

# ROLE OF DUPLEX ULTRASOUND IN THE POST OPERATIVE ASSESSMENT OF DIALYSIS ACCESS

By

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## ABSTRACT

**Background:** In patients with end stage renal disease (ESRD), the need for vascular access is mandatory to start hemodialysis (HD) as renal replacement therapy. Hemodialysis vascular access is the key point of the therapy. No working vascular access, no therapy.

**Objective:** To review the numerous roles played by Doppler Ultrasound Study (DUS) in post-operative evaluation of dialysis access function.

**Patients and Methods:** This study aimed to evaluate the role of color Doppler ultrasound in the detection and characterization of complications of arterio-venous fistula dialysis access. So, we included 50 patients with chronic renal failure and on regular hemodialysis who were referred from Benha Teaching Hospital Center for Nephrology and Dialysis within a period of twelve months from June 2019 to May 2020.

**Results:** According to dialysis access type among patients in this study, it was AVF in 48% of patients, AVG in 10% of patients, and Arterio arterial graft in 2% of patients.

Among our study population, the most common shunt complication associated with HD was access thrombosis (n=24, 48%). Diagnosis of thrombosis was established by absence of flow using color or pulsed Doppler together with hypoechoic or echogenic thrombus filling the lumen. The 2nd common diagnosis was stenosis (n=21, 42.0%). Pseudo-aneurysmal formation was detected in 12% of patients. Aneurysmal dilation was reported in 4% of patients, and dialysis induced Limb ischemia/high flow fistula was 4% of patients. The least common complication was Infection in 2% of patients.

**Conclusion:** Color duplex US accurately identified the site and nature of the problem, in dysfunctional arterio-venous fistula, and allowed the operator to plan the endovascular (or open) intervention.

**Keywords:** Duplex Ultrasound, Dialysis Access, Arterio-Venous Fistula.

## INTRODUCTION

Arterio-venous fistula (AVFs) and Arterio-venous Grafts (AVGs), the preferred vascular accesses (VA) for dialysis, are problematic: AVFs have a high rate of maturation failure and AVGs have a short life expectancy (*Pietryga et al., 2017*).

Native arterio-venous fistula (AVF) is the vascular access of choice for hemodialysis patients. Compared with grafts and central venous catheters, AVFs last longer and are associated with fewer complications (*Zamboli et al., 2014*).

In comparison to prosthetic arteriovenous grafts and central venous catheters, autogenous arteriovenous

hemodialysis accesses have higher patency rates, reduced complications, thus they're preferred. Arterio-venous fistulas can provide long-term function rather than dialysis catheters, which are associated with a higher mortality (*Helal et al., 2019*).

Femoral and subclavian vein central venous catheters (CVCs) should only be used for short periods, because of the risk of infection and Central venous occlusive disease (CVOD). Hemodialysis (HD) initiation with a CVC and a long AVF maturation time, results in poorer long-term AVF patency rates (*Schmidli et al., 2018*).

An arteriovenous fistula (AVF) for hemodialysis is a communication generated surgically between a vein and an artery. Frequently they're performed on the upper limbs, although when they fail, they can sometimes be seen in the lower limbs. Surgeons try to make it as distal as possible in the non-dominant arm. By this way, the proximal vessels are preserved for future access. Arteriovenous fistulas (AVF) are the method of choice for vascular access for patients in renal replacement therapy.

The dialysis population has comorbidities such as diabetes mellitus, coronary disease and peripheral arterial disease, among other pathologies, making the creation and permanence of fistulas difficult (*Leal et al., 2019*).

The failure rate of hemodialysis access in the first year is high. In 5.1% of patients, early thrombosis occurs within 18 days of arteriovenous fistula (AVF) creation and is associated with small arterial diameter, forearm location, small draining vein diameter, protamine use,

female gender, surgeon frustration/concern during access creation procedure and reduced or absent thrill at surgery (*Lang et al., 2020*).

Imaging evaluation of vascular access for HD encompasses preoperative assessment of vascular anatomy as well as post-operative surveillance for access maturation and diagnosis of vascular access dysfunction (*Helal et al., 2019*).

In conjunction with physical exam, Doppler ultrasonography (DUS) study provide a useful tool for dialysis vascular access (DVA) management and can play a critical role in their postoperative evaluation.

Doppler ultrasound is one of the surveillance tools. This tool has considerable number of advantages above others, as it is a non-invasive method permits the morphological and functional study of the access and with the latest generation of portable devices can be done in the HD unit at the patient's bedside. Vascular access surveillance using Doppler ultrasound has been shown to reduce vascular access complications and increase long-term patency (*Quintana-Codina et al., 2018*).

In patients with AVFs, DUS can assess fistula maturity; in patients with immature fistulas, a treatable cause of the persistent immaturity can often be identified. Furthermore, DUS able to demonstrate causes of fistula dysfunction, such as stenosis, in poorly functioning fistulas allowing for treatment prior to total fistula loss.

In patients with AVGs and clinical signs of dysfunction, DUS can identify AVG thrombosis, the most common cause

of failure. More importantly, DUS can identify vascular stenosis prior to thrombosis, allowing for potential treatment and preservation of the AVG (*Pietryga et al., 2017*).

The introduction of a well-defined standardized DUS protocol based on anatomic and hemodynamic parameters facilitates the multi-disciplinary management of VA, its monitoring and the timely prevention of any complications (*Nalesso et al., 2018*).

Doppler ultrasound helps to facilitate quick decisions and avoids wasting time referring the patient to other departments. It allows multidisciplinary team decisions on diagnosis of the pathology to be undertaken (*Quintana-Codina et al., 2018*).

So, DUS as a non-invasive tool is the first line imaging method in patients with suspected VA dysfunction (*Schmidli et al., 2018*).

**The purpose of this study was to** evaluate the role of color Doppler ultrasound (CDUS) in post-operative assessment of dialysis access function and detection of complications.

#### **PATIENTS AND METHODS**

This prospective randomized controlled trial study was conducted at the Radio-diagnosis Department of Benha Teaching & Benha University Hospitals. It included sample size of 50 patients aged from 26 to 74 years and included both males and females with an upper limb vascular access (DVAs). They were referred from Benha Teaching Hospital Center for Nephrology and Dialysis. All patients had chronic renal failure and were on regular HD.

They were referred from the nephrology- dialysis center for assessment of HD arteriovenous dysfunction, within a period of 12 months from June 2019 up to May 2020.

Approval for this study was obtained from the institutional review board, and informed consent was obtained from every patient.

#### **Inclusion criteria:**

- Both male and female patients diagnosed as ESRD with an upper limb DVA.
- Immature or malfunctioning DVA in the form of:
  - Poorly matured fistula.
  - Loss of thrill.
  - Access collapse suggesting poor inflow.
  - Distal limb ischemia.
  - Clinical signs of infection.
  - Peri-graft mass, aneurysm, or pseudoaneurysm.
  - Dialysis needle puncture difficulties.
  - Extremity swelling/edema.

**Exclusion Criteria:** Patients with chronically occluded vascular access with failed surgical or interventional attempt were excluded from the study.

#### **Patient assessment was performed before Evaluation of the Dialysis Access by:**

1. A complete history.
2. A clinical evaluation of the dialysis access was performed in all patients before US examination:

- a. Access patency was determined by the presence of a palpable thrill, in addition to the strength and consistency of a thrill throughout the access.
  - b. 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.
3. Explanation of the procedure to the patient and the expected time consumed by the study.

Written consent was obtained from every patient.

Special emphasize for infection control instructions if the patient suffered from bleeding and has an open wound.

#### **Doppler ultrasound examination:**

Patient was most often supine, with arm relaxed and extended out to the side with area to be evaluated closest to the sonographer. The sitting position was be needed for better evaluation of central veins. During DU examinations, 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.

DU examinations were performed using Elegra Siemens Medical Systems (Erlangen, Germany). Linear arrays

transducers (5–10MHz) were usually chosen for superficial vascular imaging and the access itself. However, curved transducers were utilized for deeper vascular imaging, such as central veins in the shoulder or the neck, the inflow arteries, or in obese patients.

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. The vessels were examined by B- mode to determine the site and type of the fistula, detection of wall echo pattern and dilatations, and measurement of the vessel's diameter. Color images were obtained to assess the direction of blood flow.

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°. Spectral waveforms were obtained at each level.

The following parameters were measured at the site of the afferent artery and AV anastomosis: 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 (Kumbar et al., 2012).

**Statistical Analysis:**

Data were collected, revised, coded and entered to the Statistical Package for the Social Sciences (IBM SPSS) version 20. The qualitative data were presented as number and percentages while quantitative data were presented as mean, standard deviations and ranges.

**RESULTS**

The current study included 50 patients with chronic renal failure with vascular access for dialysis including both males and females aged from 26 to 74 years. They were 25 males and 25 females with

mean age of  $43.740 \pm 8.58.45$ . There was no significant difference of patients as regards mean age and sex distribution (**Table 1**).

**Table (1): Distribution of the studied cases according to Sex and Age**

	Values	No.= 50
Sex	Female	25 (50.0%)
	Male	25 (50.0%)
Age	Mean $\pm$ SD	$43.74 \pm 8.58$
	Range	26 – 58

According to the distribution of the presenting symptom that suspect dialysis access dysfunction between the studied patient group, the most frequent presenting symptom was the difficult cannulation which was 13 patients representing 26% of the study sample; followed by failed completion of dialysis

session and clinically failed shunt maturation which was 11 patients representing 22% for each. The least frequent presenting symptom was diffuse upper limb edema in 4 patients representing 8% of the study sample (**Table 2**).

**Table (2): Distribution of the studied cases according to Presenting symptoms**

Presenting symptoms	No.	%
Difficult cannulation	13	26.0%
Failed completion of dialysis session	11	22.0%
Clinically failed shunt maturation	11	22.0%
Localized swelling	9	18.0%
Hand pain	8	16.0%
Malfunctioning graft	5	10.0%
Diffuse upper limb edema	4	8.0%

According distribution of the vascular access type, the most frequent type was the AVF including 44 patients representing 48% of the studied patient group, followed by the AVF including 5

patients representing 10% of the studied patient group. Only one patient of the studied group used Arterio-arterial graft (**Table 3**).

**Table (3): Distribution of the studied cases according to Dialysis access type**

Dialysis access type	No.	%
AVF	44	48.0%
AVG	5	10.0%
Arterio arterial graft	1	2.0%

According the distribution of vascular access type and its site; left brachio-basilic fistula was the most frequent type including 15 patients representing 30% of the studied patient group, followed by left

brachio-cephalic fistula a Left radio-cephalic fistula including 9 patients for each and representing 18 %of the studied patient group (**Table 4**).

**Table (4): Distribution of the studied cases according to DVA type**

DVA type	No.	%
Left brachio-basilic F	15	30.0%
Left brachio-cephalic F	9	18.0%
Left radio-cephalic F	9	18.0%
Right radio-cephalic F	8	16.0%
Right brachio-cephalic F	4	8.0%
Right brachio-basilic F	2	4.0%
Right ulno-basilic F	2	4.0%
Right UL loop graf	2	4.0%
Left UL straight Graft	2	4.0%
Left radio-anticubital F	1	2.0%
Left UL loop Graft	1	2.0%
Right arterio-arterial Graft	1	2.0%

According the distribution of the diagnosis evaluated by Color Duplex study between the studied cases group, the venous thrombosis was the most frequent diagnosis including 24 cases representing 48% of the studied cases, followed by

vascular access stenosis including 21 cases representing 42% of the studied cases, Infection was the least frequent diagnosis including one case representing 2%of the studied cases (**Table 5**).

**Table (5): Distribution of the studied cases according to Diagnosis**

Diagnosis	No.	%
Venous thrombosis	24	<b>48.0%</b>
Stenosis	21	42.0%
Aneurysmal dilatation	4	8.0%
Pseudoaneurysmal formation	6	12.0%
Dialysis induced Limb ischemia/high Flow fistula	2	4.0%
Infection	1	2.0%

## DISCUSSION

This study aimed to evaluate the role of color Doppler ultrasound (CDUS) in the detection and characterization of complications of AVF dialysis access.

To obtain this aim, we included 50 patients with chronic renal failure and on regular hemodialysis who were referred from Benha teaching hospital center for Nephrology and Dialysis.

*Abdelaziz et al. (2018)* aimed to evaluate the role of DU in detection and characterization of shunt complications and to determine further therapeutic options. They concluded that CDUS is a noninvasive 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 should be used as the first-line imaging modality for nonfunctional AVF.

*Chandra et al. (2010)* aimed to correlate colour duplex ultrasonography (US) with contrast fistulography for the detection of functional stenosis in the autogenous AVF (arterio-venous fistula) circuit. They concluded that Colour duplex US provides an accurate diagnostic assessment of a dysfunctional autogenous AVF, and is an important planning tool for subsequent open or endovascular intervention.

*Doelman et al. (2010)* compared Color Doppler ultrasonography (CDUS) and contrast-enhanced magnetic resonance angiography (CE-MRA) with digital subtraction angiography (DSA) for the detection of significant ( $\geq 50\%$ ) stenoses in failing dialysis accesses, and they

determined whether the interventionalist would benefit from CDUS performed before digital subtraction angiography and endovascular intervention. They suggested that CDUS can be used as initial imaging modality of dysfunctional shunts, but complete access should be depicted at DSA and angioplasty to detect all significant stenoses eligible for intervention.

Mean age among 50 studied patients included in this study was  $43.74 \pm 8.58$  years ranging between 26 & 58 years.

The mean age by *Chandra et al. (2010)* was  $57 \pm 14$  years.

This current study revealed that the number of female patients equals that of males, with 25 female patients and 25 male patients. This doesn't correlate 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. This discrepancy in fistula could be explained by smaller arterial diameter in female than male patients, yet the venous diameters are not different, therefore less likely to dilate sufficiently to maintain a blood flow adequate for HD (*Abdelaziz et al., 2018*).

According to dialysis access type among patients included in this study, it was AVF in 48% of patients, AVG in 10% of patients and Arterio arterial graft in 2% of patients.

Regarding distribution of studied cases according to shunt type, 30.0% of cases had Left brachio-basilic F, 18% had Left brachio-cephalic F, 18% had Left radio-cephalic F, 16.0% had Right radio-cephalic F, 8.0% had Right brachio-cephalic F, 4.0% had Right brachio-basilic

F, 4.0% had Right ulno-basilic F, Right UL loop graf was reported in 4% of patients, Left UL straight Graft was reported in 4% of patients. While the least common diagnoses were Left radio-antecubital F, Left UL loop Graft & Right arterio-arterial Graft, each was reported in 2% of patients.

*Chandra et al. (2010)* stated that the majority of the AVF studied were either radio-cephalic (59.1%) or brachio-cephalic (21.5%).

Regarding the Presenting symptoms among patients included in this study, the most common symptom was difficult cannulation that was presented in 26% of patients, followed by both Failure of completing dialysis session and failed shunt maturation each presented in 22% of patients, then Localized swelling in 18%, Hand pain in 16%, Malfunctioning graft in 10%. While the least common symptom was diffuse upper limb edema in 8% of patients.

Similar to this current study, *Abdelaziz et al. (2018)* reported that arm edema was detected in 8% of patients.

Among this current study, the most common shunt complication associated with HD was access thrombosis (48%). Diagnosis of thrombosis was established by absence of flow using color or pulsed Doppler together with hypoechoic or echogenic thrombus filling the lumen. The 2nd common diagnosis was Stenosis (42%). Pseudo-aneurysmal formation was detected in 12% of patients. Aneurysmal dilation was reported in 4% of patients and Dialysis induced Limb ischemia/high Flow fistula was 4% of patients. The least common complication was Infection in 2% of patients.

That was in correspondence with *Abdelaziz et al. (2018)* who reported that the most common shunt complication associated with HD was access thrombosis (48%). followed by stenosis (44% patients), aneurysmal dilatation (8%), pseudo-aneurysmal formation (12%), and infection (4%).

## CONCLUSION

Color duplex US was the first line of investigation in assessing the dysfunctional AVF. It accurately identifies the site and nature of the problem, and allowed the operator to plan the endovascular (or open) intervention.

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## دور الموجات الصوتية والدوبلر الملون في التقييم بعد الجراحي لوصلة الغسيل الكلوي

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**خلفية البحث:** فى مرضى المرحلة النهائية لاعتلال الكلية يعتبر الاحتياج لوجود منفذ وعائي ضرورة حتمية من اجل بدأ عملية الغسيل الكلوي كعلاج تعويضي حيث يعتبر المنفذ الوعائي للغسيل الكلوي مفتاح العلاج وبدونه لايمكن العلاج.

**الهدف من البحث:** مراجعة الادوار المتعددة التي تلعبها الموجات الصوتية والدوبلر الملون في التقييم بعد الجراحي لوظيفة المنفذ الوعائي للغسيل الكلوي.

**المرضى وطرق البحث:** ضمّنت الدراسة خمسين مريضاً يعانون من الفشل الكلوي المزمن ويخضعون لغسيل كلوي منتظم بمركز الكلي والغسيل الكلوي بمستشفى بنها التعليمي خلال 12 شهر في المدة من يونيو 2019 الي مايو 2021 وتم تقييم المنفذ الوعائي للغسيل الكلوي باستخدام الموجات الصوتية والدوبلر الملون لجميع مرضى العينة عند منطقة الاتصال الشرياني-الوريدي وكذلك الجانب الشرياني والوريدي للمنفذ.

**نتائج البحث:** طبقاً لنوع المنفذ الوعائي للغسيل الكلوي مثل الناسور الشرياني-الوريدي نسبة 48% بين مرضى هذه الدراسة، كما مثّلت الرقعة الشريانية-الوريدية نسبة 10% بين مرضى هذه الدراسة، ومثّلت الرقعة الشريانية-الشريانية 2% بين مرضى الدراسة، وكان التجلط الدموي في المنفذ الوعائي للغسيل الكلوي أكثر المضاعفات شيوفا بنسبة 48% بين مرضى هذه الدراسة، وقد تأسس تشخيص التجلط الدموي علي أساس غياب سريان الدم في المنفذ الوعائي للغسيل الكلوي باستخدام الموجات الصوتية والدوبلر الملون مع وجود جلطة تملأ تجويف الوعاء الدموي. وكان ضيق الوعاء الدموي ثاني أكثر المضاعفات شيوفا بنسبة 42% ممثلة في 21 مريضاً من بين عينة الدراسة، أما التمدد الوعائي الكاذب فكان نسبته 12% بين مرضى عينة هذه الدراسة، بينما مثّل

التمدد الوعائي نسبة 4% بين مرضى عينة هذه الدراسة، و مثل القصور الدموي الطرفي المستحث من المنفذ الوعائي للغسيل الكلوي نسبة 4% بين مرضى عينة هذه الدراسة، كما مثلت العدوي أقل المضاعفات شيوعا بنسبة 2% بين مرضى عينة هذه الدراسة.

**الاستنتاج:** أوضحت الموجات الصوتية والدوبلر الملون مكان وطبيعة الخلل الوظيفي للمنفذ الوعائي للغسيل الكلوي بدقة وسمحت للجراح بالتخطيط الجيد قبل التدخل الجراحي في علاج الخلل الوظيفي للمنفذ الوعائي للغسيل الكلوي.

**الكلمات الدالة:** الموجات الصوتية والدوبلر الملون، المنفذ الوعائي للغسيل الكلوي، الناسور الشرياني-الوريدي.

**الاستنتاج:** ناتج شادس 2 فاسك (CHADS2VASc) هو طريقة بسيطة و فاعلة للتنبؤ بضيق الدعامات التي تم تركيبها في الشريان التاجي الأمامي الأيسر النازل.

**الكلمات الدالة:** ناتج شادس 2 فاسك (CHADS2VASc)، حدوث الضيق في الدعامات، حالات الذبحة الصدرية المستقرة، و متلازمة الشريان التاجي الحادة.