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Evaluation of Postoperative Maturation of Brachiocephalic Arteriovenous Fistula in Chronic Kidney Disease Patients Using Doppler Ultrasonography

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ABSTRACT

Introduction: An arteriovenous fistula (AVF) is the preferred method of vascular access for patients with end-stage chronic kidney disease (CKD) undergoing hemodialysis. This study aimed to investigate whether there is a difference in the post-operative maturation of brachiocephalic AVFs at 6 weeks compared to 8 weeks in CKD patients, utilizing Doppler ultrasonography at RSUDZA Hospital.

Methods: The study involved a sample of 16 patients who underwent brachiocephalic arteriovenous fistula (AVF) surgery at Zainoel Abidin General Hospital (RSUDZA) in Banda Aceh, between November 13 and December 14, 2023. This observational study utilized a prospective cohort design, and data analysis was performed using the Wilcoxon test, with a significance level set at $p < 0.05$.

Results: The study found that most patients who underwent brachiocephalic arteriovenous fistula (AVF) procedures were women, particularly those aged between 56 and 65 years. Doppler ultrasonography was used to evaluate the patients at 6 and 8 weeks after the surgery. The results showed that 40% to 50% of patients had not met the maturation criteria set by KDOQI by the 6th week, and 30% to 40% still had not met these criteria by the 8th week.

Conclusion: There is no significant difference in the post-operative maturation of brachiocephalic AVF for 6 weeks and 8 weeks in CKD patients using Doppler ultrasonography at RSUDZA hospital.

Keywords: arteriovenous fistula, chronic kidney disease, maturation, Doppler ultrasonography.
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INTRODUCTION

Chronic Kidney Disease (CKD) is a condition characterized by kidney damage or reduced kidney function that lasts for at least three months[1,2]. CKD is classified into five stages based on the severity of glomerular filtration rate (GFR) values. End-stage CKD occurs when the kidneys stop functioning altogether, necessitating kidney replacement therapy to eliminate toxic substances from the body. The available treatment options include dialysis (hemodialysis), Continuous Ambulatory Peritoneal Dialysis (CAPD), and kidney transplantation. Among these, hemodialysis is the most commonly used form of kidney replacement therapy, typically performed using an arteriovenous fistula (AVF) for vascular access[3].

An arteriovenous fistula (AVF) is a connection between an artery and a vein. It can develop due to surgery, genetic disorders, iatrogenic injury, or trauma. However, surgically created AVFs are the most common type. The surgical creation of AVFs was first introduced by Brescia and Cimino in 1966 to provide vascular access for patients undergoing hemodialysis. According to the National Institute of Diabetes and Digestive and Kidney Diseases, in 2013, over 468,000 patients received hemodialysis, with 20% of these patients relying on surgically created AVFs. The rates of AVF creation vary significantly across different regions, with the highest rates found in the Northeast and the lowest in the Southwest of the United States[4].

According to a research study conducted by Dahlerus et al. in the United States in 2019, out of a total of 315,919 patients undergoing hemodialysis, 65.8% of them used vascular access in the form of arteriovenous fistulas (AVF)[5]. In Indonesia, data from the Indonesian Renal Registry in 2018 indicates that the majority of hemodialysis procedures also utilize AVF, with a usage rate of 75%[6]. Furthermore, the Indonesian Dialysis Patient Community (KPCDI) reported that between February 2022 and May 2023[7], 92% of patients at RSUDZA Banda Aceh had vascular access via brachiocephalic AVF. The Kidney Disease Outcomes Quality Initiative (KDOQI) recommends the radiocephalic, brachiocephalic, and brachiobasilic configurations as ideal options for AVF creation. However, the brachiocephalic AVF remains the preferred procedure when the vessels in the forearm are unsuitable for AVF placement[8].

The brachiocephalic arteriovenous fistula (AVF) procedure is commonly used

for creating AVFs due to the favorable structure of the cephalic vein, which is well-suited for hemodialysis cannulation[8]. This procedure is reported to have higher maturation and patency rates compared to the radiocephalic AVF, although a more distal formation is recommended when possible[9]. The AVF procedure is easier to perform, can be cannulated with a repeated syringe, and provides the high flow rate necessary for effective hemodialysis in a mature AVF[10].

Assessment of arteriovenous fistula (AVF) maturation can be done using the "Rule of 6" established by KDOQI. According to this guideline, 4 to 12 weeks after creating an AVF, it should exhibit the following criteria: blood flow rate of at least 600 mL/minute, minimum diameter of 6 mm, depth of less than 6 mm from the skin surface, and an access length of 6 cm to allow for cannulation. Doppler ultrasonography is utilized to evaluate AVF maturation in accordance with KDOQI criteria[10].

Doppler ultrasonography is a valuable diagnostic tool for identifying and managing various medical conditions. As technology continues to advance, its use is becoming more common and cost-effective among healthcare providers[11,12]. This technique is particularly beneficial for mapping blood vessels and aiding in the construction of fistulas, including the maturation of arteriovenous fistulas (AVFs)[13,14]. Monitoring AVF maturation with Doppler ultrasonography is crucial until the fistula is ready for use, especially for patients with slow maturation or those whose veins are challenging to assess through physical examination alone, such as individuals with obesity[12].

METHODS

This study is an observational research project utilizing a prospective cohort design. Its objective is to assess the differences in post-operative maturation of brachiocephalic arteriovenous fistulas at 6 and 8 weeks in patients with chronic kidney disease, using Doppler ultrasonography conducted at RSUDZA Banda Aceh.

The research was carried out at RSUDZA Banda Aceh, with data collection taking place from November to December 2023. The study population consisted of patients with end-stage chronic kidney disease who underwent brachiocephalic arteriovenous fistula surgery at the same hospital. For sampling, a non-probability technique, specifically total sampling, was employed. All patients who met the inclusion and exclusion criteria were included in the research sample.

The primary focus of this study was the duration of post-operative care for the brachiocephalic arteriovenous fistula and the maturation process. Data analysis included both univariate and bivariate analyses, with the Wilcoxon statistical test utilized for comparisons. This research has received approval from the ethics committee of Zainoel Abidin Hospital (Approval No. 268/etik-rsudza/2023).

RESULTS AND DISCUSSION

This research was conducted at RSUDZA Banda Aceh, specifically at the Thoracic, Cardiac, and Vascular Surgery Polyclinic and Radiology departments. The research was conducted from 13 November 2023 to 14 December 2023, and 16 out of 20 samples were obtained that met the research inclusion criteria. The research was carried out by reviewing data from Doppler ultrasonography results in the form of diameter, depth, and blood flow rate.

Characteristics of The Research Sample

As people age, it is normal for kidney function to decline slightly. This decline usually begins after a person reaches the age of 40. A study by Salsabila et al. found that 43.3% of patients with chronic kidney disease (CKD) are typically in late old age, specifically between 56 and 65 years old[15]. Other studies conducted by Ariyosep S in 2019 and Arianti A. et al. in 2020 reported that the early and late elderly (46-65 years old) faced the highest risk of developing CKD. This occurs because the kidneys cannot regenerate new nephrons, and as kidney damage occurs or the aging process continues, the number of nephrons decreases. At 40 years of age, the number of functioning nephrons decreases by about 10% every 10 years. By the age of 80, only 40% of the nephrons are functioning[16]. These findings align with this research, which shows that the majority of the study sample was in the age range of 56-65 years old, comprising 7 people (43.8%).

Gender is an important variable that affects the incidence rates of chronic kidney disease (CKD) in men and women. Several studies have been conducted on this subject, with varying results. For instance, Delima et al. (2017) and Utami et al. (2020) found that men were more susceptible to CKD than women[17,18]. However, Yanuar et al. (2018) found that the largest number of CKD patients were female[19]. According to a journal by Helena et al. published by the National Kidney Foundation, there is no significant difference in the prevalence ratio of CKD between men and women. In other words, both genders are equally at risk of developing CKD[20]. In the sample analyzed in this study, 11 out of 16 individuals (68.8%) were women.

The 6-Week Postoperative Maturation Overview

Fistulas that have matured after surgery can be identified when the small veins within the fistula enlarge and match the

Table 1. Characteristics of The Research Sample

Characteristics	Frequency (f) (N=16)	Percentage (%)
Age		
<26 years old	1	6,3
26-35 years old	1	6,3
36-45 years old	2	12,5
46-55 years old	3	18,8
56-65 years old	7	43,8
>65 years old	2	12,5
Gender		
Male	5	31,3
Female	11	68,8

Table 2. The 6-Week Postoperative Maturation Overview

Characteristics	Frequency (f) (N=16)	Percentage (%)
Diameter at 6 Weeks After Surgery		
Mature (>6 mm)	12	75,0
Not Mature (<6 mm)	4	25,0
Depth at 6 Weeks After Surgery		
Mature (<6 mm)	15	93,8
Not Mature (>6 mm)	1	6,3
Blood Flow Rate at 6 Weeks After Surgery		
Mature (>600 mL/min)	9	56,3
Not Mature (<600 mL/min)	7	43,8
Maturation at 6 Weeks After Surgey		
Yes	9	56,3
No	7	43,8

Table 3. The 8-Week Postoperative Maturation Overview

Characteristics	Frequency (f) (N=16)	Percentage (%)
Diameter at 8 Weeks After Surgery		
Mature (>6 mm)	12	75,0
Not Mature (<6 mm)	4	25,0
Depth at 8 Weeks After Surgery		
Mature (<6 mm)	16	100,0
Not Mature (>6 mm)	0	0
Blood Flow Rate at 8 Weeks After Surgery		
Mature (>600 mL/min)	10	62,5
Not Mature (<600 mL/min)	6	37,5
Maturation at 8 Weeks After Surgey		
Yes	10	62,5
No	6	37,5

Table 4. Differences in 6-Week and 8-Week Postoperative Maturation

Wilcoxon Test	
Postoperative Maturation	**p value**
6 Weeks 8 Weeks	0.317

diameter of the fistula itself, as outlined in the guidelines. Fistulas with a vessel diameter smaller than 6 mm fall into a subgroup of poorly functioning vascular access, with only 52% of these fistulas demonstrating effective function[21].

Widening of venous diameter at 6 weeks post-surgery shows a significant correlation with fistula maturation. However, its clinical significance is limited, as it does not serve as an early indicator of arteriovenous fistula (AVF) maturation. Research conducted by Zhang et al. found that 38 patients, or 52.7%, exhibited a diameter greater than 6 mm six weeks after surgery[22]. In this study, 12 patients, which amounts to 75.0%, achieved a mature diameter (greater than 6 mm) at the same time point.

KDOQI recommends that the depth of the vein from the skin surface be less than 6 mm for the creation of arteriovenous fistulas (AVFs). Research conducted by Palin AW et al. found that the average intraoperative distance of the vein from the skin was 3.10 mm. However, this average significantly decreased to 2.88 mm after 6 weeks, indicating that the vein becomes closer to the skin surface over time. Furthermore, no significant relationship was found between intraoperative venous depth from the skin surface and maturity of the AVF[23]. This finding is consistent with the report by Farrington et al., which noted a decrease in venous depth from the skin surface, particularly in the mature group; however, the change was not statistically significant[24]. In this study, the results showed that at 6 weeks post-surgery, the value of vein depth from the skin surface had the highest rate of maturity, with 15 out of 16 participants (93.8%) demonstrating significant maturation.

According to the Kidney Disease Outcomes Quality Initiative (KDOQI), a mature arteriovenous fistula (AVF) should be capable of handling a blood flow rate of 600 mL/min. A study conducted by Pratama et al. found a 186.8% increase in the blood flow rate of mature AVFs, while immature AVFs saw an average decrease of 29.83% in flow six weeks after creation. These findings suggest a significant correlation between increased flow during the first six weeks post-surgery and AVF maturation[25]. Out of 16 patients in the study, 9 (56.3%) achieved mature blood flow rate values greater than 600 mL/min at six weeks following the operation.

The 8-Week Postoperative Maturation Overview

The diameter of the vessel plays a crucial role in predicting the success of arteriovenous fistula (AVF) maturation. Previous studies have shown that a vein diameter greater than 6 mm is the key predictor of successful AVF maturation. For example, a study conducted by Zhang et al. found that patients with cephalic vein diameters less than 6 mm experienced a maturation failure rate of 55.56%[22]. Additionally, research by Pratama et al. confirmed that samples with mature AVFs had larger vein diameters by the 8th week after surgery[26]. In their study, 12 patients achieved a mature diameter (greater than 6 mm) at 8 weeks post-surgery, resulting in a 75% success rate.

An arteriovenous fistula (AVF) is deemed mature when the depth of the vein from the skin surface is less than 6 mm. Notably, the depth of veins in the mature category can decrease over time[23]. The analysis results from this study indicated that all research samples exhibited a mature vein depth from the skin surface at 8 weeks post-surgery, demonstrating a 100% success rate.

After undergoing arteriovenous fistula

(AVF) surgery, patients experience an increase in blood flow velocity. Initially, blood flow increased from an average of 21.6 ± 20.8 mL/min to 208 ± 175 mL/min after the surgery. This flow can further rise to between 600 and 1200 mL/min at 4 to 12 weeks post-surgery[13]. In this study, 10 samples showed mature blood flow rates exceeding 600 mL/min at 8 weeks after surgery, indicating a success rate of 62.5%.

Differences in 6-Week and 8-Week Postoperative Maturation

The six-week period following the creation of an arteriovenous fistula (AVF) is generally considered the maturation phase, during which essential maturation processes occur. Recent studies indicate that the median functional maturation time may extend up to 13 weeks. Additionally, during this period, the size and blood flow of the fistula vein may increase[27]. However, the main challenge in successfully creating an AVF is achieving maturation, as approximately 30-50% of AVFs do not mature as expected. While maturation typically occurs between 4 to 6 weeks after the initial surgery, this timeframe can vary significantly, with an average range of 1 to 4 months. This variability makes the maturation of AVFs a somewhat unpredictable process[14].

In 2016, Yonzi et al. conducted research on patients with end-stage chronic kidney disease (CKD), where 27 patients underwent post-operative Doppler ultrasonography examinations at 4 and 6 weeks to assess arteriovenous fistula (AVF) maturation according to KDOQI recommendations. The results of this study indicated that there was no significant difference in AVF maturation based on time[28], which aligns with the findings of our own study. Statistical tests, including the Wilcoxon test, revealed a p-value of 0.317 ($p > 0.05$), indicating no significant difference in the post-operative maturation of brachiocephalic AVF between the 6-week and 8-week marks in CKD patients, as assessed by Doppler ultrasonography at RSUDZA.

CONCLUSION

The study results lead to the following conclusions: Up to 40-50% of patients undergoing brachiocephalic arteriovenous fistulas (AVFs) do not meet the KDOQI maturation criteria by the sixth week. Furthermore, 30-40% of these patients fail to meet the maturation criteria by the eighth week. There was no significant difference in the maturation of brachiocephalic AVFs between six and eight weeks in patients with chronic kidney disease (CKD), as assessed using Doppler ultrasonography at RSUDZA.

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CONFLICTS OF INTEREST

The authors have nothing to disclose.

AUTHOR CONTRIBUTION

All authors contributed equally to this research.

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