Accuracy of Peak Systolic Velocity of Radial Artery as Predictor of Maturation of Radiocephalic Arteriovenous Fistula in Cipto Mangunkusumo Hospital

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Introduction: Hemodialysis is an essential treatment in patients with stage 5 chronic kidney disease (CKD) or End-Stage Renal Disease (ESRD). The maturity of arteriovenous fistulas determines the success of hemodialysis. FAV maturity depends on preoperative preparation. The study aims to examine the preoperative and intraoperative peak systolic velocity (PSV) of the radial artery as a predictor of the successful maturation of the radiocephalic FAV.

Method: This study used an analytic cross-sectional design to obtain the relationship of FAV maturation with preoperative and intraoperative PSV. Subjects were those who will undergo radiocephalic FAV surgery with preoperative ultrasound mapping. Shortly after anastomosis, PSV was measured. After 6 weeks, FAV was assessed for its maturity.

Results: As many as 71 patients were undergone radiocephalic FAV surgery and followed for six weeks. The mean preoperative PSV of mature fistula was significantly higher than immature (54.6 ± 11.7 cm/s and 26.7 ± 7.7 cm/s; $p < 0.001$). The mean intraoperative PSV of mature fistula was significantly higher than immature (57.9 ± 12.6 cm/s and 27.1 ± 8.1 cm/s; $p < 0.001$). The mean PSV difference in mature fistulas was significantly higher than immature (3 cm/s and 0 cm/s; $p < 0.001$). Preoperative PSV with a cut-off of 40 cm/s, intraoperative with a cut-off of 42 cm/s, and a difference of PSV with a cut-off of 2 cm/s all had 92.9% accuracy as a predictor of FAV maturation compared to "rule of 6" as a reference standard.

Conclusion: Preoperative PSV >40 cm/s and intraoperative PSV >42 cm/s had a good predictor value for radiocephalic FAV maturation.

Keywords: peak systolic velocity, maturation, arteriovenous fistula, radial artery
<https://doi.org/10.36864/jinasvs.2020.1.008>

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JINASVS 2020;1(1):30-33

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INTRODUCTION

Hemodialysis is an essential treatment in patients with stage 5 chronic kidney disease (CKD) or End-Stage Renal Disease (ESRD). On the other hand, hemodialysis can also cause complications, one of which is cardiovascular events and infections. Before undergoing hemodialysis, vascular access is needed, such as arteriovenous fistula (FAV) or dialysis catheter. The main goal of using hemodialysis access in patients with stage 4 or 5 CKD is to maintain long-term functional access with minimal complications. The choice of access depends on age, sex, life expectancy, anatomy, comorbidity, the likelihood of success (maturity rate of arteriovenous fistula, long-term patency of access with prosthetic graft), the importance of dialysis, and

the patient's desire. One of the first and best choices for hemodialysis access is arteriovenous fistula.^{1,2}

The data shows the failure rate of native FAV ranges between 20-60%. The maturity of arteriovenous fistulas determines the success of vascular access to hemodialysis. Usually, an arteriovenous fistula is ready for use within 6-8 weeks after the procedure. Based on KDOQI guidelines, the criteria for the maturity of arteriovenous fistula access suitable for cannulation are defined as the "rule of 6s", which are minimum of 6mm venous diameter, a minimum venous flow rate of 600 mL/min, and a maximum venous depth from the skin of 6 mm.^{1,3-8}

Preoperative peak systolic velocity (PSV) radial artery measurements can be performed to predict the maturation of the radiocephalic

Table 1. Characteristics of patients included in the study (n = 71)

Variable	n (%)	Mean $\pm$ SD
Age (years)		53,59 $\pm$ 7,75
Gender		
Men	40 (56,3)	
Women	31 (43,7)	
Intraoperative data		
Bloodflow (ml/minute)		182,45 $\pm$ 37,45
Diameter of artery (mm)		2,68 $\pm$ 0,34
Diameter of vein (mm)		2,55 $\pm$ 0,33
SBP (mmHg)		132,73 $\pm$ 9,67
Preoperative PSV (cm/s)		45,36 $\pm$ 1,99
Intraoperative PSV (cm/s)		47,74 $\pm$ 2,17
Difference of PSV (cm/s)		2,38 $\pm$ 0,22

SBP, systolic blood pressure; PSV, peak systolic velocity; AVF, arteriovenous fistula

arteriovenous fistula. According to Sedlacek et al.,⁹ who showed that the preoperative PSV in the radiocephalic AV fistula of ≥ 50 cm/s as a predictor of maturity success. However, the results of a study by Lockhart et al.,¹⁰ reported that there was no difference in the success of arteriovenous fistulas in PSV < 50 cm/s with PSV ≥ 50 cm/s.

The high failure rate of arteriovenous fistulas maturation and the high morbidity due to these failures makes it necessary to find the right measurements for the success of FAV maturation. This study aims to determine the use of preoperative peak systolic velocity (PSV) and shortly after making arteriovenous fistulas as a method that can be used in assessing the success of a FAV.

METHOD

This study was conducted using a retrospective cohort design study to obtain an association between peak systolic velocity of the preoperative radial artery and shortly after intraoperative using Doppler ultrasonography for maturation of the radiocephalic arteriovenous fistula in patients undergoing hemodialysis.

The study was conducted in the Division of Vascular and Endovascular Surgery Department of Surgery, Cipto Mangunkusumo Hospital, Jakarta, Indonesia. This research was performed from August to December 2018. The population was patients with CKD stage 4-5 who got hemodialysis access therapy by undergone a radiocephalic arteriovenous fistula procedure. This study used total sampling method. Inclusion criteria were patients with stage 4-5 CKD who will undergo a radiocephalic arteriovenous

fistula procedure at Cipto Mangunkusumo Hospital from January to May 2018 and systolic blood pressure > 100 mmHg measured intraoperatively during fistula procedure. The exclusion criteria were a history of cannulation before six weeks, patients with hemodialysis catheter attached to the same side as the location of the fistula making, and patients with central venous stenosis.

The data taken was the result of a Doppler ultrasound examination of a preoperative patient, shortly after intraoperatively, and six weeks after the creation of a radiocephalic arteriovenous fistula. Parameters taken from the Doppler ultrasound examination were radial artery diameter, peak systolic velocity of the radial artery, the diameter of draining vein, volume flow draining, and distance of anastomosis to the skin surface. The reference standard in this study was maturation at the 6th week with maturity criteria if the venous diameter was at least 6 mm, the volume flow rate of the vein was at least 600 mL/min, and the distance of anastomosis from the skin was a maximum of 6mm. Data will be processed using SPSS 20.0 for Windows®.

RESULTS

From a total of 71 patients, the mean age of the patients was 53.75 ± 7.82 years. For gender distribution, males and females were 55.6% and 44.4%, respectively. The mean blood flow rate was found 182.06 ± 37.34 ml/min, mean arterial diameter was 2.68 ± 0.34 mm, and the mean venous diameter was 2.55 ± 0.33 mm. The mean preoperative PSV was 45.36 ± 1.99 cm/s, the mean

Table 2. Relationship between demographic, preoperative, and intraoperative variables with maturation of radiocephalic FAV.

Variable	Mature	Immature	p
Number of patients [n]	48	23	
Age (years) [mean $\pm$ SD]	53,35 $\pm$ 8,48	54,09 $\pm$ 6,12	0,712**
Gender [n(%)]			
Men	29 (75,2)	11 (27,5)	0,456*
Women	19 (61,3)	12 (38,7)	
Intraoperative data [mean $\pm$ SD]			
Bloodflow (ml/min)	201,85 $\pm$ 27,85	141,96 $\pm$ 16,41	$< 0,001^{**}$
Diameter of artery (mm)	2,69 $\pm$ 0,38	2,665 $\pm$ 0,26	0,755**
Diameter of vein (mm)	2,54 $\pm$ 0,35	2,574 $\pm$ 0,30	0,525***
SBP (mmHg)	131,98 $\pm$ 10,35	134,3 $\pm$ 8,05	0,252***
Preoperative PSV (cm/s)	54,6 $\pm$ 11,7	26,7 $\pm$ 7,7	$< 0,001^{**}$
Intraoperative PSV (cm/s)	57,9 $\pm$ 12,6	27,1 $\pm$ 8,1	$< 0,001^{**}$
Difference of PSV (cm/s)	3 (0 s.d 5)	0 (-3 s.d 2)	$< 0,001^{**}$

SBP, systolic blood pressure; AVF, arteriovenous fistula; PSV, Peak Systolic Velocity; *chi-square test;

unpaired T test; *Mann-Whitney test

Table 3. Distribution of AUC, p value, and CI 95%.

Test Result Variable(s)	Area	p	95% Confidence Interval	
			Lower Bound	Upper Bound
Preoperative PSV	.973	<0.001	.940	1.000
Intraoperative PSV	.974	<0.001	.942	1.000
Difference in PSV	.938	<0.001	.886	.991

intraoperative PSV was 47.74 ± 2.17 cm/s; and the mean PSV difference was 2.38 ± 0.22 cm/s (table 1).

About 23 patients (32.39%) experienced failure of maturation. Blood flow rates, preoperative PSV, intraoperative PSV, and low PSV differences were associated with failure of maturation. While gender, arterial diameter, venous diameter, and systolic blood pressure in this study were found to had no significant effect on FAV maturity. In the preoperative PSV measurement for mature radiocephalic FAV, the average value was $54.6 + 11.7$ cm/s, while immature was $26.7 + 7.7$ cm/s. Intraoperative PSV measurements for mature radiocephalic FAV obtained a mean value of $57.9 + 12.6$ cm/s, while immature was $27.1 + 8.1$ cm/s. In the measurement of the difference between the preoperative with intraoperative PSV for mature radiocephalic FAV, the average value of 3 cm/s was obtained, while immature was 0 cm/s (table 2).

Figure 1. ROC curve.

Then the ROC measurements for intraoperative PSV, preoperative PSV, and PSV difference were performed for radiocephalic FAV maturation (figure 1). For preoperative PSV, an area under curve (AUC) of 97.3% was obtained (CI 95% 94% -100%). The highest sensitivity and specificity values were obtained when the preoperative PSV value was 40 cm/s. For intraoperative PSV, an area under curve (AUC) of 97.4% was obtained (CI 95%

94.2% -100%). The highest sensitivity and specificity value obtained when the intraoperative PSV was 42 cm/s. For the difference between intraoperative and preoperative PSV, an area under curve (AUC) of 93.8% was obtained (CI 95% 88.6% -99.1%). The highest sensitivity and specificity values were obtained when the difference between intraoperative and preoperative PSV was 2 cm/s. (table 3 and 4).

DISCUSSION

The factors that cause the failure of AV fistula maturation can be many things. The most common cause is neointima hyperplasia that occurs in the anastomosis. Another possibility could be due to the technical operation that caused the anastomosis stricture, the poor quality of the veins, or the diameter of the blood vessels that were too small due to an error in the estimation of ultrasound mapping.¹¹

Based on sex, this study differs from Miller et al. in this study we found no significant sex effects on AV fistula failure, where Miller et al.¹² said that the failure of maturity was higher in female sex compared to male sex, although it can be noted that the characteristic in this study is that the percentage of maturity was higher in male (75.2%) than female (61.3%). Won et al.¹³ and Johnson et al.¹⁴ also proposed that sex was not associated with the failure of AV fistula maturity.

In this study, we also found that the diameter of the blood vessels did not significantly influence the maturity of the radiocephalic AV fistula. Various literature reports that blood vessel diameter was significantly related to maturity, where the failure rate was very high in blood vessel diameter below two mm.^{12,15,16} This may be due to different patient characteristics between studies.

In this study, it appeared that the measurement of preoperative PSV and interoperative PSV shortly after creation was good for predicting the maturity AV fistula. In this study, a preoperative PSV cut-off of 40 cm/s was obtained as a predictor of whether or not the radiocephalic AV fistula will mature. This is close to the study reported by Sedlacek et al.,⁹ which showed that the preoperative PSV in radiocephalic AV fistula of >50 cm/s as a predictor success of the maturity. While Lockhart et al.¹² found that there was no significant difference between AV fistula maturity between preoperative PSV < 50cm/s and preoperative PSV >50 cm/s, and between PSV difference of <2 cm/s and PSV

Table 4. Diagnostic test of preoperative PSV, intraoperative PSV, and PSV difference.

	Sensitivity	Specificity	PPV	NPV	Accuracy
Preoperative PSV (cut-off ≥ 40 cm/s)	91,7 (80,4-96,7%)	95,6 (79,0-99,2%)	97,8 (88,4-99,6%)	84,6 (66,5-93,8%)	92,9 (84,5-96,9)
Intraoperative PSV (cut-off ≥ 42 cm/s)	91,7 (80,4-96,7%)	95,6 (79,0-99,2%)	97,8 (88,4-99,6%)	84,6 (66,5-93,8%)	92,9 (84,5-96,9)
Difference in PSV (cut-off ≥ 2 cm/s)	89,6 (77,8-95,5%)	82,6 (62,9-93,0%)	91,5 (80,1-96,6%)	79,2 (59,5-90,8%)	87,3 (77,6-93,2%)

difference of >2 cm/s. Measurements from the previous studies mentioned above were obtained by conducting intraoperative measurements using ultrasound devices with special probes with high sensitivity and accuracy of calculations so that differences are possible.

In this study, there was an increase in intraoperative PSV when compared with preoperative PSV; the mean value of the PSV difference was 2.38 ± 0.22 cm/s. A study conducted by Manos et al.,¹⁷ explained that an increase in intraoperative PSV results from a decrease in peripheral resistance when the anastomosis is made, which causes increased blood flow in the proximal area of the anastomosis. Another study by McGahan et al.¹⁸ showed an increased of arteriovenous fistula peak systolic velocity and end-diastolic velocity. This occurs due to a decrease in resistance from arterial flow entering venous flow, as well as a decrease in the resistive index (difference in peak systolic velocity with end-diastolic velocity, divided by peak systolic velocity).

In this study, follow-up was limited to a period of 6 weeks before the patient performed hemodialysis to eliminate the effects of trauma associated with recurrent punctation, where recurrent punctation could cause stenotic or hemorrhagic complications which would reduce patency of AV fistulae. This is consistent with research conducted by Saucy et al.,¹¹ who also conducted a study in the period before cannulation.

This research had technical limitations where the procedure of AV fistulas was carried out by different people, although the operators were technically qualified to have the same standards and techniques, the approach and the way of treating could be different, and this could lead to bias.

CONCLUSION

In this study, it was found that the preoperative, intraoperative, and the difference between intraoperative and perioperative PSV with a cut-off value of 40 cm/s, 42 cm/s, and 2 cm/s respectively had a good predictor values and can be used as a tools to determine maturation in patients with FAV.

ACKNOWLEDGMENTS

The author states the original work, and there is no conflict of interest in doing this research.

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