Original Research Article

# Efficiency of color doppler ultrasonography for assessment of maturation and post-operative dysfunction of hemodialysis arteriovenous fistula

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## Abstract

**Background:** In the last decades the incidence of chronic renal failure was increased with subsequent increase the need for permanent hemodialysis arterio-venous fistula. The long-term survival of patients on hemodialysis (HD) is dependent on adequate hemodialysis which depends on quality and degree of functionality of vascular access Color Doppler Ultrasound is safe, inexpensive, rapid, and repeatable imaging modality used for preoperative mapping and post operative diagnosis of vascular access (VA) complications. The aim of our study is to detect the efficiency of Color Doppler ultrasonography in evaluation of AVF. **Materials and Methods:** Between May 2017 and July 2018, 45 patients with chronic renal failure who went AVF were evaluated using Color Duplex-Doppler ultrasound preoperatively as well as on 7th day, 14th day, first, second and third months post operatively for both maturation and complications. **Results:** Our study demonstrated that about 50 % of hemodialysis arterio-venous fistulas reach maturation by the end of the first week and all reach maturation by the end of the first month. 31 patients in our study are non complicated and pass safe (68.9 %) while 14 patients had complication (31.1%) "Thrombosis 11.11 % (5 patients), stenosis 8.89 % (4 patients), aneurysmal formation 4.44 % (2 patients), infection 4.44 % (2 patients) and venous hypertension 2.22 % (1 patients). **Discussion and Conclusion:** Color Doppler ultrasound is safe, non-invasive, bed-side technique, low cost and available imaging tool that allows accurate anatomical and hemodynamical data, that is very helpful in preoperative mapping as a for HAVF creation, assessment of maturation time and subsequent availability for use, as well as early detection of complications either by the morphological or hemodynamic changes.

**Keywords**: Vascular access, End Stage renal disease, Ultrasound, Graft, Color Doppler ultrasound, Artero-venous fistula, Hemodialysis

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## INTRODUCTION

In last decades the incidence of chronic renal failure secondary to end stage renal disease (ESRD) was significantly increased and in order to save and prolong their life they underwent hemodialysis. The patients may stay years on hemodialysis for that they should underwent formation of vascular access[1].Many factors are needed for haemodialysis to be effective, it requires an adequately functioning vascular access which has good blood flow and allows easy and repetitive cannulation with two needles as well as excellent patency[2].The arteriovenous fistula (AVF) is the best way to achieve dialysis efficiency. Mean and minimum arterial pressure, velocity

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of the blood, blood flow volume, and both minimum and maximum venous pressures were identified[3].Color Doppler ultrasonography is essential for preoperative planning of AVF creation, assessment of prime time for puncture, detect complications early and choice of appropriate therapeutic procedure for their treatment[4]. After surgical creation, the vein destined to become a successful arteriovenous fistula (AV) 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.[5] The time needed for maturation of arteriovenous fistula (AVF) is still controversial with early detection of access complications and dysfunction give chance for rapid treatment of these complication to save the access and reduces its failure[6].Failure of the arterio-venous fistula has no time limit, it can occur early or late. Early failure of the vascular access considered if happened in the period between creation of the access and the beginning of the work of the fistula, or within the first three months of its use. But late failure is considered if it happened after three months of its use for hemodialysis[7].Ultrasound and color Doppler are very helpful for detection of other complications associated with arterio-venous fistulas including aneurysm, abscess, steal syndrome and hematoma[8].

## PATIENTS AND METHOD

This study is a prospective study done within a period of fourteen months starting from May 2017 to July 2018, after obtaining the approval for the protocol of the this study by our institute researcher board (IRB).All the patients were examined before and after the surgery by Color Doppler examination. The non-dominant limb usually selected for fistulas formation after assessment of the veins and arteries of this limb for their suitability for fistulas formation according to the inclusion criteria. Urgent patients as those with hyperpotassemia or with significant impaired renal function were preserved on dialysis through catheter until the fistula reach the maturation criteria, but non urgent patients waited to perform hemodialysis by using the hemodialysis arterio-venous fistula.

**Inclusion criteria includes**

- Chronic renal failure-Stage IV and V.
- Stable clinical status.
- Diameter of the artery should be 2 mm or more.
- Diameter of the vein should be 2 mm or more..
- No significant difference in blood pressure between the two upper limbs (not more than 20 mmHg).
- Patients referred for native AVF in upper limb for hemodialysis.
- Depth of the vein from the skin surface < 5 mm
- Superficial vein continuing to the deep venous system
- Absence of stenosis in central venous system.
- Absence of occluded arterial segment or segmental stenosis.
- Patent palmar arch (Allen test).
- Availability of the patient for post operative assessment

**Exclusion criteria includes**

- Preoperatively deformed or scarred upper limb.
- Loss of one of the post operative examinations
- Upper limb arterial disorder like Reynaud's syndrome.
- Need to puncture the graft before maturation.
- Not meeting one of the inclusion criteria.

**Ultrasound technique:** During examination all patients were in sitting position with their arms relaxed of table of examination. First B-Mode ultrasound assessment was performed follow by color Doppler assessment. The ultrasound machine used was ToshibaAplio500 (Tokyo, Japan) with linear probe have7–12 MHz broadband to assess the arteries and veins of the upper limbs. Firstly superficial venous system were scanned with caution to avoid applying any pressure to veins. Basilic and cephalic vein patency and diameter were assessed. Second step was the assessment of the normal continuity and flow of the deep venous system to axillary and subclavian veins with exclusion of any stenotic areas within the deep venous system or central venous system. Followed by assessment of the ulnar and radial arteries diameters and patency. Palmar arch patency also was assessed by doing Allen maneuver. After the operations all patients subjected to reassessment at the 7th day, 14$^{th}$ day and, first, second and third months for both maturation (diameter and flow volume) and complications. Blood flow volume should be assessed at a site away from the site of anastomosis to overcome the turbulent flow normally seen at this site. Three measurements were performed in each site and the Doppler sample was place within the center of the vessel with no external pressure and at angle about 60º. After that the vessel diameter and depth from the skin were measured after freezing the image, as well as flow volume measurement was then calculated by the software of the ultrasound machine. The final values reported in this study were the arithmetic mean of study measurements (three consecutive measurements) for the flow and diameter.

**Maturation criteria after fistula formation**

- The diameter of the vein should be more than 4 mm

away from the site of the fistula.

- The depth of the vein should be less than 5 mm from skin surface.
- The flow volume should be more than 400 ml/min away from the site of the fistula.

**ASSESSMENT OF AVF COMPLICATIONS**

**Sites of examination included:**

- The afferent artery.
- Site of anastomosis.
- The draining veins as far as the subclavian vein.
- The arterial tree distal to the AVF in cases suffering from steal syndrome.

**Statistical analysis:** Our results subjected to analysis by using Statistical Package for the Social Science (SPSS) computer program version 23.0 (IBM Corporation, Armonk, New York, USA). The final results are presented as mean and standard deviation (± SD). The difference is considered significant if P value less than 0.05.

## RESULTS

Forty-five patients were evaluated including 27 men (60 %) and 18 women (40 %), their mean age with standard deviation were 45.4 ± 16.8 (ranging between 26 - 64 years), and all were in need for hemodialysis, and all the patients met the inclusion criteria. According to the type of hemodynamic arterio-venous fistulas, the most frequent type of them was radio-cephalic fistula with frequency about 22 cases representing about 48.89 % followed by brachio-cephalic with frequency about 11 cases representing about 24.44 % followed by brachio-basilic with frequency about 12 cases representing about 26.67 % of cases. Assessment of the venous diameter after fistula formation revealed significant increase in there diameters in the first week followed by variable changes in diameters in the following weeks. Table 1 shows the diameters of the examined veins in the form of mean ± standard deviation. Statistically the change in diameter was significant at the wrist at 7$^{th}$ days and 14$^{th}$ days examination post operatively P < 0.0012 and P< 0.008 respectively but changes of the diameter at the elbow show no statistically significance.

**Table 1:** show preoperative and postoperative diameters of the examined veins at the wrist and elbow

| | At the wrist | | At the elbow | |
|---|---|---|---|---|
| | Mean | ± SD | Mean | ± SD |
| Preoperative | 3.31 | 1.4 | 3.83 | 1.36 |
| 7$^{th}$ day | 4.69 | 0.83 | 5.93 | 1.28 |
| 14$^{th}$ day | 4.92 | 1.09 | 6.18 | 1.38 |
| 1$^{st}$ month | 5.23 | 0.92 | 6.82 | 1.34 |
| 2$^{nd}$month | 5.94 | 0.91 | 7.54 | 1.30 |
| 3$^{rd}$ month | 6.46 | 0.88 | 7.96 | 1.27 |

Maturation, from the diameter aspect considering diameter more than 4 mm measured by ultrasound, it occurred in 84.9% of the arterio-venous fistulas at the wrist and in 100% of the arterio-venous fistulas at the elbow at the 7$^{th}$ day post operatively. On the 14$^{th}$day postoperatively, 82.5% of arterio-venous fistulas at wrist and 94.3% of the arterio-venous fistulas at the elbow reached the minimal maturation diameter, and on the 1$^{st}$ month postoperatively, 100% of the wrist and elbow arterio-venous fistulas reached the minimal diameter for maturation. As regard the volume of blood flow, the preoperative measurement was very low and not used for comparison, but post-operative data was used for comparison. At the 7$^{th}$day postoperatively mean volume of flow with standard deviation was 496.8 ± 256.4 ml/min at the wrist and 968.8 ± 328.4 ml/min at the elbow; on the 14$^{th}$ postoperative day, mean flow volume with standard deviation 528.39 ± 265.36 ml/min at the wrist and 1094.65±415.00 ml/min at the elbow; on the 1$^{st}$ month postoperatively, mean hemodynamic arterio-venous fistula value was 580.3 ± 254.53 ml/min at the wrist and 1138.6 ± 588.72 ml/min at the elbow; and on the 2$^{nd}$ month, it was 684.71 ± 269.59 ml/min at the wrist and 1194.62 ± 584.61 ml/min at the elbow and lastly on the 3$^{rd}$ month, it was 697.36 ± 238.43 ml/min at the wrist and 1172.28 ± 566.9 ml/min at the elbow. Statistical significance was detected for hemodialysis arterio-venous fistula flow volume at the wrist around the 7$^{th}$ day postoperatively (p = 0.009) but no other statistical significance detected in other measurements at the wrist or elbow (p > 0.05). Assessment of maturation by using blood flow volume, considering 400 ml/min as the minimal value, in this study only 59.4% of arterio-venous fistula at the wrist reach minimal maturation flow volume but all the fistulas reach minimal maturation flow volume at the elbow after the 7$^{th}$ day postoperatively. On the 14$^{th}$day postoperatively, about 74.9% of arterio-venous fistulas at the wrist reach the minimal maturation flow volume while about 90.9% of elbow arterio-venous fistula reached the minimal maturation flow volume, on 1$^{st}$month postoperatively, 100 % of wrist and elbow hemodialysis arterio-venous fistulas had volume of blood flow more than 400 ml/min. As regard the time of maturation

(including both venous diameter and volume flow) in this study both HAVF at the wrist and elbow show minimal criteria of maturation at the end of the first month. As regard the complications that detected post operatively many complications detected post-operative, table 2 summarizes the number of normal and complicated cases and table 3 summarizes the frequency of each complication detected in the study as well as table 4 summarizes the site of the lesion in relation to the type of complication.

**Table 2:** Frequency and percentage of normal and complicated fistulae

| | Frequency | Percentage |
|---|---|---|
| Normal | 31 | 68.9 % |
| Complicated | 14 | 31.1 % |
| Total | 45 | 100 |

The patient population consisted of 31 normal fistulas (68.9%) and 14 complicated fistulas (31.1%). Complications varying from thrombosis to stenosis, infection, venous hypertension, and aneurysm formation (table3)

**Table 3:** Frequency and percentage of different complications

| Complications | All Patient = 45 | |
|---|---|---|
| | Frequency | % |
| **Thrombosis** | 5 | 11.11 % |
| **Stenosis** | 4 | 8.89 % |
| **Aneurysm** | 2 | 4.44% |
| **Venous Hypertension** | 1 | 2.22 % |
| **Infection** | 2 | 4.44% |

From this table, the most common complication was thrombosis (Figure 1) followed by stenosis (Figure 2) as the second common complication, with equal incidence of aneurysm formation (Figure 3) and infection as third complication (Figure 4 and 5), with least incidence of complication was venous hypertension.

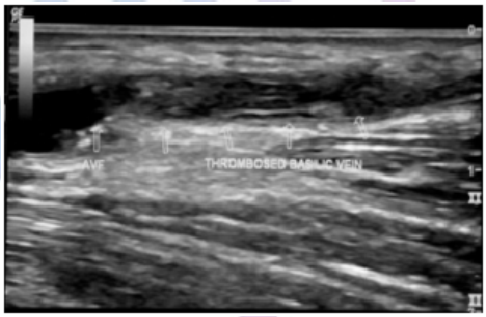



**Figure 1:** B-Mode shows total occluded basilic vein (arrows).

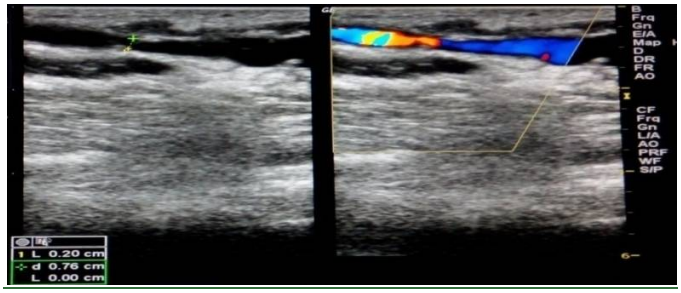



**Figure 2:** The cephalic vein show short segment of stenosis of the cephalic vein with subsequent aliasing of the post-stenotic flow

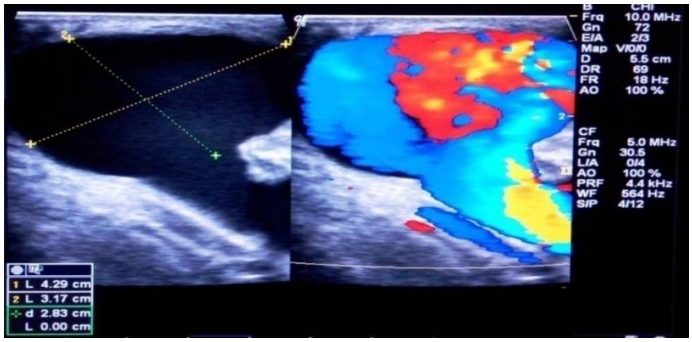
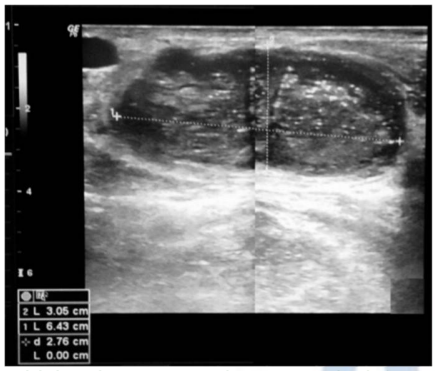



**Figure 3:** Color Doppler ultrasound: shows color swirl of large pseudoaneurysm at the basilic vein



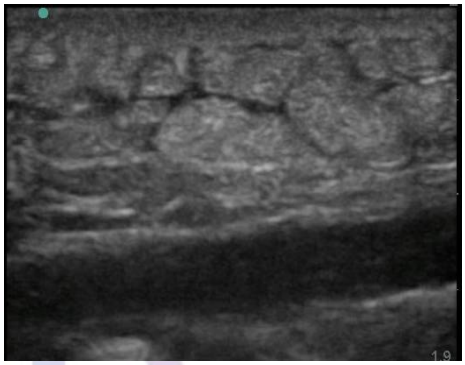



**Figure 4:** Multiple subcutaneous abcesses at the left arm; **Figure 5:** Subcutanous edema (cobble stone appearance)

The following table summarizes the site of the lesion in relation to the type of complication encountered:

**Table 4:** Site of complication in relation to its type

| Complication | Site of Complication | | |
|---|---|---|---|
| | At anastomosis | Venous | Arterial |
| **Thrombosis** | 1 | 3 | 1 |
| **Stenosis** | 3 | 1 | 0 |
| **Aneurysm** | 0 | 2 | 0 |
| **Venous hypertension** | 0 | 1 | 0 |
| **Total** | 5 | 6 | 1 |

The following table shows the relation between the types of fistula constructed to the type of complication seen

**Table 5:** Relation between type of fistula and type of complication

| Complication | RC | BB | BC |
|---|---|---|---|
| **Thrombosis** | 3 | 1 | 1 |
| **Stenosis** | 3 | 1 | 0 |
| **Aneurysm** | 0 | 1 | 1 |
| **Venous hypertension** | 0 | 1 | 0 |
| **Infection** | 1 | 1 | 0 |
| **Total** | **7** | **5** | **2** |

From this table the most type of fistula associated with complication was the radio-basilic followed by the brachio-cephalic while the brachiocephalic type associated with less incidence of complication.

## DISCUSSION

The recent expansion of replacement therapy for end stage renal disease leads to increase number of patients that require permanent hemodylasis arterovenous fistula (vascular access). The vascular access has became the most widely used mean for end-stage renal disease patients on regular hemodialysis [9]. Many types of hemodylasis arterio-venous fistulas are known, but the most widely used one is that created with autogenous material, because they have very good primary and secondary patency than those fistulas created with synthetic graft[10]**.** Catheters or grafts liable for many complications that lead to early failure of the vascular access. These complications includes higher incidence

of thrombosis, infection, ischemia, and occlusion secondary to initimal hyperplasia, providing higher morbidity and mortality rates for the patients when compared with an autogenous HAVF[11]**.** According to the National Kidney Foundation, the best vascular access for hemodialysis is the Native HAVF[7, 10]**.**There is variation in the literature about the minimal diameter of the vein to be used in hemodylasis arterio-venous fistula, some consider 1.8 mm as the lowest limite while others consider 2 mm as the lowest diameter[12, 13, 14]**.** Nearly the same controversy about the diameter of the donor artery is present many author consider it should not be less than 2 mm while others use 1.8 mm, however 2.0 mm diameter is the most widely accept lower limit. Malovrh[15], found significant increase in the risk of early failure of the hemodialysis arterio-venous fistula when the donor artery diameter is less than 1.6 mm. The most important factor for maintenance of the vascular access patency is the periodic follow up, as early detection of complication and access dysfunction leads to early intervention with subsequent reduction of access failure[16]**.**Doppler ultrasonography is the best modality for post operative follow up and early detection of complications as standard techniques used to assess arterio-venous fistula flow and anatomy have many major limitations. These techniques include indicator dilution techniques, clinical assessment, and pulsed-wave Doppler alone without ultrasonographic imaging do not give detailed anatomical information[17].Some authors considered color Doppler ultrasonography is more superior for assessment of the vascular access patency and abnormalities than angiography which considered the gold standard technique for imaging the abnormalities of the vascular access. As color Doppler ultrasonography provides functional and morphological information's about the vascular access, in addition it is bedside examination, non invasive, cheap, could be used as guide for further interventional procedures and not use ionizing radiation or radiocontrast material. For these advantages color Doppler ultrasononggraphy considered the first imaging modality and first investigation in assessment of autogenous arterio-venous fistula dysfunction[16]**.**In this study, the radio-cephalic fistula was the most common type of the AVF represent about 48.89 % followed by brachio-cephalic about 24.44 % and lastly brachio-basilic about 26.67 % of cases. These results agree with Keith and Melih[18], as they reported that most common type of hemodialysis arterio-venous fistula is radio-cephalic followed by brachio-cephalic and lastly brachio-basilic.In this study, the age of the fistulae maturation, was variable with more than 50 % reach maturation as regard the diameter and flow volume after one week, and about 80% reach maturation by the end of the 2nd week, with all fistulas reach maturation by the end of the first month, This not agree with the study done in 2007 by Lynda[19], who stated that the arterio-venous fistula maturation occurs usually within the first two weeks after the operation. From that early evaluation of the AVF maturation is very important and should be started immediately after AVF creation. In the other hand our results agree with the results obtained by Jeferson *et al.*[10], as they reported that maturation of arterio-venous fistula usually occurred in a variable period from 4-12 weeks. In this study complicated arterio-venous fistula was detected in 14 patients (31.1%) while 31 patients had uncomplicated AFV (68.9%). Complication varies from thrombosis which is the most common complication to venous hypertension which is the least common complication. Thrombosis detected in 5 patients (11.11%), stenosis in 4 patients (8.89%), aneurysmal formation in 2 patients (4.44%), venous hypertension in 1 patient (2.22 %) and infection in 2 patients (4.44 %), These results similar to the resulted obtained by Iftikhar Ahmed *et al.*[20]**.**The results of this study demonstrated that 5 patients out of 45 had thrombotic lesions, which represents the majority of our complicated cases. Most of them (4 patients) were detected at the venous side of the fistula, while only one case had arterial side thrombosis. Which goes together with Lumsden *et al.*[21], that proved that the most common cause of vascular access failure is venous thrombosis. And similar with results obtained by Culp K *et al.*[22]**,** in which they found thrombosis was the most common complication and consider the Color Doppler ultrasound the modality of choice for differentiating partial from complete thrombosis and detect the length of the thrombosed segment that could not be assessed by venography or angiography. Also this agree with the results obtained by Elcheroth *et al.*[23], as they found thrombosis is the most common complication and considered color Doppler ultrasound is sufficient for diagnosis of thromobosis that appear as anechoic or hypoechoic clot within the vessel with absence of blood flow noted during pulsed or color Doppler study. However Khaled M.[17], found that stenosis was more common than thrombosis in this study. In present study, low volume of blood flow was measured in all complicated patients in cases suffering from thrombotic lesions. The National Kidney Foundation: Dialysis Outcomes Qualitative Initiative Guidelines (NKF-k/DOQI, 2006)[24]also stated that a decrease in hemodialysis vascular access blood flow is a powerful predictor of vascular access thrombosis. In one duplex ultrasonography study of 831 PTFE grafts and 477 AV fistulae, flow volumes less than 80 ml/min in PTFE

grafts and less than 800 ml/min in AV fistulae were shown to be predictive of graft failure Paun *et al.*[25]The second most common complication in the present study was stenosis, 4 cases detected representing about 8.89 %., most of these detected at the anastomotic site (3 cases) and only one case detected at the venous site. This agree with Van Tricht *et al.*[26], they found graft stenosis usually develop in the venous outflow tract at the site of anastomosis between the graft and the vein and it is usually the underlying cause for thrombosis**.** But less than the results obtained by Culp K *et al.*[22] and by Daniel *et al.*[27].The location of the stenotic segment differs from one study to another. In our study, 3 stenotic segments were found at the region of AVF, one in the venous limb distally this agree with the results obtained by Hill and Donato[28], but not agree with results obtained by Sullivan KL *et al.*[29], in which venous site stenosis was the most common site. Color Doppler ultrasonography by measuring the resistance of blood flow at the level of the AVF can detect stenosis very early and should be used for follow up. In normal AVF the waveform pattern is usually biphasic which represent low resistance flow with high diastolic flow. So, any change in the pattern of this waveform when compared with the previous examination denote the presence of vascular access dysfunction as well as change in the pattern of the waveform from biphasic to triphasic which means high resistant flow indicate vascular access dysfunction Matsui *et al.*[30].Not easy to identify presence of stenosis with maintained blood flow; in these cases the measurements of the peak systolic velocity with continuous follow up and comparison can detect stenosis very early and help in decision making for the next step of management. When the peak systolic velocity less than 300 cm / sec present with maintained flow, follow up of the vascular assess flow is very important to detect any drop of the flow which means vascular access dysfunction Federico *et al.*[3]Pseudoaneurysms were easily to diagnosed clinically by the presence of pulsatile mass with systolic murmur. However, Color Doppler ultrasound is the modality of choice for detecting the lesion and determined its extent as well as the presence of any thrombus inside Wiese P and Nonnast DB.[14].Out of the examined cases in our study 2 patients had pseudoaneurysm (4.44%), both at the venous side of the AVF. Our results were low than these obtained and published by Daniel *et al.*[27] who found that 7 patients out of 51 with a percentage of 13.72% had pseudoaneurysms at the AVF. Venous hypertension results from arterialization of the venous system proximal to an arteriovenous fistula with central venous occlusion, Moore[31]. Our study included 1 patients with venous hypertension (2.22%) due to central venous stenosis.

## CONCLUSION

Color Doppler ultrasound is a safe, bedside examination, non invasive technique and available that accurately allows the preoperative mapping of the vessels by measuring their diameters and exclude any obstructing or stenosis cause as well as normal assessment of the vascular anatomy. After that the patients suitable for hemodylasis arterio-venous fistula will be selected and postoperatively will subjected to color Doppler ultrasonography follow up to assess hemodynamical and morphological changes. Adding more advantage for color Doppler ultrasonography, is free from ionizing radiation and not use radiocontrast material as well as its low price so, suitable for all patients. Post operatively color Doppler ultrasound plays a very important role in assessment of HAVF morphology and hemodynamic. With subsequent early detection of complications and vascular access dysfunction leading to rapid intervention to save the access rather than forming new one. It is excellent in detection of lumen patency, narrowing and formed thrombus as well as detect the hemodnamical changes that may appear before morphological changes and so, pick up the complication very early.

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