ESRD) patients receiving continuous hemodialysis, a functional blood vessel (vascular access) must be available. Even though an arteriovenous fistula (AVF) is the ideal access method, 20–60 % of AVFs do not develop enough for dialysis. The AVF diameter and blood flow must both significantly rise for an AVF to develop enough to allow maintenance hemodialysis. It is simpler to cannulate an easily perceptible AVF with a small depth from the skin than a deeper one.[1]

To establish whether an AVF may be cannulated and utilized for hemodialysis, a physical examination is often employed. Clinical maturation, or the capacity to use the AVF for dialysis, is accurately predicted by physical examination by a qualified examiner in 72–80 % of patients, while there may be significant variations across dialysis personnel and/or facilities. To enhance the evaluation of AVF progress toward clinical maturity, a test that is objective, repeatable, accurate, noninvasive, and reasonably priced is required.[2]

The reported primary AVF failure rates range from 10 to 50 %. Aging, diabetes, and systemic atherosclerosis are comorbidities connected to primary AVF failure. Successful early AVF development minimizes the need for transient vascular access, which lowers patient morbidity and death.[3]

The major causes of morbidity in chronic hemodialysis patients are vascular access issues, which also account for a significant portion of hospital admissions and high healthcare expenses. Therefore, it is crucial to analyze vascular access to

Accepted 25 August 2023.
Available online 5 March 2024

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https://doi.org/10.58675/2682-339X.2186

determine if it is adequate in light of suggested recommendations and to lower morbidity and enhance the quality of life for dialysis patients.[4]

Clinical examination alone has generally been used to establish anatomical eligibility for AVF creation, although this may be challenging in individuals who are obese or have undergone prior access procedures. Previous research has looked at the possible advantages of vascular imaging in determining the proper anatomy.[5]

Several small, single-center studies have used postoperative ultrasound measures to forecast AVF clinical maturation. These studies measured blood flow and brachial or radial artery or AVF vein inner diameter in various brachial or radial artery or AVF vein locations, which limited comparability. A 2002 University of Alabama research focused on early AVF clinical maturity criteria, which emphasized AVF blood flow and diameter.[1]

A later Kidney Diseases Outcomes Quality Initiative (KDOQI) suggested that the ultrasonography requirements for AVF maturation be 600 ml/min blood flow, 0.6 cm in diameter, and less than 0.6 cm depth from the skin. The likelihood of AVF clinical maturation when the postoperative ultrasonography only satisfies two of these three requirements is uncertain since this 'rule of sixes' (Ro6) is based on opinion and has not been confirmed. Additionally, it is questionable if measuring AVF blood flow in an artery or vein is more accurate. As a result, it is still unclear whether early ultrasound measures can accurately forecast AVF clinical maturation.[6]

The objective of this study was to assess the efficacy of the Ro6 in predicting AVF maturation in hemodialysis patients.

2. Patients and methods

This prospective observational research was conducted in the Faculty of Medicine, Al-Azhar University, in the Vascular Surgery Department.

Fifty ESRD patients who underwent AVF formation at Sayed Galal University Hospital's Vascular Surgery Department were included in the research.

Inclusion criteria: patients who had a defective AVF and needed to create a new fistula at the opposite limb, as well as patients who needed proximal and distal (B.C., B.B., and R.C.) hemodialysis for both male and female patients who had been diagnosed with ESRD.

Exclusion criteria: patients who declined to participate in the trial or be randomly assigned, under 16 years old. Patients with active peptic ulcer disease, known bleeding disorders, severe liver dysfunction, and patients with small-cephalic vein diameter, thrombophlebitis, or A, V grafts are not candidates for RC-AVF owing to technical reasons. Blood pressure and patients' EF less than 30 % hypotensive patients 100/60, patients with upper limb infections and patients with PAD in the upper limb.

2.1. Ethical consideration

All participants provided signed informed consents and agreed to follow the research protocol, which was approved by the local ethics committee. All the patients who had been involved completed an informed permission form and promised to attend the post-procedure appointments. The permission was accompanied by a description of the desired procedure's nature, advantages, and potential drawbacks.

2.2. Methods

The following were administered to each patient who participated in the study:

Patient evaluation: all patients had a thorough medical history review, physical examination, radiographic evaluation of the radial artery and cephalic vein, and laboratory testing.

Age, sex, smoking, congestive heart failure, diabetes mellitus (DM), hepatic deficiency, aspirin allergy, and treatment of antiplatelet or anticoagulation.

Clinical examination included examination of arterial pulses, measurement of bilateral brachial systolic pressure, evaluation of the course and straightness of the upper limb superficial veins, detection of the existence of venous collaterals over the shoulder, anterior chest wall, or upper arm, and evaluation of motor function and sensory assessment.

Laboratory investigations include complete blood count, international normalized ratio, random blood sugar, electrolytes, liver enzymes, and arterial blood gases.

3. Results

Table 1 showed that: the mean ± SD of age (years) and BMI (kg/m^2) were 59.8 ± 8.10 and 22.9 ± 2.31,

Table 1. Demographic characteristics of the studied cases.

Characteristics	Mean ± SD	Range
Age (years)	59.8 ± 8.10	20.0–74.0
BMI (kg/m^2)	22.9 ± 2.31	21.9–39.9
	n (%)	
Sex		
Males	30 (60.0)	
Females	20 (40.0)	

Total = 86.

respectively. More than half (60.0 %) were males, the remaining 40 % were females (Figs. 1-3).

Table 2 showed that age and BMI were significantly lower in cases with mature AVF. No statistically significant difference according to the maturation of AVF regarding sex.

Table 3 revealed that there was substantial variation between mature and failed AVF as regards diabetes and systolic blood pressure ($P < 0.001$).

Table 4 revealed that there was highly substantial variation between mature and failed AVF as regards vein diameter, flow rate, and vein depth ($P < 0.001$).

Table 5 showed that each Ro6 criteria, BMI, and diabetes were separately linked to maturation in a multivariable analysis.

Table 6 showed that the receiver operating characteristic area under curve (AUC) for meeting all three Ro6 criteria together was slightly more than any criteria alone in which the role of six showed 95 % sensitivity, 83 % specificity, 93 % positive predictive value (PPV), and 64 % negative predictive value (NPV) (Figure 4).

4. Discussion

Impaired renal function, which is gradual and irreversible, defines chronic renal failure. The number of people who need hemodialysis has increased in recent years as a result of advancements in the identification and management of renal disorders. Dialysis patients have risen by around 8 % per year.[7]

For ESRD patients receiving continuous hemodialysis, a functional blood vessel (vascular access)

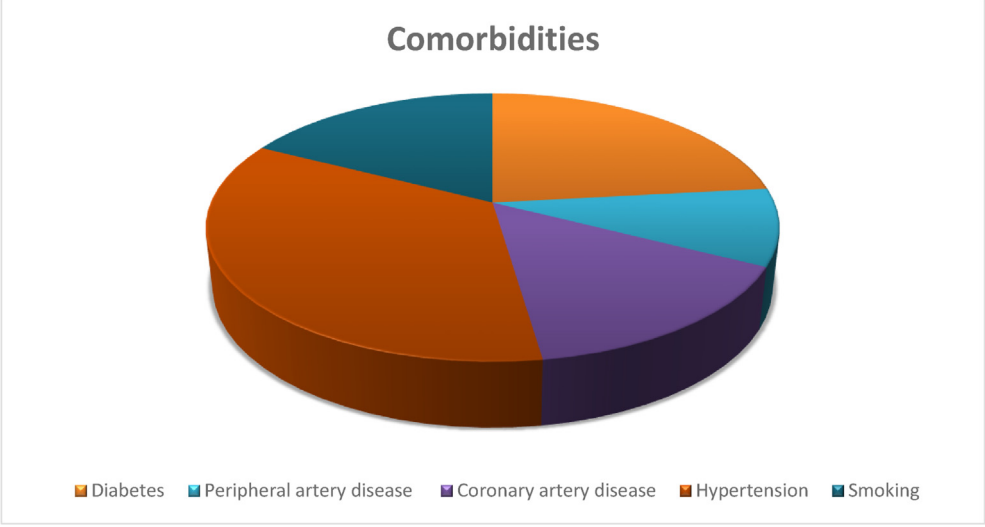

Fig. 1. Frequency distribution of comorbidities among studied cases.

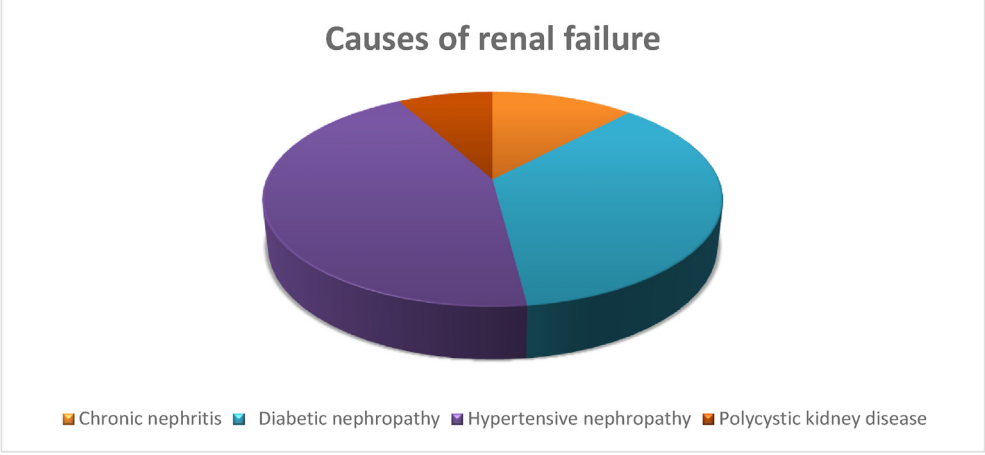

Fig. 2. Frequency distribution of causes of renal failure among studied cases.

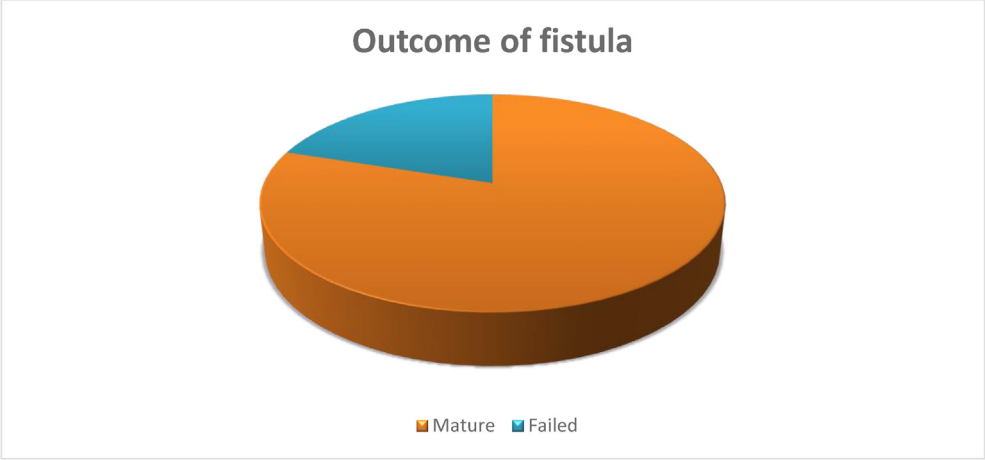

Fig. 3. Frequency distribution of outcome of fistula among studied cases.

Table 2. Comparison of fistula maturation regarding demographic characteristics.

Characteristics	Mature (total = 40)	Failed (total = 10)	*P* value
Age (years)	58.0 ± 7.67	68.3 ± 3.08	0.002[a,c]
BMI (kg/m^2)	31.0 ± 4.8	33.4 ± 3.7	0.013[a,c]
Sex [*n* (%)]			
Male	18 (45.0)	4 (40.0)	0.637[b]
Female	22 (55.0)	6 (60.0)	

[a] Indepednent *t* test.
[b] χ^2 test.
[c] Significant.

Table 4. Comparison according to Doppler data of the arteriovenous fistula among the studied groups.

Time	Mature (total = 40)	Failed (total = 10)	*P* value
Arterial diameter (mm)	4.6 ± 1.05	4.04 ± 1.13	0.056
Vein diameter (mm)	7.02 ± 3.5	5.02 ± 2.7	0.001*
Flow rate (ml/min)	993.2 ± 788.5	209.6 ± 545.5	0.001*
Vein depth (mm)	4.7 ± 1.47	5.8 ± 2.4	0.001*

Total = 86. *P* value >0.05: Not significant, *P* value <0.05 is statistically significant, * statistically significant.

must be available. Despite the fact that AVFs are the preferred kind of access, 20–60 % of AVFs do not develop enough for effective dialysis usage.[8]

In this study, we found that the mean age (years) and BMI (kg/m^2) was 59.8 ± 8.10 and 22.9 ± 2.31, respectively. More than half (60.0 %) were males, and the remaining 40 % were females.

Gomes et al.[9] found 41 individuals had BB AVF, while 91 patients had BC AVF. 69.2 % of the population was male, with an average age of 71 years (range: 18–88 years).

In this study, we illustrated that 40 % of studied cases had diabetes, 60 % had hypertension, 30 % were smokers, 26 % had coronary artery disease, and 16 % had PAD.

Chan et al.[10] found that 92 % of patients had hypertension, 57 % had diabetes, 33 % had coronary

Table 3. Comparison according to clinical data of the studied groups.

Comorbidities	Mature (total = 40) [*n* (%)]	Failed (total = 10) [*n* (%)]	*P* value
Diabetes	14 (35)	6 (60.0)	0.04*
Hypertension	25 (62.5)	5 (50.0)	0.21
Smoking	12 (30.0)	3 (30.0)	0.47
Coronary artery disease	10 (25.0)	3 (30.0)	0.34
Peripheral artery disease	6 (15.0)	2 (20.0)	0.98
Clinical examination	**Mature (total = 40)**	**Failed (total = 10)**	***P* value**
SBP (mmHg)	167.0 ± 37.0	145.0 ± 23.0	0.03*
DBP (mmHg)	79.5 ± 17.0	75.0 ± 15.0	0.41
MBP (mmHg)	107.5 ± 25	102.3 ± 14.33	0.78
PP (mmHg)	90.0 ± 26.5	64.0 ± 34.0	0.02*

Independent *t* test. *P* value >0.05: Not significant, *P* value <0.05 is statistically significant, * statistically significant.
[a]χ^2 test.

Table 5. Multivariate logistic regression of independent arteriovenous fistula maturation predictors.

Variables	OR	95 % CI	*P* value
Vein diameter (mm)	4.05	1.53–10.76	0.005*
Flow rate (ml/min)	6.77	3.09–14.86	<0.001*
Vein depth (mm)	3.30	1.31–8.29	0.011*
All three criteria	9.80	4.40–21.82	<0.001*
Age	1.01	0.98–1.04	0.581
BMI	0.93	0.89–0.98	0.003*
Diabetes	0.97	0.99–1.48	0.002*

CI, confidence interval; OR, odds ratio. *P* value >0.05: Not significant, *P* value <0.05 is statistically significant, * statistically significant.

artery disease, 25 % had congestive heart failure, 15 % had a peripheral arterial illness, and 14 % were heavy smokers.

In this study, we found that 12 % of studied cases had chronic nephritis, 36 % had diabetic nephropathy, 44 % had hypertensive nephropathy, and 8 % had polycystic kidney disease.

Abd-Elmageed et al.[11] found that in the research, 47 % of the participants had chronic nephritis as their major renal illness, 24 % had diabetic nephropathy, 13 % had hypertensive nephropathy, 8 % had polycystic kidney illness, and 8 % had unidentified primary renal disease.

In this study, we demonstrated that 80.0 % of cases had mature AVF and only 20 % had failed AVF, in which causes of failure were 50 % failed to mature, 30 % had hematoma, 10 % was thrombosis, and 10 % was infection.

Hakim et al.[12] found that 52 (26 %) AVFs failed to mature, whereas 150 AVFs [74 %; primary, $n = 101$ (50 %); aided, $n = 49$ (24 %)] did so.

In this study, we cleared that age and BMI were significantly lower in cases with mature AVF. No statistically significant difference according to the maturation of AVF regarding sex.

Abd-Elmageed et al.[11] found that there was a very strong correlation between age and the fistula's prognosis. The failing group's average age was 68.3 ± 3.08 vs. 58.0 ± 7.67 older than the mature group's ($P = 0.001$).

In this study, we revealed that there was substantial difference between mature and failed AVF as regards diabetes and systolic blood pressure ($P < 0.001$).

Abd-Elmageed et al.[11] found that there was a substantial statistical connection between the fistula's fate and DM ($P = 0.001$), and the prevalence of DM was greater in the failure group (72 %) than in the mature group (28 %).

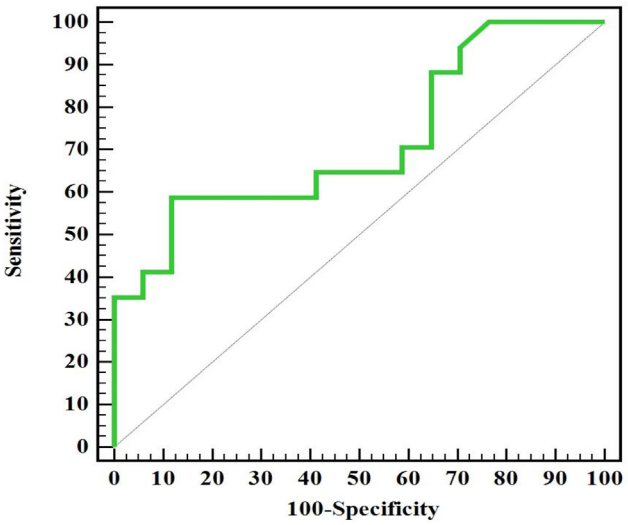

Figure 4. ROC curve for role of six to discriminate functional AVF maturation. AVF, arteriovenous fistula; ROC, receiver operating characteristic.

In line with previous research, Feldman et al.[13] found that DM raises the possibility of AVF failure. However, contrary to previous studies, female sex was not a risk factor in our investigation.

Gomes and colleagues found that 48-h patency was linked to greater systolic blood pressure and PP ($P = 0.013$).

In this study, we revealed that there was a substantial difference between mature and failed AVF as regards hemoglobin and platelet count ($P < 0.001$).[9]

Ahmed et al.[14] found that there was a statistically considerable distinction in the platelet count between the research groups, with the nonfunctional group having an increased platelet count (166.5) than the functioning group (115.4).

Bashar et al.[15] found that hemoglobin concentrations statistically had an impact on the functional maturation process in their research ($P < 0.001$).

In this study, we illustrated that there was highly considerable distinction between mature and failed AVF as regards vein diameter, flow rate, and vein depth ($P < 0.001$).

Table 6. Diagnostic performance of the role of six for functional arteriovenous fistula maturation.

Factors	AUC	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Flow volume >600 ml/min	0.784	85	75	92	51
Vein depth <6 mm	0.641	89	41	87	51
Vein diameter >6 mm	0.588	92	27	78	57
All three criteria	0.874	95	83	93	64

AUC, area under curve; NPV, negative predictive value; PPV, positive predictive value.

This result is in accordance with Ahmed et al.[14] who noted a considerable distinction between Doppler parameters (flow rate, diameter, and depth) based on A-V function in hemodialysis patients, as they found that these parameters were increased in patients with functioning AVF.

Pasqui et al.[16] found that regarding velocity, flow rate, and venous diameter, there were considerable distinctions between the study groups; however, there was no statistically substantial variation between the research groups with respect to arterial diameter.

In this study, we found that each Ro6 criteria, BMI, and diabetes were separately linked to maturation on multivariable analysis.

Additionally, Siddiqui et al.[17] found that those who had preoperative veins larger than 6 mm had a five-fold higher rate of maturation of the fistula than those who had veins less than 6 mm (odds ratio, 4.532; 95 % confidence interval, 2.063–9.958; $P < 0.001$).

In this study, we demonstrated that the receiver operating characteristic AUC for meeting all three Ro6 criteria together were slightly more than any criteria alone in which the role of six showed 95 % sensitivity, 83 % specificity, 93 % PPV, and 64 % NPV.

Abd-Elmageed et al.[11] found that blood flow measurements' sensitivity for predicting fistula failure in the early postoperative period is 99 %, with NPV 94 %, accuracy 97 %, specificity 89 %, and PPV 98 %.

Patel et al.[18] found that the effective maturation of AVF was shown to be reasonably predicted by VD (AUC = 0.650). VD has an NPV of 50 % and a PPV of 84.88 %.

Robbin et al.[1] found that predicting future clinical maturation using vein depth, AVF blood flow, and vein diameter was greatly enhanced.

4.1. Conclusions

The Ro6 are substantially linked with the overall maturation of a dialysis AVF when fulfilled utilizing the maximum or lowest values for flow (≥600 ml/min), vein diameter (≥6 mm), and vein depth (≤6 mm). Flow volume and vein depth have much more predictive power than the vein diameter alone.

Conflicts of interest

There are no conflicts of interest.

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