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ROLE OF COLOR DOPPLER ULTRASONOGRAPHY IN ASSESSMENT OF COMPLICATIONS OF HEMODIALYSIS A-V FISTULA

By

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ABSTRACT

Background: Arterio-venous fistulas (AVFs) are the vascular access of choice for hemodialysis (HD) with a lower incidence of complications and longer survival than prosthetic grafts or central venous catheters.

Objective: To evaluate the role of color Doppler ultrasound (CDUS) in the detection and characterization of complications of arterio-venous fistula (AVF) dialysis access.

Patients and methods: The study was carried out at the Department of Radiology, El-Zaitoun Specialized Hospital, Cairo. The study was carried out during the period between August 2020 till April 2021. A total of 50 patients were selected from those referred from the nephrology dialysis center. All patients were subjected to assessment of AVF complications by CDUS.

Results: Out of 50 patients with complicated AVF of them, 22 patients (44%) were males, and 28 patients (56%) were females. The total complications frequencies were 65. Of them venous thrombosis was found in 24 patients (37%), stenosis in 17 patients (26%), aneurysm in 13 patients (20%), pseudoaneurysm in 5 patients (8%), hematoma in 3 patients (5%), clinical suspicion of infection in 2 patients (3%), and steal phenomenon/syndrome in 1 patient (1%).

Conclusion: The CDUS was a non-invasive diagnostic tool for early detection of complications of AVF that allowed monitoring of the AVF blood flow, and detection of possible causes of vascular access malfunction. Owing to its low cost and availability, it was used as the first-line imaging modality for non-functional AVF.

Keywords: Arterio-venous fistula, Complications, Hemodialysis, Color Doppler Ultrasound.

INTRODUCTION

The long-term survival and quality of life of patients with chronic end-stage renal failure on HD are dependent on the adequacy of dialysis via an appropriately placed vascular access. AVFs are the preferred initial HD access owing to their longer patency than prosthetic arterio-venous grafts. However, arterio-venous grafts remain clinically important in patients whom AVFs are not feasible, and possibly in special populations such as the elderly. The creation and maintenance of a patent and well-functioning AVF have become a real challenge to nephrologists and vascular surgeons *(Teodorescu et al., 2012)*.

The type of surgically placed fistula is dependent upon numerous factors. It is accepted practice to begin surgical planning as distally as feasibly possible. The adequate venous diameter may limit

or preclude a distal A-V access site. The ideal preferences for placement of fistula are the creation of AV fistula is radial-cephalic, brachial-cephalic, and then brachial-basilic transposition *(Segal and Qaja, 2020)*.

After surgical creation, the vein distended to become a successful AVF. Fistula undergoes a remodeling process that is referred to as maturation. Although somewhat variable, these changes occur relatively rapidly, resulting in a fistula that can be repetitively used and which can provide adequate dialysis treatments. CDUS can provide all aspects of vascular access care, including vascular mapping, maturation evaluation, and surveillance *(Cho et al., 2017)*.

CDUS enables preoperative vascular mapping for AVF creation, assessment of prime time for puncture, early detection of complications, and choice of appropriate therapeutic procedures for correction *(Gerald el at., 2016)*.

Complications associated with hemodialysis AVF are considered one of the most important causes of morbidity among patients with end-stage renal disease. Access failure is usually owing to thrombosis associated with anastomotic or outflow vein stenosis. Multiple salvage procedures are required to restore functionality or creation of a new access *(Bittl et al., 2010)*.

Stenosis of HD AVF is common and may lead to thrombosis and the loss of the access. Thus, detection of stenosis in AVF before thrombosis could offer a strategy to improve AVF survival by early intervention *(Soliman et al., 2015)*.

Puncture of an AVF either as part of standard dialysis needling or from intervention can result in prolonged bleeding and pseudo-aneurysm formation. However, the mechanism of formation of true aneurysms in AVFs is less clear. This is may be attributed also to repeated needling with consequent development of multiple small fibrous scars in the vessel wall that expand with time and result in localized aneurysmal areas *(Zamboli et al., 2014)*.

The present work aimed to evaluate the role of CDUS in the detection and characterization of complications of AVF dialysis access.

PATIENTS AND METHODS

This prospective study comprised 50 patients who have complicated HD AVF that were investigating CDUS at the Radiology Department, El-Zaitoun Specialized Hospital. Ethical approval from Al-Azhar University Ethics Committee was obtained. The study was carried during the period between August 2020 till April 2021.

Informed consents were obtained from the participants before any procedure was undertaken.

A clinical evaluation of the dialysis access was performed in all patients before CDUS examination:

1. Access patency was determined by the presence of a palpable thrill, in addition to the strength and consistency of a thrill throughout the access.
2. Visual inspection of the limb and access site to detect areas of swelling, redness as well as the presence of

dilation, collateral vessels and palpable prominent localized areas of pulsations (suggesting pseudoaneurysm) was done.

Inclusion criteria:

- Clinically stable.
- Patients on HD with late complication of AVF.
- Age group from 30 to 70 years old.
- Those with late complications.

Exclusion criteria:

- Diabetic patients.
- Patients with peripheral vascular disease.

Doppler ultrasound examination:

During CDUS examinations were performed using grey scale and color Doppler TOSHIBA–Xario 200 ultrasound machine with high frequency transducers (8–10 MHz). Standard supplies for ultrasonic exam: acoustic coupling gel, gloves, and skin wipes. The patient positioning was most often supine, with the arm relaxed and extended out to the side, with the area to be evaluated closest to the sonographer. The patient may be positioned in a Trendelenburg position with hands over the head or examined in the sitting position. Patient position should be optimized so that gravity helps dilate the veins.

Examination included the afferent artery, site of anastomosis, the draining veins as far as the subclavian vein, as well as the arterial tree distal to the AVF in cases experiencing steal syndrome.

All vessels were examined in both transverse and longitudinal planes using gray-scale and color images. At first, the vessels were examined by B-mode to determine the site and type of the fistula, detection of wall echo pattern and dilations, and measurement of the vessel's diameter. Then, color images were obtained to assess the direction of blood flow. Finally, Doppler studies were performed, in the longitudinal orientation. The wall filter was set at 50–100 Hz, and the sample size was maintained below 5mm and was located at the center of each vessel. The spectral waveform was angle corrected, and the Doppler angles of incidence were less than 60°.Then, spectral waveforms were obtained at each level.

The arterial diameter 2 cm proximal to the site of fistula and diameter of the fistula, peak systolic velocity (PSV), and end diastolic velocity. Then, examination of proximal, mid, and distal outflow vein for diameters, patency, and mean velocities was performed. In the presence of stenosis, the degree of the stenosis was calculated. Waveforms and PSVs were documented in any area where velocity increase or turbulence was noted. Stenosis was diagnosed when there was reduction of the vessel diameter of more than 50% and an increase in PSV ratio (PSV in the stenotic area/ PSV upstream the stenotic area) greater than 2:1 in the draining vein or greater than 3:1 in the anastomotic area.

Statistical analysis:

The data were collected, tabulated, and analyzed by Statistical Package for Social the Sciences (SPSS Inc., Chicago, Illinois, USA) computer software version 20.0 and other statistical programs.

Different types data were done:

- Qualitative data were expressed as frequency and percentage.
- Quantitative data were expressed as mean (x) and standard deviation (SD).

RESULTS

The study included 50 patients. It was conducted in radiology department of El-Zaitoun specialized hospital. Mean age of patients was 47.84±9.984 (Mean±SD) with minimum of 30 years old and maximum of 70 years old. 22 of our sample were males and 28 were females **(Table 1)**.

Table (1): Demographic characteristics of the study participants

Variables \ Patients	Numbers	%
Sex		
Male	22	44
Female	28	56
Age		
Mean ± SD	47.84±9.984	
Median (IQR)	46(39.75-56)	

Among 50 patients with clinical symptoms and signs of insufficiency AVF, 41 patients (82%) presented with poor of arterial flow with HD, 25 patients (50%) did not have thrill sensations and 16 (32%) patients had week thrill sensation,1 patients (2%) showed distal tingling, numbness and pain during HD, 25 patients (50%) had impaired fistula and 16 patients (32%) had week impaired fistula, 2 patients (4%) showed clinical suspicion of infection, and 8 patients (16%) had dilated superficial veins **(Table 2)**.

Table (2): Clinical symptoms and sign of insufficiency A-V fistula

Variables \ Patients		Numbers	%
Poor of arterial flow with hemodialysis	No	9	18
	Yes	41	82
Thrill sensation	Good	9	18
	No	25	50
	Week	16	32
Distal tingling, numbness and pain during hemodialysis	No	49	98
	Yes	1	2
Impaired fistula	No	9	18
	Week	16	32
	Yes	25	50
Clinical suspicion of infection	No	48	96
	Yes	2	4
Dilated superficial veins	No	42	84
	Yes	8	16

Among 50 patients with CDUS evaluated of AVF and detected complications ,regarding the fistula site, 10 patients (20%) had brescia-cimino fistula, 1 patient (2%) had brachio-brachial fistula , 15 patients (30%) had upper arm basilic, and 24 patients (48%) had upper arm cephalic. Regarding the fistula type, 15 patients (30%) had brachio-basilic, 1 patient (2%) had brachio-brachial, 24 patients (48%) had brachio-cephalic, and 10 patients (20%) had brachio-cephalic fistula. Regarding the draining vein, 15 patients (30%) had basilic vein, 1 patient (2%) had brachial vein, and 34 patients (68%) had cephalic vein. Regarding the afferent artery, 40 patients (80%) had brachial artery and 10 patients (20%) had redial artery (Table 3).

Table(3): AVF types of the study patient

Variables \ Patients		Numbers	%
Site of fistula	Brescia-cimino	10	20
	Brachio-brachial	1	2
	Upper arm basilic	15	30
	Upper arm cephalic	24	48
Type of fistula	brachio-basilic	15	30
	brachio-brachial	1	2
	brachio-cephalic	24	48
	redio-cephalic	10	20
Draining vein	Basilica	15	30
	Brachial	1	2
	Cephalic	34	68
Afferent artery	Brachial	40	80
	Redial	10	20

Among 50 patients with CDUS evaluated through specific parameters including, mean of diameter fistula 9.90±12.121 (Mean±SD) with minimum 2 mm and maximum 45mm, distance of fistula from skin 6.56±4.272 (Mean±SD) with minimum 3mm and maximum 30mm, PSV 25.66±29.893 (Mean±SD) with minimum 0 cm/sec and maximum 90cm/sec, time averaged mean velocity (TAMV) 24.40±28.638 (Mean±SD) with minimum 0 cm/sec and maximum 80 cm/sec and blood flow volume rate 349.88±732.409 (Mean±SD) with minimum 0 ml/min and maximum 4775 ml/min **(Table 4)**.

Table (4): Parameters of AVF of study patients

Parameters	Mean	SD	Median	IQR
Diameter fistula	9.90	12.121	5	4 – 6.5
Distance of fistula from skin	6.56	4.272	6	5 – 6
PSV	25.66	29.893	19	0 – 42.5
TAMV	24.40	28.638	16.5	0 – 41.5
Blood flow volume	349.88	732.409	154	0 – 379

IQR: interquartile range.

Additionally, 16 patients (32%) had week blood flow, 25 patients (50%) had abnormal blood flow, 4 patients (8%) had Yin-yang pattern, 23 patients (46) had black zone in the lumen, 15 patients (30%) were aliasing, and 1 patient (2%) had abnormal results in examination of distal arterial tree where PSV decreased in cases suffering from steal syndrome and increased with occluded fistula **(Table 5)**.

Table (5): CDUS scan parameters of the study patients

Variables \ Patients		Number	%
Normal blood flow	No	25	50
	Week	16	32
	Yes	9	18
Yin-yang pattern	No	46	92
	Yes	4	8
Black zone in the lumen	No	27	54
	Yes	23	46
Aliasing	No	35	70
	Yes	15	30
Distal arterial tree	Normal	49	98
	Abnormal	1	2

*The distal arterial tree was examined in cases suffering from steal syndrome
* PSV decreased was examined in cases suffering from steal syndrome and increase with occluded fistula.

The total complications frequencies were 65 among 50 patients, of them venous thrombosis was found in 24 patients (37%), stenosis was found in 17 patients (26%), aneurysm was found in 13 patients (20%), pseudoaneurysm was found in 5 patients (8%), hematoma was found in 3 patients (5%), clinical suspicion of infection was reported with 2 patients (3%), and steal phenomenon/syndrome was found in 1 patient (1%) **(Table 6)**.

Table (6): Different complications of AV fistula of the study patients

variables \ Patients		Number	%
Clinical suspicion of infection	No	48	96
	Yes	2	4
Venous thrombosis	No	26	52
	Yes	24	48
Aneurysm	No	37	74
	Yes	13	26
Pseudoaneurysm	No	45	90
	Yes	5	10
Stenosis	No	33	66
	Yes	17	34
Hematoma	No	47	94
	Yes	3	6
Steal phenomenon or syndrome	Yes	1	2
	No	49	98

In this study, we used gray scale of US to diagnose AVF thrombosis **(Figure 1)**.

Figure (1): Male patient 38 years old total thrombosis of brachio-basilic fistula. Brachio-basilic fistula since2 years difficulties of vein cannulation: (a) Total thrombosis and stenosis of brachio-basilic fistula **(b)** Total thrombosis of basilic vein

In this study, we used gray and color scales of US to diagnose AVF stenosis associated with thrombosis **(Figure 2)**.

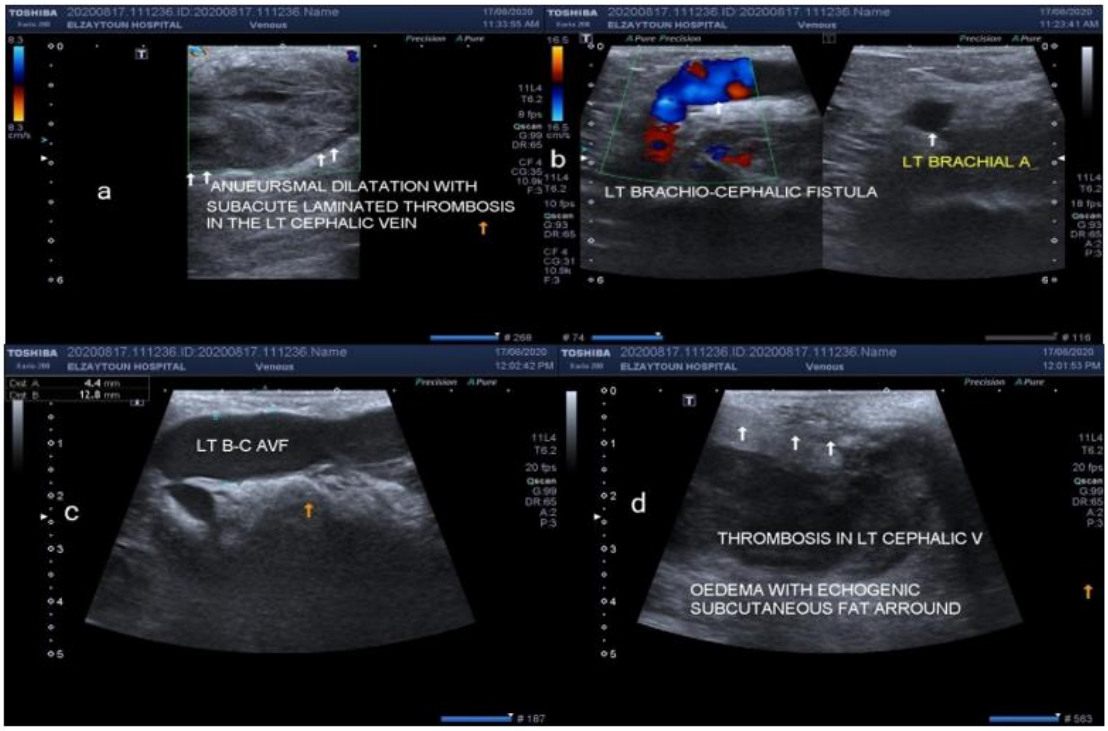

Figure (2): Female patient 55 years old had left brachio-cephlaic fistula since 4 yares. (a,b&c) Aneurysmal dilation with acute –sub acute laminated thrombosis at the distance4.5cm form the site of fistula. **(d)** Associated total thrombosis of left cephalic vein and subcutaneous hyper echogenic fat around it likely acute –sub acute thrombophlebitis.

CDUS was useful to determine the pseudoaneurysm and its signs (yin-yang sign and to and fro flow sign) by color and power Doppler study **(Figure 3)**.

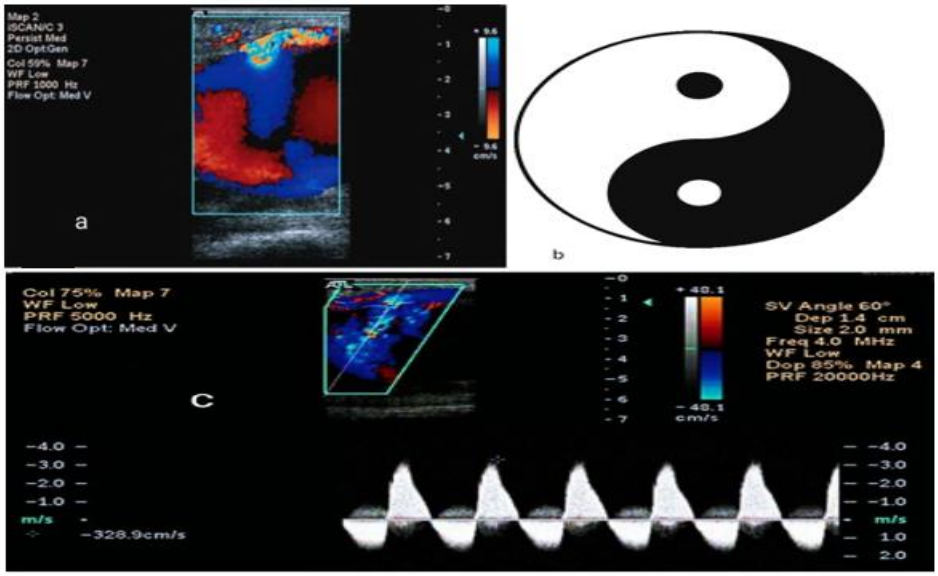

Figure (3): Male patient 39 years old pseudoaneurysm of the cephalic .(A) Duplex scan illustrating the yin and yang sign **(B)** Yin–yang symbol. **(C)** Triplex scan illustrating biphasic ‘‘to-and-fro’’ at the pseudoaneurysm neck.

In this study, decreased the PSV of the radial and ulnar arteries when the fistula was functioning and then elevated PSV when it occluded. When the ratio of velocities (PSV fistula occluded/PSV fistula functioning) was superior to 2, steal syndrome occurred **(Figure 4)**.

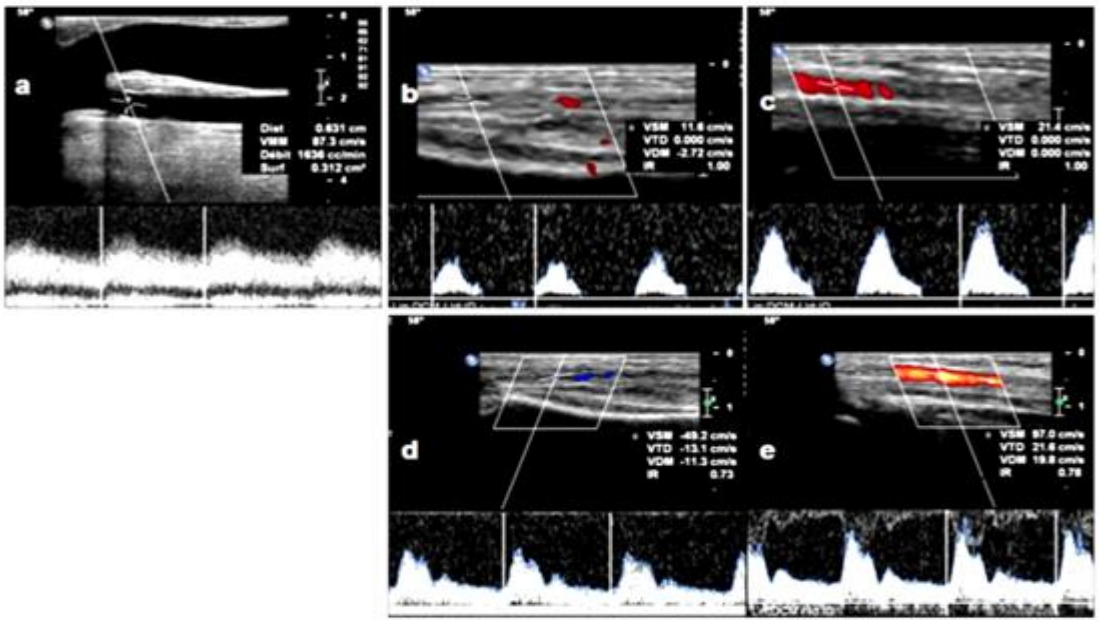

Figure (4): Female patient 60 years old. Steal syndrome. Brachial-basilic fistula since3years.Cold sensation of the hand during hemodialysis since 3 months, fingers ulcerations (a): Excessive flow of the fistula=1636 ml/min **(b) + (c):** Radial and ulnar PSV decrease, **(d) + (e):** Radial and ulnar PSV increase with occluded fistula (PSV Ratio=4.5).

In this study, we used gray scale of US to diagnose infected hematoma and patients had an infected AVF **(Figure 5)**.

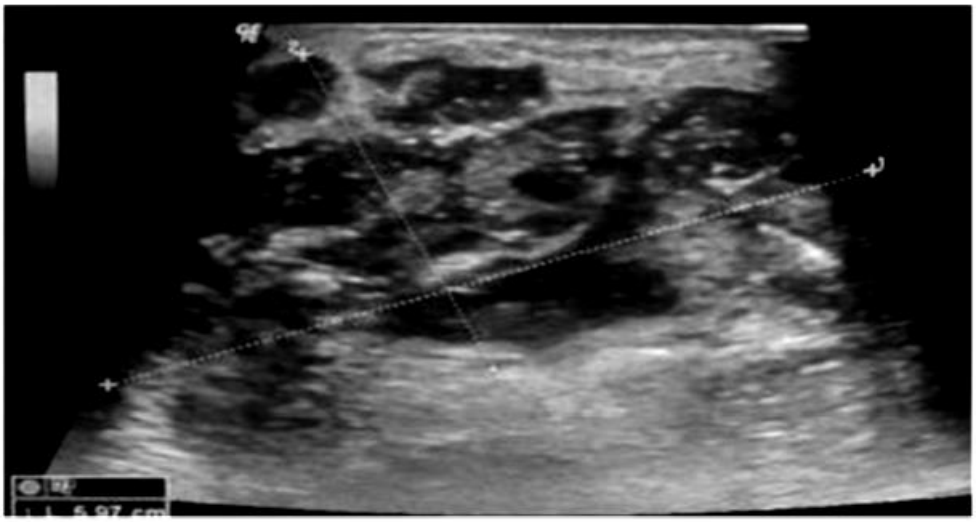

Figure (5): Female patient 56 years old. Infected hematoma .Gray scale image shows an infected hematomas forming subcutaneous abscesses

DISCUSSION

Vascular access problems remain the vulnerable point of modern HD *(Kumbaret al., 2012)*. For evaluation of access dysfunction, the initial, most practical and cost-effective method is physical examination *(Salman and Beathard, 2013)*. US confirms the results of physical examination such as inflow stenosis and outflow stenosis. Moreover, it provides important information about the functional severity like brachial artery flow rates *(Lomonte et al., 2015)*. By combining the findings of US and physical examination, the treatment methods can be determined, such as angioplasty, revision surgery, or conservative management *(Cho et al., 2017)*. Moreover, Doppler US shortens angioplasty time, as it gives information on the stenosis site *(Matsui et al., 2012)*, Thus, by the use of US more clinical needs are satisfied *(Cho et al., 2017)*.

In this study, we evaluated the clinical utility of DU for early detection of complications in AV dialysis access. The number of female patients exceeded that of males, with 28 female patients and 22 male patients. This correlated with the findings of the previous studies who found that fistulas are less likely to be usable for dialysis in female than in male patients *(Soliman et al., 2015)*.

Stenosis of HD vascular access is common and may lead to thrombosis and the loss of the access. Thus, detection of stenosis in AVF before thrombosis could offer a strategy to improve AVF survival by early intervention *(Yoo et al., 2014)*. Stenosis in AVF develops more frequently in juxta-anastomotic location, up to 4 cm from the anastomosis *(Tirinescu et al., 2016)*.

Among 17 patients diagnosed with stenosis, four cases had post-fistula stenosis, eight cases had stenosis at the

anastomotic site, whereas five cases had central stenosis. This was in accordance with the finding of *Tirinescu et al., (2016)* who reported juxta-anastomotic localization of stenosis in most cases, in the forearm and in the upper arm AVF equally.

In AVF, stenosis is caused by the intimal or fibromuscular hyperplasia secondary to endothelial damage because of the pressure increase in the venous system. The diagnosis of stenosis relies on the PSV ratio in addition to measurement of the minimum diameter of the stenosed area in addition to PSV to differentiate true significant stenosis from borderline stenosis *(Malik et al., 2014)*.

Among our study population, the most common shunt complication associated with HD was access, venous thrombosis (48%) and stenosis (34%). Thrombosis is usually located in the arteriovenous anastomosis of the AVF. In our study, thrombosis was detected at the venous side of the fistula in all cases. Diagnosis of thrombosis was established by absence of flow using color or pulsed Doppler together with hypoechoic or echogenic thrombus filling the lumen.

Aneurysm occurred in 26 %. The increase in blood flow in an AVF causes a continued increase in vessel size. When there was a marked degree of aneurysmal change in a fistula, downstream venous stenosis was suspected or associated with thrombosis. Thinning of the skin was evaluated carefully as it can lead to ulceration, rupture and severe hemorrhage. Sonographic features of vein aneurysm are characteristic, consisting of an abrupt increase in caliber of a given vessel (> 2 cm). Thrombosis within an aneurysm is usually detectable by sonography *(Henda et al., 2014)*.

Pseudoaneurysms (10 %) occurred at the site of puncture or at the anastomoses. Puncture of an AVF either as a part of standard dialysis needling, or from intervention resulted in prolonged bleeding and pseudoaneurysm formation. However, the mechanism of formation of true aneurysms in AVFs was less clear. This is could be attributed to repeated needling with consequent development of multiple small fibrous scars in the vessel wall that expand with time and result in localized aneurysmal areas *(Lazarides et al., 2014)*.

The clinical finding of a pulsatile mass and a systolic murmur usually allowed correct diagnosis of aneurysm and pseudoaneurysms. However, CDUS is of the utmost importance as it allowed better estimation of the extent of aneurysm (less or more than 5 mm) size of its neck and degree of mural thrombosis. Additionally, CDUS can differentiate pseudoaneurysm from hematomas as they have a typical ‘to-and-fro’ pattern *(Mudoni et al., 2015)*. In this study, (36%) of patients had aneurysm and pseudoaneurysm. CDUS was useful to determine the extent of the aneurysm and evaluate the presence of luminal thrombus as well as to determine if the patient requires surgery or not.

Steal phenomenon or syndrome (2 %) occurred in approximately in forearm and arms fistulas in 6% and 10-20% of cases respectively. It occurred frequently in fistulas with large anastomosis and high flow. Its clinical manifestations included various signs and symptoms ranging from coldness, pallor, mild paresthesia, and pain during dialysis to severe symptoms

such as pain at rest, palsy, ulceration, tissue necrosis and loss.

Steal syndrome can be generalized resulting in lower limbs and bowels ischemia and in heart attack. On Doppler examination, arterial steal is defined as retrograde flow in the native artery distal to the anastomosis. There is an inverted or a bidirectional flow (anterograde in the systole and retrograde in the diastole. The compression of the fistula results in gradual restoration of the anterograde flow *(Hendaet al., 2014)*.

In this study, PSV of the radial and ulnar arteries also decreased when the fistula was functioning and then elevated PSV when it occluded. When the ratio of velocities (PSV fistula occluded/PSV fistula functioning) was superior to 2, steal syndrome was considered.

Hematoma was in 6% and local infection in 4%. Tenderness and erythema along the access indicated infection. An untreated access infection lead to bacteremia, sepsis, hemorrhage, and if left untreated, possible death occurred *(Henda et al., 2014)*.

CONCLUSION

The CDUS is a non-invasive diagnostic tool for early detection of complications of AVFs that allows monitoring of the AVF blood flow and detection of possible causes of vascular access malfunction. Owing to its low cost and availability, it was used as the first-line imaging modality for non-functional AVF.

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دور التصوير بالموجات فوق الصوتية والدوبلر الملون في تقييم المضاعفات المصاحبة للوصلة الشريانية الوريدية المستخدمة في الغسيل الكلوي الخارجي

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خلفية البحث: تعتبر التوصيلات الشريانية الوريدية منفذاً للأوعية الدموية المفضل لغسيل الكلي من الرقعة الشريانية الوريدية الاصطناعية أو القسطرة الوريدية المركزية حيث أنها أقل في معدل حدوث المضاعفات و أكثر إستمرارية.

الهدف من البحث: تقييم دور التصوير بالموجات فوق الصوتية والدوبلر الملون في اكتشاف وتوصيف مضاعفات التوصيلة الشريانية الوريدية المستخدمة في الغسيل الكلوي.

المرضي وطرق البحث: أجريت هذه الدراسة بقسم الأشعة بمستشفى الزيتون التخصصي بالقاهرة ما بين أغسطس 2020م حتي أبريل 2021م حيث تم إختيار 50 مريضا من بين أولئك الذين تم تحويلهم من مركز الغسيل الكلوي لقسم الأشعة حيث خضع جميع المرضي لتقييم مضاعفات الغسيل الكلوي بالتوصيلة الشريانية الوريدية بواسطة التصوير بالموجات فوق الصوتية والدوبلر الملون.

نتائج البحث: من بين 50 مريضا يعانون من مضاعفات بالتوصيلة الشريانية الوريدية المستخدمة في الغسيل الكلوي كان 22 مريضا بنسبة 44% من الذكور و28 مريضا بنسبة 56% من الإناث وقد بلغ إجمالي عدد المضاعفات في المرضى جميعا 65 منها تكوين الجلطات في 24 مريضا، ومنها ضيق التوصيلة في 17 مريضا، ومنها التمدد الحقيقي في الأوعية الدموية في 13 مريضا، ومنها التمدد الكاذب في الاوعية الدموية في 5 من المرضى، ومنها الورم الدموي بجوار

التوصيلة في 3 من المرضى, ومنها التهاب التوصيلة والمنطقة المجاورة لها في 2من المرضى، ومنها متلازمة سرقة الدم من الأوعية الدموية في مريض واحد.

الاستنتاج: التصوير بالموجات فوق الصوتية والدوبلر الملون أفضل أداة تشخيصية غير تداخلية للكشف المبكر عن مضاعفات التوصيلات الشريانية الوريدية المستخدمة في الغسيل الكلوي والتي تسمح بمراقبة تدفق الدم في التوصيلة وأكتشاف الخلل المحتمل المتسبب في تعطيل التوصيلة. إضافة لذلك يعتبر التصوير بالموجات الصوتية والدوبلر الملون أقل تكلفه وأكثر توفرا لذلك، يجب إستخدامه كخطوه أولى في تشخيص أعطاب التوصيلة الشريانية الوريدية.

الكلمات الدالة: التوصيلة الشريانية الوريدية، المضاعفات، الغسيل الكلوي، التصوير بالموجات فوق الصوتية والدوبلر الملون.