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Intraoperative Blood flow Rate as a Predictor for Maturity of Radiocephalic Arteriovenous Fistula

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Abstract

Introduction. Arteriovenous fistula (AVF) is the best access for hemodialysis. The failure of arteriovenous fistula maturation is currently a major problem faced today. This study aims to assess whether an intraoperative blood flow rate measured with Doppler ultrasound can be a predictor of the maturity of radiocephalic AVF.
Method. Subjects were patients to be made radiocephalic AVF with USG mapping according to the standard. Shortly after, the anastomosis blood flow rate was measured with a linear probe Doppler ultrasound. This study used a cross-sectional analytic design to obtain radiocephalic AVF maturation relationship with intraoperative blood flow rate.
Results. Radiocephalic AVF (n = 71) in 71 patients were made and evaluated in 6 weeks. The mean intraoperative blood flow rate in mature fistulas was significantly higher than those which did not mature (201.85 and 141.96 mL/min; p <0.001). The blood flow rate with a cut-off value of 165.5 mL/min has a sensitivity of 93.8%, specificity 95.7%, positive predictive value 97.8% and negative predictive value 88.5%.
Conclusion. Blood flow rate >165.5 mL/min has a good predictor value for radiocephalic AVF maturation. Thus, it can be used as a reference to determine whether the surgeon needs for further assessment and revision intraoperatively, which in turn is expected to decrease the maturation failure rate of arteriovenous fistula.

Keywords: *arteriovenous fistula, blood flow rate, maturity predictor*

Introduction

Chronic kidney disease (CKD) referred to a global health problem with increasing prevalence and incidence of kidney failure. Increased prevalence of chronic kidney disease is caused by increased elderly population and prevalence of diabetes and hypertension. A systematic review by Hill et al (2016) reported the global prevalence of chronic kidney disease reached up 13.4%.[1] The 2013 RISKESDAS data recorded a 0.2% prevalence of chronic kidney disease in Indonesia. Indonesian renal registry recorded that in 2015, as many as 30,554 terminal kidney failure patients received routine hemodialysis. US renal data system (2013) recorded 103,382 patients who underwent routine hemodialysis out of 117,162 patients diagnosed with terminal kidney failure.

Hemodialysis is the most common kidney replacement therapy in the final stage of kidney disease. Vascular access is an important component in hemodialysis therapy because the blood flows to the dialysis machine through the vascular access. Several studies showed that the use of arteriovenous fistula (AVF) has decreased morbidity and mortality of chronic kidney failure (CKF) patients.[1-3] Vascular access guideline of the National Kidney Foundation, Kidney Disease Outcomes Quality Initiative (K/DOQI) stated that arteriovenous fistula (AVF) is the most appropriate access for hemodialysis.[1,2,4] It is reported in the guideline that natural AVF has low thrombosis count, needless intervention and support long term success in vascular access. Further stated that the cost needed for AVF creation and maintenance are the lowest compared to other dialysis access.[3,5] Natural AVF study showed 66% brachiocephalic creation compared to radiocephalic AVF with 34%.[6] In accordance with K/DOQI, a wrist fistula or radiocephalic fistula is the first method of choice out of other access for some reasons: creating a new access is relatively simple, and preserves a proximal vascular access for future placement, has a lesser complication, low vascular steal incidence, and low thrombosis and infection rate in the matured fistula. The guideline recommends the creation of AVF in most patients. However, the main drawback of radiocephalic AVF is a high rate of primary failure (15%) and a moderate rate of secondary patency (62%).

The current study showed that almost 17% of natural AVF failed in the first three months.[7] Asif et al. (2006) found that approximately 28–53% AVF failed to mature, and unable to support long term hemodialysis,(8) as reported in many studies.[9-11] Sofiar et al. (2013) reported AVF maturation failure rate in RSCM in 2012 up to 18.02%.[12] This high–AVF failure rate driven a study that aimed to found out the prediction using intraoperative assessment. The current measures of preoperative

assessment namely history of illness, physical diagnosis and ultrasound mapping, postoperative care, early Doppler ultrasound evaluation, and the advancement of the fistuloplasty procedure has been proven to improve the success rate of AVF maturation. However, all those measures did not proceed intraoperatively during AVF creation.[13,14] Studies showed that intraoperative BFR measurement during AVF creation can predict AVF maturation.[15-18] These studies were conducted using transit time ultrasound using a special vascular probe. The importance of novel ways of improving AVF maturation rate and decrease the morbidity of the fifth stage of CKD caused by vascular access triggered a question of whether intraoperative BFR measurement during AVF creation measured with Doppler ultrasound using linear probe can predict AVF maturation.

Intraoperative BFR evaluation during AVF creation can be a new measure in improving maturation rate if the predictive value and value limit of BFR to AVF maturation is known. A previous study of Pratama (2014) regarding intraoperative BFR evaluation of brachiocephalic fistula, it is known that intraoperative BFR using Doppler ultrasound with a linear probe can predict the maturation of brachiocephalic fistula with a limit value of BFR and ROC graphic measurement remains showing an error value of 15%. However, the study showed a limited sample size. Further study of Harisandi (2016) using a larger sized sample concluded a cut–off the value of 211.3 mL/min to have a sensitivity of 95.45% and specificity of 92.59%. The positive predictive value was 95.5% for brachiocephalic AVF maturation. Both studies assessed intraoperative BFR in brachiocephalic AVF. Thus, a more study required to assess intraoperative BFR in radiocephalic AVF to be used as a reference in the Vascular Surgery Division of CMGH.[13,14]

Method

An analytical cross-sectional design used to find out the relationship between AVF maturation and BFR in the draining vein during intraoperative AVF creation. The population was stage 4–5 CKF who underwent natural AVF creation as hemodialysis vascular access. The accessible population was those with CKD who underwent hemodialysis using radiocephalic AVF vascular access created in the Vascular Division of Department of Surgery FKUI–RSCM. The samples were those who met the criteria of inclusion and exclusion. The consecutive sampling was employed, enrolling subjects with stage 4-5 CKD to carrying out hemodialysis.

Those with stage 4-5 CKD subjected to radiocephalic arteriovenous fistula creation, ultrasound mapping result according to the standard held in the Vascular Surgery Division (vein with <6 mm depth, >2 mm diameter, regular and thin walls, fully compressed, >2 mm arterial diameter), >100 mmHg systolic pressure measured intraoperatively during AVF creation, well consented and willing to participate in the study were enrolled. Those with a puncture lesion in the arms were excluded. Drop-out were those who died and having conditions that enforce the av fistula closure. Calculated samples were 66 based on assumption of alpha = 0.05 and power = 0.80 (beta = 0.84).

Preoperatively, all subjects proceeded the physical diagnosis on upper extremities, shoulder, and neck to find out any sign or history of previous trauma, venous hypertension related to venous obstruction or chronic ischemic sign. USG mapping carried out using Doppler ultrasonography with a 5-12 MHz linear probe (Mindray DP-10). Arterial were assessed from clavicle to wrist. Vascular diameter and its variations were evaluated. Any detected arteriosclerosis or plaque was recorded. Venous diameter, presence of thrombus, compressibility, venous distance to skin surface and branches in the vein that may reduce flow were evaluated. These preoperative assessments are the standard procedure held to determine the best of vascular access suited for the specific individual.

The surgical procedures proceeded under local anesthesia. Blood flow examination was performed using Doppler Ultrasonography on draining vein 4 cm distal of anastomosis at 10 minutes after the anastomosis completed. Direct reading on Ultrasonography monitor was recorded in mL/min for three times. Systolic and diastolic pressure during blood flow measurement was also recorded. A post-operative evaluation carried out in six weeks following AVF creation with approximately two days of tolerance. Feeding artery, draining vein, and anastomosis were checked for stenosis. Blood flow was read on the draining vein by measuring flow volume and venous lumen diameter using Doppler ultrasonography. The distance from the draining vein to the skin surface was also measured. Hemodialysis cannulation can be started on AVF that matured according to the criteria of NKF-DOQI.
Data were analyzed using SPSS 20.0 for Windows. The means of blood flow in draining vein of a mature and immature radiocephalic AVF were compared, including the cut–off point using diagnostic test of receiver operator curve (ROC).

Results

A total of 72 subjects enrolled in this study. An addition of 10% to calculated samples (66 subjects) has been made. During follow up, a subject died (dropped out) let only 71 left at the end of the study.

Subjects characteristics including demographic characteristics, intraoperative findings, vascular diameter, and systolic blood pressure are presented in table 1. Mean patient age was 53.75 ± 7.82 years old. Distribution of gender was more or less balanced, with males and females were 55.6% and 44.4%, respectively. Mean blood flow rate was 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. (Table 1)

Table 1. Subjects characteristic: CKD with RCAF

Variable	n (%)	Mean ± SD
Age (year)		53.59 ± 7.75
Gender		
Male	40 (56.3)	
Female	31 (43.7)	
Intraoperative measures		
Blood flow (mL/mi		182.45 ± 37.45
Arterial diameter (m		2.68 ± 0.34
Venous diameter (m		2.55 ± 0.33
SBP (mmHg)		132.73 ± 9.67

Note: RCAF: radiocephalic arteriovenous fistula, SBP: systolic blood pressure

Depicted a comparison between successful maturation and failed maturation. There were 23 subjects (32.39%) with failed maturation. Lower blood flow rate significantly correlated with maturation failure. In the study, gender, arterial diameter, venous diameter, and systolic blood pressure were found correlated insignificantly to AVF maturation.

BFR measurement in all radiocephalic AVF samples 6 weeks after creation showed a mean flow of 522.14 ± 305.12 mL/min, in which there was 186.8% increase compared to intraoperative flow. Immature radiocephalic AVF experienced decreased blood flow rate of 29.83% from the mean of 141.96 ± 16.41 mL/min to 99.61 ± 18.87 mL/min, while blood flow rate in mature AVF received 258.98% increased from mean of 201.85 ± 27.86 to 724.6 ± 96.21 mL/min.

Table 2. Analysis results of the correlation between demographic and intraoperative variables and AVF maturation

Variable	Mature RCAF	Immature RCAF	p
Number of subjects [n]	48	23	
Age (year) [mean ± SD]	53.35 ± 8.48	54.09 ± 6.12	0.712**
Gender [n (%)]			
Male	29 (75.2)	11 (27.5)	0.456*
Female	19 (61.3)	12 (38.7)	
Intraoperative data [mean ± SD]			
Blood flow (mL/min)	201.85 ± 27.85	141.96 ± 16.41	<0.001**
Arterial diameter (mm)	2.69 ± 0.38	2.665 ± 0.26	0.755**
Venous diameter (mm)	2.54 ± 0.35	2.574 ± 0.30	0.525***
SBP (mmHg)	131.98 ± 10.35	134.3 ± 8.05	0.252***

SBP – systolic blood pressure, RCAF – radiocephalic arteriovenous fistula *Chi–square test; **unpaired T-test; ***Mann–Whitney test.

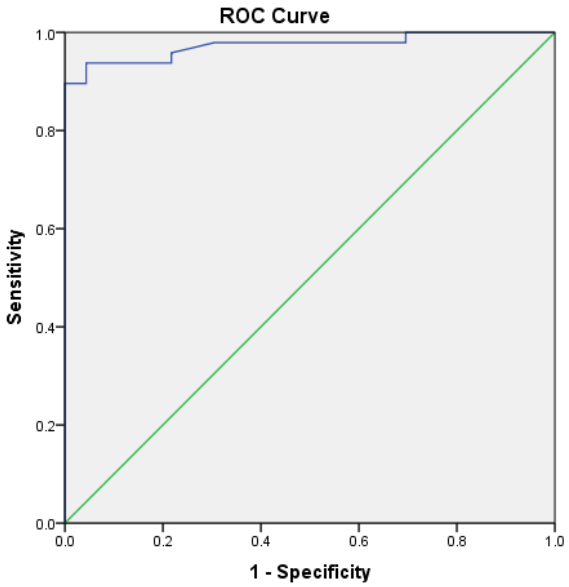

Figure 1. ROC curve showing 97.4% area under the curve (AUC) with 95% CI of 94–100%.

ROC measurement (Figure 1) showed 97.4% area under the curve (AUC) with 95% CI of 94%-100%. The highest sensitivity and specificity were found if the intraoperative blood flow was 165.5 mL/min. The value was then determined as the cut–off value for the limit of radiocephalic AVF maturation prediction with a sensitivity of 93.8% (95% CI = 83.16-97.85%), the specificity of 95.7% (95% CI = 79.01-99.23%). The positive predictive value was 97.8% (95% CI = 88.66-99.62%) and negative predictive value was 88% (95% CI = 70.04-95.83%).

Discussion

This study showed an insignificant correlation of gender to AVF failure even though showing a trend of more maturation found in males (75.2%) compared to females (61.3%). This result was in accordance with Won, et al. (2000) and Johnson, et al. (1998) who stated that gender has no correlation with AVF maturation failure.[11,15] In contrast with Miller et al. (2003) who reported maturation failure was higher in females with smaller mean arterial and venous diameter compared to males.[20]

In the study also found, the vascular diameter correlated insignificantly to radiocephalic AVF maturation. There were reports showing the vascular diameter significantly affects maturation where very high failure rate found as the diameter less than 2 mm.[3,13,19,20] This highlighted the importance of ultrasonography mapping, thus the blood vessel for AVF creation would have a good diameter.

This study showed that intraoperative BFR measurement immediately after creation was beneficial to predict maturation of AVF. Statistically, cut–off value was determined at 165.5 mL/min as a predictor for radiocephalic AVF maturation, which was close with the report by Johnson, et al. (1998) who showed 170 mL/min BFR in radiocephalic AVF as a predictor for maturation failure that was not affected by demographic variables such as age, gender, race, and diabetes-accompanying disease.[15] In line with Won, et al. (2000) who analyzed 50 radiocephalic AVF and concluded that BFR less than 160 mL/min had a higher maturation failure rate and not related to diabetes, old age, gender, radial artery flow, and cephalic vein size parameters.[11] Meanwhile Saucy, et al. (2010) obtained the cut-off value of BFR at 120 mL/min.[16] Some consideration should be made, that previous measurement mentioned above were obtained through intraoperative measurement using ultrasonography with special probe and high sensitivity and accuracy. Therefore, some kind of validation test is needed with larger sample size.

In this study, the follow–up was limited to 6 weeks before the patient undergoes hemodialysis with the aim to eliminate effect from trauma related to repeated puncture which can cause

stenosis complication or hemorrhage which may decrease AVF patency. This was in line with Saucy et al. (2010) Previous studies reported longer follow-up but still not ruled out traumatic effect related to hemodialysis.[16]
This study found an increase of flow at 6 weeks after creation at 186.8% in mature radiocephalic AVF and decreased flow means at 29.83% in immature radiocephalic AVF. This finding indicated that there was a correlation between increased flow during the first 6 weeks after surgery and radiocephalic AVF maturation. Intraoperative BFR measurement and post-operative evaluation showed that mean BFR was significantly higher in mature AVF compared to immature AVF. We found cut–off value of intraoperative BFR in radiocephalic AVF at 165.5 mL/min with sensitivity of 93.8% (95% CI = 83.16-97.85%), specificity of 95.7% (95% CI = 79.01-99.23%). Positive predictive value was obtained at 97.8% (95% CI = 88.66-99.62%) and negative predictive value at 88% (95% CI = 70.04-95.83%).

AVF maturation failure can be caused by many things. The most common cause is neointimal hyperplasia which occurred in the anastomosis. Other possibilities may be caused by operation technical which caused stricture anastomosis, poor vein quality or overly small vascular diameter caused by a mistake in USG mapping estimation.[16] If the low flow rate was found during AVF creation, Lin, et al. (2008) suggested intraoperative fistulography to detect technical defects such as stricture anastomosis and to identify the poor arterial and venous condition. They also stated that if intraoperative AVF fistulography was technically considered good and did not require correction, then strict postoperative observation should be conducted for early intervention when needed and to improve secondary patency.

Relocation of brachiocephalic or brachio-basilic autogenous AVF creation or prosthetic graft implantation with the same setting can only be considered for diabetic patients with low flow rate.[18]
This study had a technical limitation where AVF creation was performed by different operators. Even though all operators had the same standard and technique according to technical qualification, personal approach and the way they handle tissues were still different and it caused some bias

Conclusion

This study found that intraoperative BFR analysis using Doppler ultrasonography immediately after radiocephalic arteriovenous fistula creation with a cut-off value of 165.5 mL/min had good predictor value with a sensitivity value of 93.8%, the specificity of 95.7%, positive predictive value 97.8% and negative predictive value 88.5%. These results can be a consideration to determine operational strategy, whether or not intraoperative fistulography is needed, or whether or not intraoperative revision procedure is needed, which in the end was expected to decrease the failure rate of arteriovenous fistula maturation.

Disclosure

Author disclose there was no conflict of interest.

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