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Original Article

Is there correlation between flow volume and Kt/V ratio in upper arm arteriovenous fistula in patients end stage renal failure?

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Abstract

Introduction: Chronic kidney disease is irreversible and may result in end-stage renal failure (ESRF). The kidney replacement program is determined by calculating Kt/V ratios, one of the dialysis efficiency indicators in treatment planning in routine dialysis applications in ESRF patients. We aimed to investigate whether there is a correlation between flow rate and Kt/V ratio.

Methods: All patients were evaluated by B-mode ultrasonography (US) and color doppler ultrasonography (CDUS). The anastomosis line diameter was measured in the B-mode US. The fistula flow rate was calculated in a spectral examination at the anatomical location where the fistulized flow was best obtained at the anastomosis level. Patients with a fistula flow rate above 300 mL/min in CDUS examinations were considered reasonable flow rates. The fistula flow rate in these patients was compared with the Kt/V ratios. Spearman's rank correlation coefficient was calculated since the normal distribution condition was not met to determine the relationship between variables.

Results: The results of this study showed a high level ($r=0.72$, $P=0.001$) of positive and statistically significant correlation between flow rate and Kt/V ratio in upper arm arteriovenous fistula in patients with end stage renal failure.

Conclusion: We found a highly positive and statistically significant correlation between fistula flow rate and Kt/V ratio. Low Kt/V ratios have different causes. Low fistula flow should be considered first in low Kt/V values.

Introduction

Chronic kidney disease is irreversible and may result in end-stage renal failure (ESRF).[1] Hemodialysis (HD) is the most preferred renal replacement option in patients with ESRF. Autogenous arteriovenous hemodialysis accesses (AAHA) is the preferred method for HA compared to prosthetic arteriovenous grafts and central venous catheters due to the advancement of technology, more accessible access to health, the increase in the number of patients due to the side effects of the treatments, and keeping comfort in the foreground. In addition, AAHA is preferred because it can be surgically created more efficiently, with higher patency rates and low complication-cost rates.[2,3]

The most commonly used method for measuring HD adequacy, based upon urea clearance, is Kt/V ratio (where K = dialyzer clearance of urea, t = dialysis time, and V = volume of urea distribution, approximately equal to patient's total body water). Gotch and Sargent developed this ratio through a post hoc mechanistic study of the National Cooperative Dialysis Study (NCDS) data.[4] Dialysis dose as measured by Kt/V can be influenced by many factors, especially treatment time (TT) and blood flow rate (BFR), but also by dialysate flow, session interruption (hypotension or clotting), access functionality (stenosis and recirculation), needle size and placement, dialyzer characteristics, and proper blood sampling.[5] Many studies have indicated that lower than recommended Kt/V may increase mortality.[6-8] Therefore, clinicians who cannot achieve the desired result at the calculated Kt/V ratios watch influenced factors. İf sufficient efficiency is not obtained, Color Doppler Ultrasonography (CDUS) is required for fistula dysfunction. In the CDUS examination, findings such as stenosis, thrombus, and infection that may occur throughout the entire vascular trace, especially at the fistula discharge and at the fistula level, are evaluated.[9]

We aim to investigate whether there is a correlation between BFR and Kt/V ratio.

Methods

Patients

Our institutional review board approval was taken for this

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study. Our task was conducted prospectively, and written informed consent was obtained from reviewed subjects due to the prospective nature of the investigation. Between April 2019 and September 2019, a total of 58 patients, 19 females (32.8%) and 39 males (67.2%), were analyzed in the study, between the ages of 20-85, who were admitted to Van Yuzuncu Yil University Departmant of Radiology and had previously created AV hemodialysis fistula. The inclusion criteria were all types of fistulas, such as upper arm or forearm, native fistulas, and redo accesses, all information for kt/V ratio calculation, and patients with a fistula flow rate above 300 mL/min. The exclusion criteria were patients with a fistula flow of 300 mL/min or less, missing information for kt/V ratio calculation, and total fistula thrombosis.

Technical application, flow measurement, and calculation of Kt/V ratio

All participants included in the study were evaluated by B-mode ultrasonography (US) and CDUS. The examinations were performed using the AFFINITY G 70 ultrasound system (Philips Ultrasound, Bothell, WA) and a 9-12 MHz 12L3 linear probe.

US examinations were performed with the participant in the supine position. The examination environment was at the average room temperature, and the temperature of the ultrasound gel was set at the level that would not cause vasocontraction. The subclavian region was started to the distal forearm, respectively; Arterial structures, fistula anastomosis line, and venous structures were evaluated in axial and longitudinal planes.

In the arterial system, subclavian, axillary, brachial, radial, and ulnar arteries were evaluated, and significant thrombus and stenosis were assessed. Then, the localization of the arm of the HA fistula in the participant and which artery and vein anastomosis were noted. Next, the anastomosis line diameter was measured in B-mode, where multiplanar can be best evaluated (Figure 1). Finally, in a spectral examination, the fistula flow rate in mL/min was calculated at the anatomical location where the fistulized flow was best obtained at the anastomosis level (Figure 2). While performing all spectral measurements, attention was paid to the baseline, sample volume, angle between vascular trace and sound beam, and pulse repetition frequency (PRF) was adjusted so that aliasing artifact did not occur. Then, the fistula flow rate was measured 3-5 times and averaged.

The conductive vascular structure was evaluated with B-mode and CDUS. The conductive vascular structure flow rate was measured and compared with the flow rate calculated from the anastomosis level. Attention was also paid to avoid aneurysmal dilatation at the flow

Figure 1. Anastomosis line diameter in B-mode in the plan where multiplanar can be best evaluated

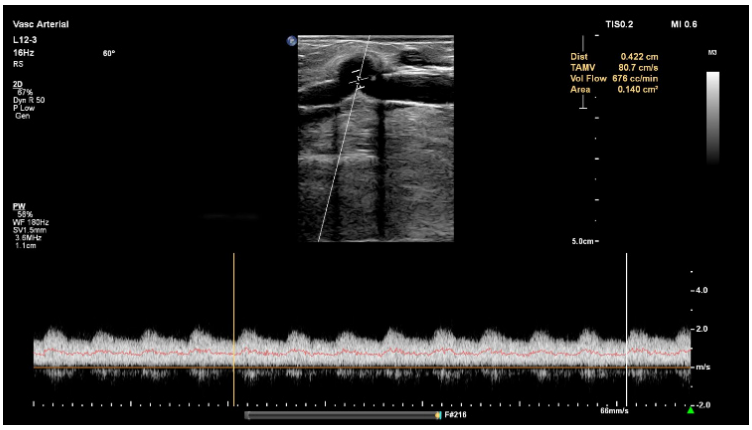

Figure 2. In a spectral examination, the fistula flow rate in mL/min was measured at the anatomical location where the fistulized flow best obtained at the anastomosis level

measurement site of the efferent vascular structure, thrombus that could cause severe stenosis, and segment phlebitis longer than 4 cm. Segment phlebitis longer than 4 cm was present in 6 patients, and the flow rate was not measured from the efferent vascular structure in these patients. The flow rate was calculated 3-5 times and averaged (Figure 3). Then, the diameters of the efferent vascular system according to the fistula's location were noted separately in the arm and forearm as proximal, middle, and distal (Figure 4).

Participants with a fistula flow rate above 300 mL/min in CDUS examinations were considered sufficient flow rates.[10] The fistula flow rate in these participants was compared with the Kt/V ratios. Participants with a fistula flow of 300 mL/min or less were considered insufficient flow. Kt/V ratios of the patients with total fistula thrombosis and poor flow were not calculated.

CDUS processes took about 20-25 minutes, and all the obtained data was recorded. Finally, the dialysis efficiency value of Kt/V ratios was calculated by examining the laboratory data recorded in our hospital system and the information recorded in all participants' dialysis units. In the Kt/V ratio, the dialyzer urea clearance (K) is multiplied by dialysis time (t), the product is then divided by the patient's urea distribution volume (V).[11]

Blood flow measurements were made by a radiologist who received five years of training on Doppler and who has a particular interest in it. Kt/V ratios were calculated by an internal medicine specialist who had five years of activity on this subject in the dialysis unit.

Statistical analysis

Descriptive statistics are expressed as mean, standard deviation, minimum, and maximum. Kolmogorov-

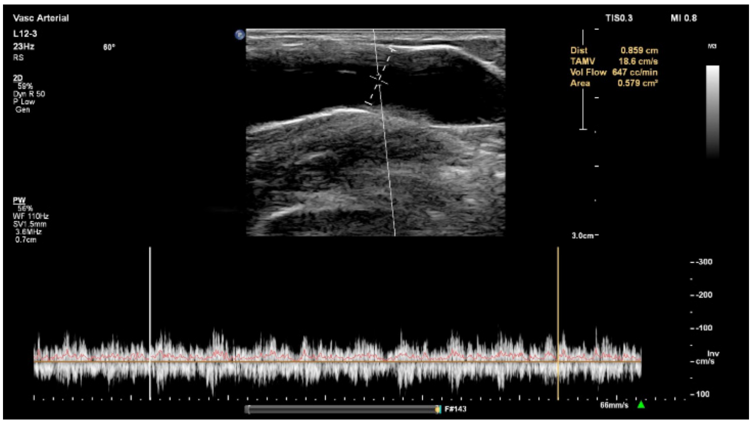

Figure 3. The conductive vascular structure flow rate measured the best anatomical location

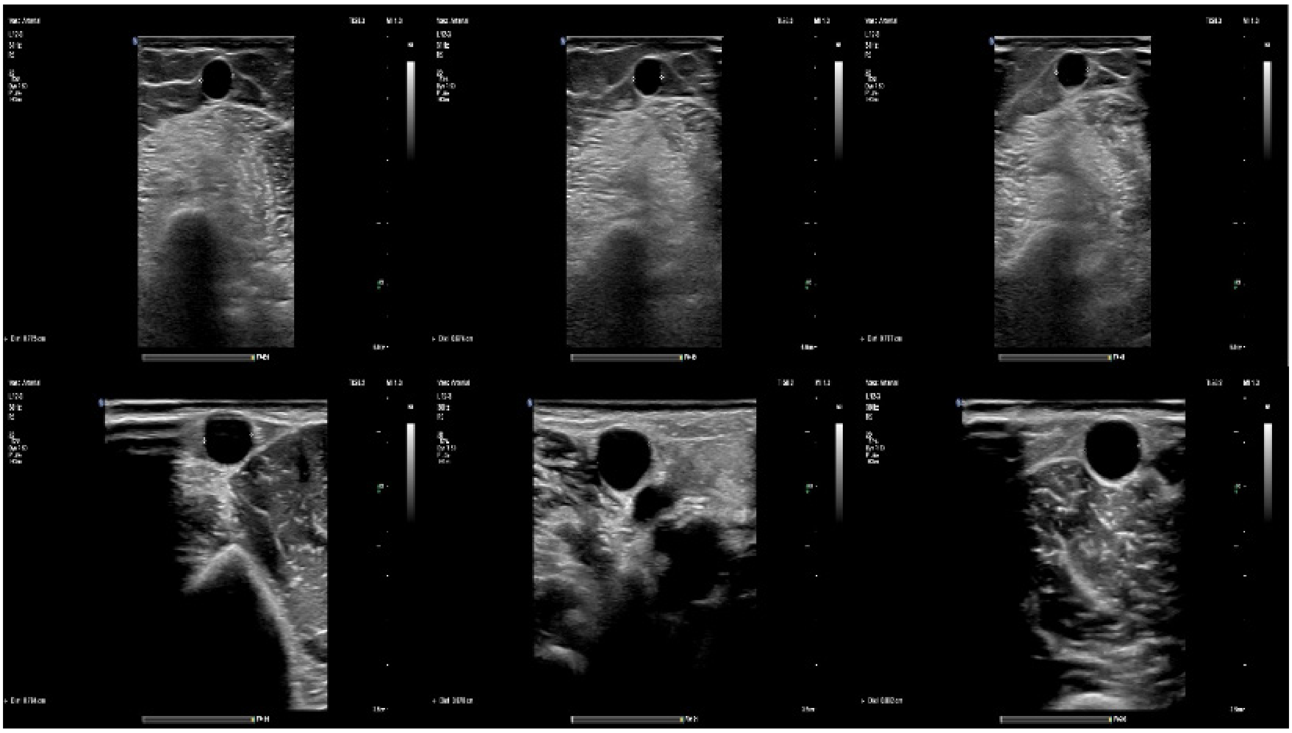

Figure 4. Diameters of the efferent vascular system. From top left to right arm as proximal, middle, and distal. From bottom left to right forearm as proximal, middle, and distal

Smirnov and Shapiro-Wilk tests were used for normality tests. Spearman's rank correlation coefficient was calculated since the normal distribution condition was not met to determine the relationship between variables. Statistical significance level was taken as $P<0.05$ in calculations, and SPSS 20.0 Version Statistical Package Program was used for analyses.

Results

A total of 58 patients, 19 females (32.8%) and 39 males (67.2%), were analyzed in the study. The fistula of 9 patients was total thrombosis. The fistula flow rate of 8 patients was below 300 mL/min and was considered insufficient. The fistula flow rate of 41 patients was 300 mL/min and above, and it was accepted as sufficient flow. In 11 patients with a fistula flow rate of 300 mL/min and overhead, the carrier basilic vein was determined as the carrier cephalic vein in 30. Since the cephalic vein was chosen as the vascular access site in 6 patients with its carrier basilic vein, it was referred to us in terms of fistula dysfunction. Because the cephalic vein did not carry enough blood in these patients, the patient could not receive dialysis. The Kt/V value was calculated in 41 patients. Descriptive statistics for Kt/V, flow rate, and efferent vascular diameter are detailed in Table 1.

Correlation coefficients between variables are given in Table 2 which revealed a high level of $r=0.72$ ($P=0.001$) between flow rate and Kt/V ratio, and a high level of positive and statistically significant correlation between flow rate and diameter efferent vascular structure $r=0.86$ ($P=0.001$) ($P<0.05$) (Figures 5 and 6).

The flow rate was also measured from the efferent vascular system since there was no phlebitis longer than 4 cm, and there was no significant stenosis in the efferent vascular structure of 35 patients in the flow rate measurements made from the anastomosis level.

Descriptive statistics regarding the anastomosis level and flow rate measurements from the efferent vascular are given in detail in Table 3.

The correlation between the level of anastomosis and efferent vascular structure is given in Table 4. After examining the, a high level of positive and statistically significant correlation was found between the anastomosis level and the efferent vascular structure ($P<0.05$) (Figure 7).

Table 1. Descriptive statistics for Kt / V, flow rate, and efferent vascular diameter

	n	Mean ± SD	Minimum	Maximum
Kt/V	41	1.8093 ± 0.38987	1.32	2.98
Flow rate	49	613.26 ± 408.087	200	1641
Efferent vascular structure	58	6.084 ± 2.7610	1.8	14.0

Kt/V: one of the dialysis efficiency indicators in treatment planning in routine dialysis applications in ESRF patients.

Table 2. Correlation coefficients between kt/V ratio, flow rate and efferent vascular structure

	Kt/V	Flow rate	Diameter
kt/V	1.000		
Flow rate	0.719**	1.000	
Efferent vascular structure	0.492**	0.860**	1.000

Kt/V: one of the dialysis efficiency indicators in treatment planning in routine dialysis applications in ESRF patients

Table 3. Descriptive statistics regarding the anastomosis level and flow rate measurements from the efferent vascular structure

Flow rate	n	Minimum	Maximum	Mean	SD
Anastomosis	35	315	1641	805.71	408.267
Efferent vascular structure	35	178	1393	647.66	320.257

Table 4. Correlation between the level of anastomosis and efferent vascular structure

Flow rate	Anastomosis mean	Efferent vascular structure mean
Anastomosis mean	1	
Efferent vascular structure mean	0.871**	1

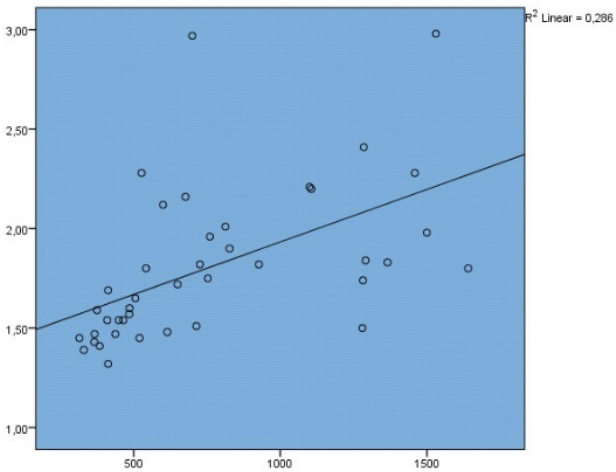

Figure 5. Correlation between Kt / V and flow rate

Discussion

We evaluated the flow rate below 300 mL/min to favor fistula dysfunction. Our study found a highly positive and statistically significant $r=0.72$ ($P=0.001$) correlation between fistula flow rate and Kt/V ratio. In two different studies by Zamboli et al and Lomente et al, it is advocated that flow rates should be between 700-1300 mL/min for an ideal flow.[5,10] While we generally agree with this view, we support a wider fistula flow range (500-1500 mL/min). Also, in two different studies by Zamboli et al and Wiese et al a flow rate below 300 mL/min is stimulating for fistula dysfunction and thrombosis that may develop.[5,11] Therefore, we recommend that the fistula flow rate be kept as 500 mL/min and above as much as possible.

Although there is no consensus about the location of flow measurement in patients with AV fistula, Zamboli et al measured flow rate at the brachial artery level from the efferent vascular structure.[5] We measured from two different localizations. We did the first from the fistula

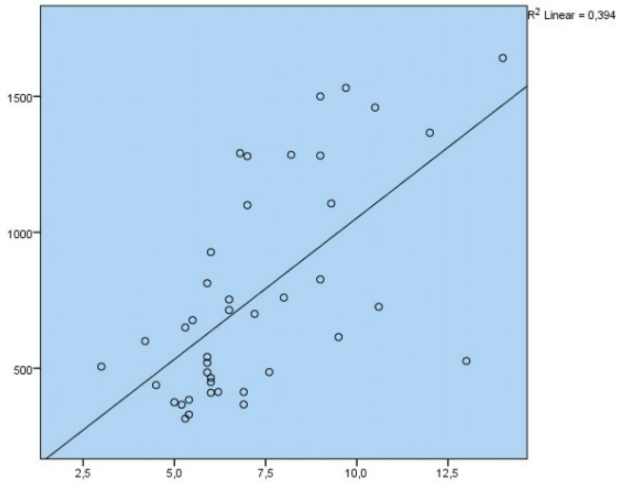

Figure 6. Correlation between flow rate and diameter efferent vascular structure

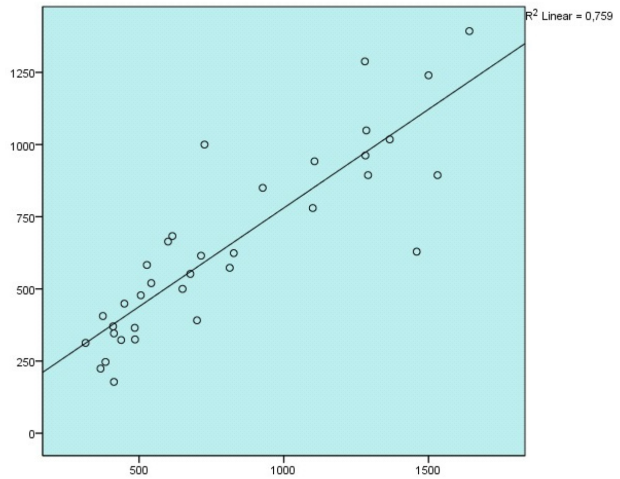

Figure 7. Correlation between the anastomosis level and the efferent vascular structure

anastomosis line the second from the efferent vascular system. We noted the absence of aneurysmatic dilatation, the lack of segment phlebitis longer than 4 cm in the afferent vascular structure, and compression that would not change the vein's diameter. In the measurements we made, we observed that the anastomosis level and the flow rate in the efferent vascular structure were positively and highly correlated in patients without phlebitis or thrombosis in the efferent vascular system. Although we agree with Zamboli et al[5] regarding fistula measurement localization, we argue that the measurement can be made from the fistula anastomosis line and the efferent vascular structure outside the brachial artery. Especially in patients with a more than 50% thrombus in the efferent vascular system and segment phlebitis longer than 4 cm, we observed that the efferent vascular structure's flow rate was disproportionately lower than the anastomosis level. We think this situation is due to collaterals developing secondary to phlebitis. We believe that the problem can improve with the treatment of phlebitis.

Our study determined that the fistula flow rate's adequacy is proportional to the efferent vascular structure's diameter. In our research, we found that the efferent vascular structure diameter of patients with fistula flow over 300 mL/min was 5 mm and above, and we found a moderately positive and statistically significant correlation between the flow rate and the efferent vascular diameter of $r=0.66$ ($P=0.001$) ($P<0.05$). In their study, Lauvao et al stated that the diameter of the efferent vascular structure is a determinant in fistula maturation, and we found similar findings with our research.[12] Also, in our study, the efferent vein diameter of patients with fistula flow less than 300 mL/min and thrombosis of the fistula was determined to be less than 4 mm.

We observed that the carrier vein was a basilic vein starting from the arm level in 6 patients with a sufficient fistula flow rate and problems in dialysis. These patients had proximal radiocephalic, and two had distal radiocephalic fistula. Although fistula cannulation is not a problem in most patients, it should be kept in mind that the carrier vein may be the basilic vein, especially in patients with sufficient fistula flow and a thrill in the fistula. Because the basilic vein in these patients is located more in-depth than the cephalic vein, it may not be felt by palpation. CDUS has a significant role in renal replacement therapy in these patients. Thus, these patients will not be diagnosed with fistula dysfunction unnecessarily.

One limitation of our study is that while measuring the patients' blood flow, it was not taken into account whether the patients were on dialysis or not. The other limitation is that our study included a limited number of cases. With a larger sample size, these promising results could be confirmed. In addition, since Kt/V includes the rates in the same month, the rates in other months have not been compared.

Conclusion

We found a highly positive and statistically significant correlation between fistula flow rate and Kt/V ratio. Low kt/V ratios have different causes. Low fistula flow should be considered first in low Kt/V values.

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Authors' Contribution

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Supervision: Cemil Goya, Ali Mahir Gunduz.
Validation: Fatma Durmaz.
Visualization: Ensar Turko.
Writing–original draft: Ensar Turko.
Writing–review & editing: Ali Mahir Gunduz, Cemil Goya.

Study Highlights

What is current knowledge?

- As a result of fistula dysfunction, flow rate is affected. For a patient undergoing dialysis, a session is organized based on the kt/V ratio or the patient's treatment plan is changed.

What is new here?

- There is a statistically significant correlation between kt/V ratio and fistula flow.

Competing Interests

The authors declare that they have no conflict of interest.

Ethical Approval

This prospective study was approved by the institutional review board of Van Yuzuncu Yil University institution with a number of 2019/15 on the 17.04.2019

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