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Flow volume measured by duplex ultrasound in native arteriovenous fistula for hemodialysis: a case report



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ABSTRACT

Background: Native arteriovenous fistula (AVF) is the vascular access of choice for hemodialysis patients. AVF lasts longer than artificial grafts or central venous catheters. In addition, AVF has fewer complications than other vascular accesses. Doppler ultrasound is used to facilitate fistula construction (vascular mapping), including AVF maturation, to see if AVF can be used. Doppler ultrasound monitoring for maturation of AV fistulas should be monitored sonographically until the fistula is ready for use, especially when maturation is slow and in patients whose veins cannot easily be assessed by physical examination alone (e.g., because of obesity).

Case report: A man, 52 years old, who has done AV Fistula two weeks ago. Currently, patients are using a double lumen catheter (CDL) for routine hemodialysis. One day the patient had his CDL removed. Even though the patient feels a thrill in the AV fistula, the nephrologist still doubts whether the AV fistula is ripe and can be used. For this reason, a Duplex Ultrasound is performed to assess the diameter, velocity flow, PSV and TAMV. The Doppler velocity test detects a systolic peak velocity by positioning the sample volume in the presumed stenosis site.

Conclusion: To improve the accuracy of Doppler imaging, the examiner should use color as a tool to locate high-velocity flow areas to help facilitate pre-stenosis. In addition, it is advisable to check the sample volume with Pulsatile Wave Doppler to detect discrete changes in blood flow. Pulse Wave Doppler method is used in monitoring AV fistula maturation

Keywords: Arteriovenous Fistula, Duplex Ultrasound, Flow Volume, Hemodialysis

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INTRODUCTION

The best modality in patients with End-Stage Renal Disease (ESRD) grade V is an arteriovenous fistula (AVF) in the hemodialysis process.¹ This is related to the hemodialysis process through a central venous catheter (CVC) which has a large morbidity rate, namely an increased incidence of local and systemic infections, requiring hospitalization, and higher costs.²⁻⁸ Patients undergoing dialysis via CVC have a fairly high mortality rate of about 40% higher than dialysis via AVF.⁹

However, there are obstacles in hemodialysis patients because the AV fistula maturation process takes about three months to be ready for use. This is because of the operation of venous arterialization in the AVFs. This case report deals with the literature related to ultrasound surveillance (US) of AVF.

However, there are several types of fistula variations that need to be identified as fistula maturation.¹⁰⁻¹² Several ultrasonic characteristics can help characterize fistula maturation.¹³ Several studies have tried to use ultrasound to characterize early maturation, immediately after fistula creation, but studies have shown fistula maturation to be associated with increased fistula blood flow, even on the first day after formation AV Fistula.^{14,15} Thus, assessing the starting point of the fistula maturation process can predict later patency.

This article reported a case of hypertension, non-diabetic and stage 5 chronic renal failure. The patient was finally put on the US and met the AVF maturation criteria from the US maturation checklist without inserting a new CDL.

CASE REPORT

A man, 52 years with hypertension, non-diabetic and stage 5 chronic renal failure, has undergone routine HD with CDL access. This patient also had AVF creation two months ago. During the hemodialysis period in the second month after AVF insertion, the patient had an infection with seroma in the puncture area at the CDL insertion site. At that moment, in physical examination (PE), the thrill of the AVF was felt, and the bruit auscultation was very clear. Laboratory results show leucocyte value was 12.000 mg/dL that related to CDL infection. There is some question from the author whether to use the rule of six where the new AVF could be used or could US help see the maturation of the AVF so that the patient did not need to re-install the CDL on the other side. Due to the AV Fistula being still two

months old, the clinician was doubtful to use its AVF for hemodialysis access directly. Based on the rule of six, AVF will mature three months after AVF creation. The patient was finally put on the US and met the AVF maturation criteria from the US maturation checklist without inserting a new CDL.

DISCUSSION

In this study, the duplex US shows the diameter of the vein is 0.53 cm with a depth of 0.86 cm with good PSV and volume flow. So we use the AVF, although just four weeks of AVF creation. Duplex ultrasound may be used before AVF creation for mapping or surveillance AVF creation. It might challenge the advantage of diagnostic maturation of AVF creation. In mapping AVF to an evaluation of a non-dominant arm first. Diameter of a peripheral artery at least 1.6 mm. Meanwhile, peripheral veins diameter for AVF at least 2 mm without tourniquet and more than 2.5 mm with a tourniquet. In central veins, respiratory phasicity.^{16,17}

Based on The North American Vascular Access Consortium (NAVAC), the minimum criteria for successful use of fistulas for conventional hemodialysis using 2-needle cannulation with periods of two to three times a month. In addition, the average blood flow rate (total blood that took place during the hemodialysis process) was measured. For each hemodialysis process, 300 ml of blood was drawn in a hemodialysis session for 3.5 hours.¹⁶ KDOQI Guidelines 2006, in mature AVF, requires at least 300 mL/min flow and low venous resistance during hemodialysis. It also has easy, safe cannulation & hemostasis. It should full fill of rule of six, that is six weeks post-construction, blood flow > 600 mL/min, diameter > 6 mm and depth < 6 mm.¹⁸

In the hemodialysis duplex US evaluation document, representative duplex images at predetermined locations along the course of the fistula or graft as follows: (i) inflow artery proximal to the fistula or graft; (ii) inflow artery distal to the fistula or graft; (iii) anastomotic sites (fistula has one site, graft has two sites); (iv) puncture sites; (v) proximal, mid, and distal outflow vein or graft; (vi) axillary and subclavian veins. Duplex US

also showed focal stenosis. There is no clear/rigid velocity criteria for stenosis. The stenosis AVFs in the US showed flow turbulence and is often bidirectional. In measure Flow velocities are high concomitant with color mosaic always seen.¹⁹ Anastomosis can be evaluated on Doppler Ultrasound examination with B-mode, and access from the skin surface can be measured. Vascular ultrasound can also assess the vein segment that appears superficial enough for cannulation (0.6 cm or less from the skin surface). In an ideal AV fistula, the superficial segments are at least 10 cm long with representative proximal, middle and distal diameters, including aneurysms. The diameter

measurement is required to calculate the volume of flow according to Poiseuille's law, which states that for a given pressure drop per unit length, the volume flow rate is inversely proportional to the viscosity and is proportional to the fourth power of the vessel radius.¹⁷

Normal Doppler US in AVFs shows monophasic flow in the feeding artery. Anastomosis tissue vibration shows turbulent flow over a long stretch, in draining vein Pulsatile flow (arterialized vein). The measurement of volume flow should be more than 500 mL/min. Measurement of flow volume was cross-sectional area times mean velocity. It should be 60 (mL/min). Duplex US also

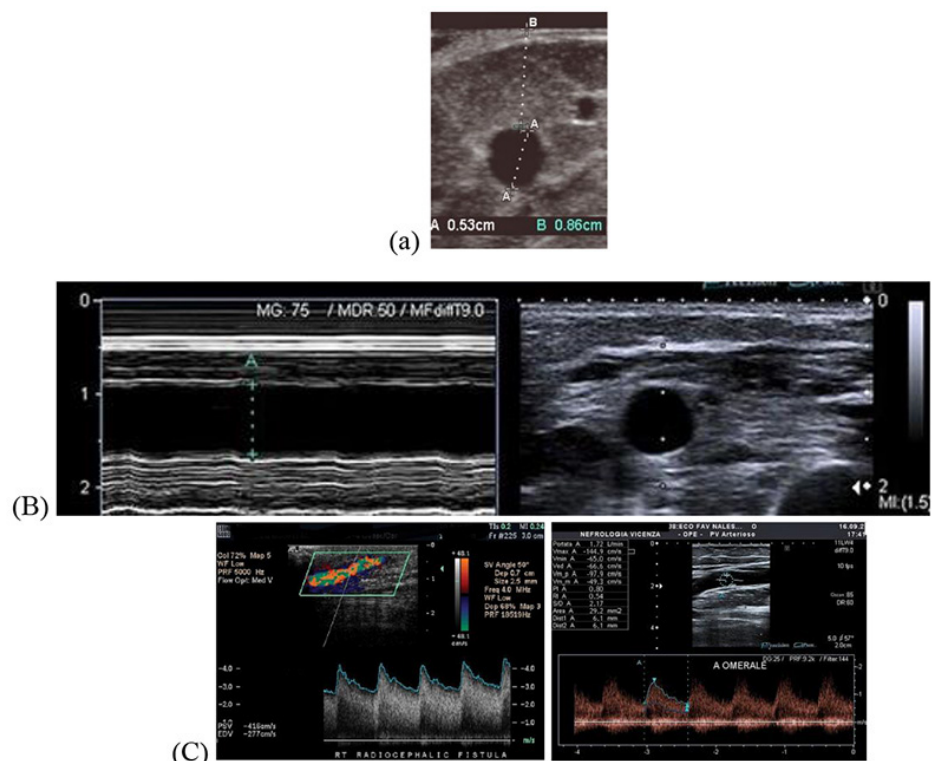


Figure 1. (A) US show diameter of AVF; (B). US show distance AVF from the skin; (C) PSV measurement

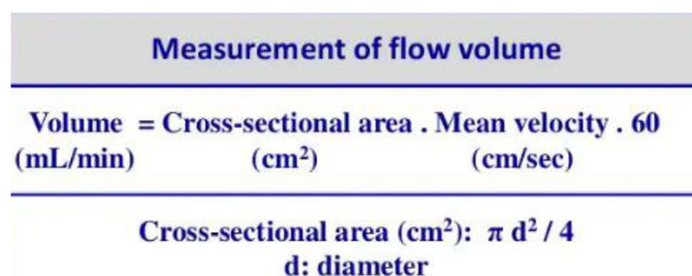


Figure 2. Measurement of Flow Volume.²⁰

Table 1. Protocol steps for the analysis of a vascular access.²²

Step-by-step protocol for the assessment of vascular access		Structure to analyze
1	By a transverse scan: – identify the brachial artery – describe diameter of brachial artery, its course and its bifurcation into the radial and ulnar arteries – use M-mode* on the brachial artery to identify the average diameter in relation to the pulsatility over the time (Fig. 1)	Brachial artery
2	By a longitudinal scan: – identify the velocity spectrum at the Doppler on brachial artery and provide the calculation of the flow rate*. The information obtained from this step is essential to identify an estimated blood flow in the vascular access and the real resistance in the downstream according to the morphology of Doppler velocity spectrum* the previous M-mode diameter of brachial artery reduces the error in the calculation of blood flow.	Brachial artery
3	Describe the anastomosis between artery (brachial/radial) and vein/graft in terms of 2 diameters (mm) and maximum peak systolic velocity (cm/s)	Anastomosis at the artery
4	By a longitudinal and traverse scan in B-mode (if required in M-mode): – Describe the average diameter of the efferent vein/graft, its depth from the skin, its course. According to the minimum diameter of 6 mm and the maximal depth of 6 mm, identify the best region where proceed with cannulation and verify the blood flow in this region and in the vascular access. By a longitudinal scan: – Analyze the wall and the lumen of the access Describe any alteration in term of structure, dimension, impact on hemodynamics in 2 different planes of scan (aneurysm, pseudo-aneurysm, thrombosis, wall integrity) – Analyze also the soft tissue peri-access Describe any alteration in terms of structure, dimension, impact on hemodynamics in 2 different plan of scan (hematoma, peri-access liquid film, edema in the soft tissue) – Analyze the colorDoppler in order to identify aliasing or black zone in the lumen (stenosis, thrombosis, wall alteration with thrombosis)	Efferent vein/graft
5	Describe the anastomosis between the graft and the vein in terms of two diameters (mm) and maximum peak systolic velocity (cm/s) or between the vein and its confluence in another bigger vessel (generally a central vein)	Anastomosis at the vein (graft or vein confluence in another vessel)
6	By a transverse scan: – identify the graft diameter – use the M-mode* on graft in order to minimize measurement errors in the identification of the average diameter in relation to the pulsatility over the time – measure the blood flow directly (the graft is not squeezable by the probe as in the case of arteriovenous fistula)	Graft flow
7	By longitudinal and trasverse scan: – identify and describe all alterations in the soft tissue providing their quali-quantitative characteristics in terms of dimension, structure, rrelationship with the access and other anatomical structures By colorDoppler: – describe the vascularization of any abnormalities found in the soft tissue and in the perivascular access By the appropriate scan identify all collateral vessels that can dissipate the blood flow from the effluent vein in order to provide the best follow-up for the access maturation	Soft tissue and accessory vessels
8	For any alteration found provide: – B-mode: describe the nature of the alteration and its content (aneurysm, pseudo-aneurysm, hematoma, fluid collection, liquid film, edema, etc.) – B-mode in 2 different scan: describe the dimensions (latero-lateral and cranio-caudal diameters, if possible also the antero-posterior diameter) – ColorDoppler: describe any alteration detectable by this modality (blood flow, blood flow present due to the continuity with the VA or other vessels, etc.)	Complications

measurement of flow volume /Feeding artery (TAMV). Diameter perpendicular to axis and sample volume across the width of the vessel. The sample volume is in the same site of diameter measurement. The correct estimation of angle TAMV: 3 – 5 cardiac cycles.²⁰

Doppler Ultrasound also examines arteries from proximal to access anastomosis with Pulsatile Wave mode. In this mode, peak systolic velocity (PSV) and end-diastolic velocity (EDV) are measured. A proximal anastomosis can be described from these examinations, a Pulsatile Doppler Systolic Volume (PSV) waveform. On dialysis access, there is an outflow that has lower resistance than arteries. On ultrasound examination, it is expected to evaluate the spectral

widening of diastolic flow throughout the venipuncture area. From the PSV waves in some of the stabbing areas, an increase in speed or turbulence appears. PSV examination should be performed in all segments starting from the proximal and distal to increased velocity or turbulence. So, ultrasound Doppler surveillance examination should be performed for the sample volume throughout the anastomotic area.²¹

Ultrasound and Color Doppler techniques can be used to evaluate the maturity of AV fistulas because they are relatively inexpensive, non-invasive, can be performed repeatedly and can obtain fast results. Besides, Doppler ultrasound is quite accurate for early diagnosis of vascular access (VA) complications in

hemodialysis patients. The use of the Echo Color Doppler (ECD) protocol is the standard for assessing the maturity of AV Fistula to be used safely. The sensitivity of Duplex US for AVF maturation is almost 90%, due to sonographer experiences.^{20,23} There are some tips for volume flow measurement: Avoid significant turbulence (circular flow) and determine vessel diameter accurately. Besides, it uses an adequate insonation angle ($\leq 60^\circ$) to catch sample volume covering the vessel's entire area. There is no significant diversion of blood through accessory vein and flow determined in feeding artery if complex vein anatomy.²⁴

Duplex US is also a non-invasive method to look at maturation of AVF. It is also cheap and safe because it doesn't use contrast like AVF angiography. In Chinese patient with Chronic Kidney Disease stage V, Duplex US in AVF, which cephalic vein diameter >5.2 mm and blood flow >529 ml/min could be used to predict fistula maturity.²⁵ From this case report, it is suggested that Duplex US of AVF evaluation is needed to see the construction and follow-up after AVF surgery, especially AVF maturation to be ready for use in hemodialysis. In patients on hemodialysis routine, it recommended evaluation of AVF every three months to see the surveillance of AV Fistula.^{25,26}

CONCLUSION

Based on the ultrasound criteria defined for the cut-off point between mature AVF or not, it can be concluded that most AVF had proper diameter and flow for puncture soon after the first week of the postoperative period. There was progressive improvement in maturation standards throughout the weeks, and these should be preferentially punctured four weeks after the surgery.

DISCLOSURE

Conflict of Interest

All authors declared that there is no conflict of interest regarding this publication

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Author Contribution

All authors contributed equally in the writing of this article

Ethic Approval

This study had been ethically approved by ethical commission of Faculty of Medicine, Universitas Kristen Krida Wacana

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