

## Brachial Arteriovenous Fistula Flow and post Fistula Venous Diameter in HemoDialysis Patients

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### ABSTRACT:

#### BACKGROUND:

An arteriovenous fistula must be able to sustain the flow demands of the hemodialysis machine; the flow rate in the fistula only has to be marginally greater than the demands of the blood pump. So fistula flow should be in the range of 600 to 700 mL/min. Overflow occurs when flow rate exceeds 20% of cardiac output.

#### OBJECTIVE:

Evaluation of arteriovenous fistula flow rate and post fistula venous diameter in patients on regular hemodialysis to highlight the prevalence of overflow fistula and its relation to gender, comorbidities, signs and symptoms.

#### PATIENTS AND METHODS:

The measurements of fistula flow rate and post fistula venous diameter in a randomly selected sample of 43 hemodialysis patients (all are brachiocephalic AV-fistula) in the department of dialysis in al-Yarmouk Teaching Hospital in the period from the 1<sup>st</sup> of August 2010 till the 28<sup>th</sup> of February 2011. Statistical analysis using Chi-square test and Pearson correlation has been done via SPSS software version 17.

#### RESULTS:

From the 43 patients enrolled in the study, 31(72%) patients have a fistula flow rate over 1300 mL/min, overflow group; 12 (28%) patients have a flow rates within  $1000 \pm 300$  mL/min, optimal flow group and none has a fistula flow rate less than 700 mL/min. There is a significant association between overflow fistula with (hypertension, the presence of peripheral cyanosis in the fistula corresponding hand, the occurrence of numbness in the fistula corresponding hand and the occurrence of dizziness during hemodialysis) and a strong linear correlation between the measurements of post fistula venous diameter and corresponding fistula flow rates, Pearson correlation coefficient ( $r$ ) of +0.8005.

#### CONCLUSION:

Our study shows a high prevalence of overflow fistula in the patient sample, and this high flow rate is associated with significant complications.

**KEYWORDS:** hemodialysis, arteriovenous fistula, flow rate, doppler.

### INTRODUCTION:

The importance of obtaining long-lasting accesses is due to the increased incidence of renal diseases, life expectancy of the general population and especially of the population with chronic renal disease. The access that is created is routinely used for hemodialysis (HD) 2-5 times per week.<sup>(1)</sup> Many patients who are not candidates for renal

donor transplantation or those for whom a compatible cannot be secured are dependent on hemodialysis for their lifetime.<sup>(2)</sup>

Catheters, grafts and arteriovenous fistulae have been used as vascular accesses for HD. Low rates of complications, clotting and infection all contribute to the fistula's reputation as the "gold standard" of vascular access.<sup>(3)</sup>

Creation of a native arteriovenous fistula (AVF) requires that an anastomosis be made between an adequate artery and an adequate vein in close proximity to each other.<sup>(2)</sup> The side-to-end anastomosis is the most commonly used technique

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and is absolutely indicated when the artery and vein are far apart.<sup>(4)</sup>

The side-to-side anastomosis is technically simple, but there is a definite risk of venous hypertension and excessive flow, particularly if the AVF was in the elbow area.<sup>(5)</sup> In the end-to-end anastomosis, fistula flow is limited, thus avoiding a hyper circulatory state, but it is technically more demanding and there is an increased risk of ischemia of the hand; this is particularly high in elderly and diabetic patients.<sup>(4)</sup>

Normal blood flow rate in the brachial artery is 85 to 110 milliliters per minute (mL/min). After the creation of a fistula, the blood flow rate increases to 400-500 mL/min immediately, and 700-1,000 mL/min within one month; both the artery and the vein dilate and elongate in response to the greater blood flow and shear stress, and here the vein dilates more and becomes "arterialized".<sup>(6)</sup> The formation of an AVF leads to a large decrease in peripheral resistance. This lowered peripheral resistance causes the heart to increase cardiac output in order to maintain proper blood flow to all tissues.

Currently available HD vascular access monitoring techniques include physical examination, static and dynamic venous pressure monitoring, vascular access blood flow monitoring, color Doppler ultrasound study, vascular access imaging and measurement of access recirculation.<sup>(2)</sup> Monitoring of grafts and fistulae reduces morbidity, hospitalization, need for surgical interventions and thrombosis, and improves long-term patency.<sup>(3)</sup>

The flow rate in the hemodialysis machine may range from 250–500 mL/min.<sup>(7)</sup> In order to be used as a dialysis access, an AVF must be able to sustain the flow demands of the dialysis machine; the flow in the fistula only has to be marginally greater than the demands of the blood pump. This should be in the range of 600 to 700 mL/min.<sup>(8)</sup> Vascular-access blood flow less than 600 mL/min necessitates investigations for a reason.<sup>(9)</sup> Fistula overflow occurs when fistula flow exceeds 20% of cardiac output<sup>(10)</sup>. In the study of Valek, Martin and Lopot flow rates greater than 1.300 mL/min were considered excessive.<sup>(11)</sup> Access guidelines, suggests that a working AVF should have a blood flow more than 600 mL/min, a diameter less than 0.6 cm with discernible margins, and be at a depth of 0.6 cm (between 0.5 and 1.0 cm) from the surface 6 weeks after creation.<sup>(12)</sup>

Complications such as infection, thrombosis, ischemia (steal syndrome) and pseudoaneurysm or

aneurysm, significantly limit the quality of hemodialysis, increase long-term morbidity and mortality.<sup>(13)</sup> Venous hypertension occurs in approximately 3% of fistulas and is usually related to central vein stenosis (CVS).<sup>(12)</sup> Fistula overflow occurs when fistula flow exceeds 20% of cardiac output; this can result in two problems: ischemia distal to the site of the fistula and high cardiac output.<sup>(10)</sup> Occasionally extremely high flow rates may be observed, in excess of 3 to 4 liters per minute; this can lead to high output cardiac failure. Ischemic steal syndrome secondary to a HD arteriovenous access occurs in approximately 5 to 10% of cases<sup>(14)</sup>. Ischemia of the hand and fingers can cause permanent loss of digits, small regions of infarction, or ischemia on exercise. Minor degrees of ischemia are common and manifest simply as reduced temperature or numbness.<sup>(3)</sup>

Aim of study Objective evaluation of fistula flow rate and post fistula venous diameter in patients with end stage renal failure on regular hemodialysis to highlight the prevalence of overflow fistula and its relation to gender, comorbidities, medications, signs and symptoms in patients undergoing regular hemodialysis.

### **PATIENTS AND METHODS:**

A randomly selected sample of 43 patients (23 males and 20 females) with ESRF on regular hemodialysis in the department of dialysis in al-Yarmouk Teaching Hospital have been enrolled in our study that extended from the 1<sup>st</sup> of August 2010 till the 28<sup>th</sup> of February 2011; all those patients have a brachial artery AV fistula.

Exclusion criteria are: patients with an AVF of less than one month since creation, premature; patients who had surgical revisions on their AVFs; patients with active infection, bleeding or thrombosis in their AVFs and patients with limb amputations.

Flow measurements and post fistula venous diameter have been obtained by color Doppler study using a 7.5 Mega Hz linear probe of the Philips HD 11XE ultrasound machine. A study by Moghazy Km, Value of color Doppler sonography in the assessment of hemodialysis access dysfunction, showed a sensitivity rate of 96.4% for color Doppler in the detection of AVF flow abnormalities or dysfunction.<sup>(15)</sup> Doppler study was performed by the same operator for all patients.

Flow in peripheral arteries, like the brachial artery, is of tri-phasic pattern. In the first phase, flow increases abruptly till it reaches a plateau which represents the peak flow measurement in the color Doppler study. In the second phase, flow gradually

falls till it reaches a zero value and that marks the beginning of the third phase where flow actually reverses. This is why the measurements of mean fistula flow rates are more accurate than peak fistula flow rates.<sup>(16)</sup> Tri-phasic flow patterns are seen in the brachial artery, AVFs and the post fistula vein. Patients have been divided to overflow group, optimal flow group or underflow group according to the measurements of mean fistula flow rates.

Patients are considered to be hypertensive if they have had a blood pressure of 140/90 mm Hg or higher for more than three months. Patients are considered smokers if they have had a one pack year of smoking or more during the past seven years. Patients are considered to be diabetic if they have had a fasting blood sugar  $\geq 126$  mg/dL (7.0 mmol/L) on two occasions. Patients are considered to be in heart failure if they have had chronic symptoms identical to any of the New York Heart Association classes with echocardiographic findings including those of systolic or diastolic dysfunction or high output HF.<sup>(17)</sup>

A thorough medical examination was conducted for each patient with particular emphasis on the condition of peripheral pulse and the presence of weakness, discoloration, atrophic skin changes, hair loss, ulcers or gangrene distal to the fistula site.

### Statistical analysis

All data were expressed in means, standard deviations, percentages and cross tabulation tables. Association was considered to be significant at a P value  $< 0.05$  level using Chi-square test. Correlation between post fistula venous diameter and fistula flow rate was calculated using Pearson correlation coefficient ( $r$ ).

### RESULTS:

From the 43 patients enrolled in the study, none has a fistula flow rate less than 700 mL/min, 31 patients (72%) have been found to have a fistula flow over 1300 mL/min, overflow group, and 12 patients (28%) have been found to have a flow within  $1000 \pm 300$  mL/min, optimal flow group.

Figure (1) shows flow distribution in the study sample.

From the twelve patients in the optimal flow group, six are males (50%) and six are females (50%); six (50%) have a history of smoking of more than five pack years during the past ten years; five (42%) are hypertensives; four (33%) are diabetics and one (8%) has heart failure. Table (1) shows the

distribution of co-morbidities and gender of the patients in the study sample.

From the twelve patients in the optimal flow group, three (25%) develop dizziness during hemodialysis; three (25%) have numbness in their fistula corresponding hand during hemodialysis; two (17%) have weaker radial pulse in their fistula corresponding limb compared to the other limb; three (25%) have peripheral cyanosis in their fistula corresponding hand compared to the other limb; one (8%) has atrophic (dry and thin) skin or hair loss in their fistula corresponding hand compared to the other limb and none (0%) have ulcerations or gangrene in their fistula corresponding hand, Table (2) shows the distribution of signs and symptoms and limb condition in the patients of the study sample.

From the 31 patients in the overflow group, 17 are males (55%) and 14 are females (45%); 13 (42%) have a history of smoking of more than 5 pack years during the past ten years; 23 (74%) are hypertensives; 15 (48%) are diabetics and 9 (29%) have heart failure disease. Table (1) shows the distribution of co-morbidities, medications used and gender of the patients in the study sample.

From the 31 patients in the overflow group, 24 (77%) develop dizziness during hemodialysis; 22 (71%) have numbness in their corresponding hand during hemodialysis; eight (26%) have weaker radial pulse in their fistula corresponding limb compared to the other limb; 22 (71%) have peripheral cyanosis in their fistula corresponding hand compared to the

other limb; four (13%) have atrophic (dry and thin) skin or hair loss in their fistula corresponding hand compared to the other limb and only three (10%) have ulcerations or gangrene in their fistula corresponding hand. Table (2) shows the distribution of signs and symptoms and limb condition in the patients of the study sample.

### DISCUSSION:

There is a high prevalence of over flow fistula in the patients of the study sample; from the 43 patients in the study, 31 (72%) have a fistula flow over 1300 mL/min, and twelve (28%) have a flow of less than 1300 mL/min. This could be due to the wide difference in fistula age between the two groups  $12.42 \pm 7.25$  months for the optimal flow group and  $30 \pm 13.26$  months for the over flow group, as shown in table (3). The fact that all patients in our study have a brachiocephalic AVF

could also be a contributing factor for the high percentage of overflow.

In our study, the AVF flow rate ranges from 828 mL/min to 1662 mL/min with a mean of 1282.95 mL/min and a standard deviation of 259.73 mL/min. In the study of Jeferson Freitas Toregeani and others showed an AVF mean flow of 1031.62 mL/min with a standard deviation of 614.81 mL/min.<sup>(1)</sup> This is statistically comparable with flow rates in our study. This means the our AV fistulae have higher flow rate.

In our study, the post-fistula-venous diameter ranges from 7.5 mm to 19.5 mm with a mean of 13.6 mm and a standard deviation of 4.2 mm. Post fistula venous diameter mean is 8.1 mm with a standard deviation of 0.4 mm in the optimal flow group. Post fistula venous diameter mean is 15.7 mm with a standard deviation of 2.8 mm in the over flow group. A study by Corpataux and others showed that the venous diameter of the brachiocephalic fistula increased to 5.04 mm at one month after creation; after the 3rd month, it reached a maximal diameter of 6.62 mm.<sup>[18]</sup> The study of Jeferson Freitas Toregeani and others showed, for the brachiocephalic fistula, a post fistula venous diameter of  $6.15 \pm 1.16$  mm<sup>(1)</sup>. The study of Corpataux measured post fistula venous diameter after one, two and three months after the procedure of creating the fistula. The study of Jeferson Freitas Toregeani and others measured post fistula venous diameter after seven, 14, 21 and 28 days after the procedure of creating the fistula, while the patients in our study had a longer period elapsed since fistula creation,  $12.42 \pm 7.25$  months for the optimal flow group and  $30.00 \pm 13.26$  months for the overflow group. So our sample has a wider post-fistula-venous diameter at time of creation and grows wider with time.

Statistically significant associations, p value <0.05, have been shown between overflow fistula and the

Recommendations:

It is wise to start with creating a radial fistula first, and brachiocephalic fistula should be attempted after the failure of radial fistula. Encourage periodic color Doppler ultrasound for monitoring fistula

flow in hemodialysis, particularly in patients with peripheral cyanosis in the fistula corresponding hand, hypertensives and patients who develop dizziness or numbness in the fistula corresponding hand during hemodialysis.

presence of hypertension, peripheral cyanosis distal to the site of the fistula, dizziness during hemodialysis, numbness in their corresponding limb distal to the site of the fistula during hemodialysis, as shown in table (1) and (2). The findings associated with fistula overflow occur because of the lower resistance of the arteriovenous fistula than other distal vascular beds; this leads to a reduced distal blood flow. Ischemia of the hand and fingers can cause permanent loss of digits, small regions of infarction, ulcers, hair loss, atrophic skin changes or ischemia on exercise.<sup>(3)</sup> Minor degrees of ischemia are common and manifest simply as reduced temperature or numbness.<sup>(16)</sup>

Our study showed a strong linear correlation between the measurements of fistula flow and post fistula venous diameter in all patients in the study sample, Pearson correlation coefficient (*r*) of +0.8005.

### Recommendations:

It is better to start with creating a radial arteriovenous fistula first. Brachiocephalic arteriovenous fistula should be created if the radial arteriovenous fistula fails.

### CONCLUSION:

There is high prevalence of overflow fistula in hemodialysis patients in this sample. Color Doppler study is a good tool to screen overflow fistula in hemodialysis patients. There is statistically significant association between AVF overflow and the presence of hypertension; peripheral cyanosis in the fistula corresponding hand; the occurrence of numbness in the fistula corresponding hand during hemodialysis and the occurrence of dizziness during hemodialysis.

There is strong linear correlation between the measurements of post fistula venous diameter and corresponding fistula flows.

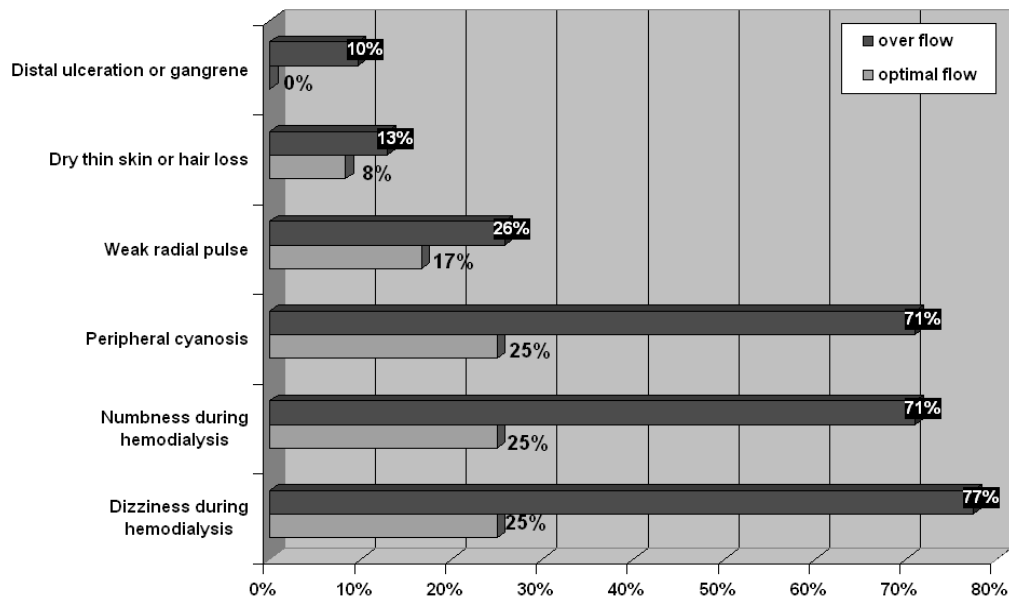
**Table 1: Gender and co-morbidities of patients in study sample.**

Gender & co-morbidities	Optimal flow group		Over flow group		P value
	No.	%	No.	%	
Male gender	6	50%	17	55%	0.7753
Smokers	6	50%	13	42%	0.6329
Hypertensives	5	42%	23	74%	0.0447
Diabetics	4	33%	15	48%	0.3726
Heart failure	1	8%	9	29%	0.1495

**Table 2: Signs, symptoms and limb condition in patients of study sample.**

Signs, symptoms and limb condition	Optimal flow group		Over flow group		P value
	No.	%	No.	%	
Dizziness during hemodialysis	3	25%	24	77%	0.0014*
Numbness during hemodialysis	3	25%	22	71%	0.0061*
Weak radial pulse	2	17%	8	26%	0.5246
Peripheral cyanosis	3	25%	22	71%	0.0061*
Dry thin skin or hair loss	1	8%	4	13%	0.6749
Distal ulceration or gangrene	0	0%	3	10%	0.6750

- Statistically significant



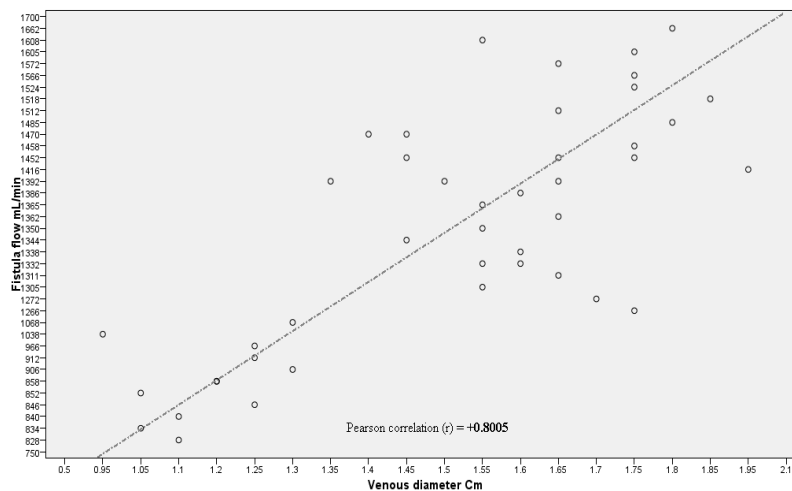
**Figure 3: Clinical characteristics of patients in study sample**

**Table 3: Biometric characteristics of patients in study sample.**

Parameter	Optimal flow group		Over flow group	
	Mean	S.D.	Mean	S.D.
Fistula flow (mL/min)	900.50	81.85	1431.00	104.08
Age (years)	41.33	11.83	43.00	9.58
Duration of renal impairment (months)	17.58	7.60	34.97	13.65
Duration of hemodialysis (months)	14.00	7.21	31.87	13.30
Age of fistula in use (months)	12.42	7.25	30.00	13.26
Peak fistula flow (mL/Sec)	34.34	3.72	41.99	2.46
Mean fistula flow (mL/Sec)	15.01	1.36	23.85	1.73
Venous diameter (Cm)	0.81	0.04	1.57	0.28
Wight (Kg)	67.25	5.15	65.87	6.36
Height (Cm)	167.50	4.48	164.32	4.32
Body mass index	23.97	1.54	24.42	2.40

**Table 4: Age distribution of patients in study sample.**

Age (years)	≤20	21-30	31-40	41-50	≥60	Total
Optimal flow group	1 (8.33%)	2 (16.67%)	3 (25%)	2 (16.67%)	4 (33.33%)	12 (100%)
Over flow group	1 (3.23%)	3 (9.68%)	4 (12.90%)	17 (54.84%)	6 (19.35%)	31 (100%)



Pearson correlation coefficient ( $r$ ) of +0.8005, strong linear correlation.

**Figure 3: Correlation between post fistula venous diameter and fistula flow.**



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