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Diagnostic accuracy of Color Doppler Ultrasound in determining arteriovenous fistula stenosis

Sobia Mazhar[1], Ali Mansoor[2], Aamer Nadeem Chaudhary[3]

[1] Consultant Radiologist, Jinnah Burn and Reconstructive Surgery Center, Allama Iqbal Medical College, Lahore
[2] Senior Registrar, Radiology Department, Mayo Hospital, Lahore
[3] Professor and Head of Radiology Department, Jinnah Hospital, Lahore

Author`s Contribution

[1,2] Drafting the work or revising it critically for important intellectual content
[3]Final approval of the version to be published

Funding Source: Nil
Conflict of Interest: Nil

Received: January 21, 2019
Accepted: September 15, 2019

Address of Correspondent
Dr. Sobia Mazhar
Consultant Radiologist, Jinnah Burn and Reconstructive Surgery Center, Allama Iqbal Medical College, Lahore
drsobiamshahid@gmail.com

ABSTRACT

Objective: To determine the diagnostic accuracy of color doppler ultrasound in determining arteriovenous fistula stenosis.

Methodology: A descriptive, Cross-sectional study was conducted at Radiology Department, Jinnah Hospital, Lahore from November 2014 to March 2016. A total 105 patients with 20-70 years of age having recent mature fistulas of more than 12 weeks were included. Patients with acute hemodialysis, receiving hemodialysis through AV graft and hemodynamically unstable patients were excluded. All the patients underwent blood flow and luminal diameter measurement of AV fistula by color Doppler ultrasound. After this, Digital Subtraction Angiography (DSA) was performed and results of Color Doppler Ultrasound (CDS) were correlated with DSA which was taken as the gold standard. Linear regression was used for analysis. P and r2 values calculated for each of these.

Results: Mean age of the patients was 42.08 ± 11.90 years. Out of these 105 patients, 73 (69.52%) were males and 32 (30.48%) were females with a ratio of 2.28:1. CDS detected AVF stenosis in 64 (60.95%) patients, out of which, 58 were True Positive and 06 were False Positive. Among 41 CDS negative patients, 30 were False Negative and 11 were True Negative. Overall sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy of CDS for the detection of AVF stenosis, taking DSA as the gold standard was 84.06%, 83.33%, 90.62%, 73.17%, and 83.81% respectively.

Conclusion: Color Doppler ultrasonography is a highly sensitive and accurate non-invasive modality for detecting AVF stenosis, and should be used routinely in order to reduce invasive digital subtraction angiography.

Keywords: Arteriovenous fistula, Dialysis, Doppler, Stenosis, Ultrasound.

Cite this article as: *Mazhar S, Mansoor A, Chaudhary AN. Diagnostic accuracy of Color Doppler Ultrasound in Determining Arteriovenous Fistula Stenosis. Ann Pak Inst Med Sci. 2019;15(2): 56-60.*

Introduction

Every year as the number of patients with kidney failure increases, so does the need of initial creation and then maintenance of a functional hemodilaysis (HD) access. A well functioning vascular access becomes the lifeline for patients on HD[1-3]. Arteriovenous fistula (AVF) is the most widely used means of vascular access for long-term HD in patients with end stage renal disease (ESRD).[4] Maintenance of vascular access and long-term treatment of its complications has become an important cause of hospitalization, morbidity and financial burden in patients with chronic kidney disease.[5,6] The complication rate related to AVF remains high and access related problems account for 50% of hospitalizations of these patients.

Most of these complications are related to the thrice-weekly trauma to the fistula inflicted by large core needles required for HD treatment.[7]

Potential sites for vascular access are limited therefore extending the life of an existing fistula is of great benefit. Thus, early detection, localization, and characterization of lesions that compromise HD are extremely important because they may allow correction before the failure of the access.[8] The frequency of occurrence of recurring access problems mandates a method of examination that is accurate, noninvasive, and can be repeated as often as needed to evaluate the morphology and function of the fistulas.

Currently, the gold standard for detection of stenosis is Digital Subtraction Angiography (DSA) which is an invasive procedure requiring higher expertise, contrast injection, intervention and a long time of the study. On the other hand, CDS offers a method for non-invasive, contrast free detection of early stenosis. This method enables assessment of the morphologic characteristics and functions of the AVF. Arterial and venous stenosis, infection, pseudoaneurysm formation, and arterial steal are complications that may threaten or destroy the functioning and can be detected with screening CDS. Earlier detection of complications provides rapid and effective interventional treatment. There are three main applications of CDS in workup of AVF. The first is the pre-operative evaluation of the forearm arteries and veins as an adjunct to surgical planning. Second is the testing of AVF maturation. Third is the evaluation of complications. This study is based on role of CDS in identifying AVF stenosis.[17]

The rationale of this study is to predict the outcome of AV fistula through early detection of its complications using Doppler ultrasound. The life cycle of an AVF starts with its creation and evolves through phases of physiological maturation and initial clinical use. Failure of the mature AVF is frequently suspected during monitoring designed to detect stenosis so that it can be identified and treated prior to thrombosis, usually on the basis of physical examination findings, flow measurements, or duplex ultrasound. Vascular access blood flow monitoring along with preventive interventions should be the standard of care in chronic hemodialysis patients. Currently there is no data available that shows the frequency of complications that develop after the AVF formation. Use of this technology is important because the etiology of access problems must be identified before appropriate interventions can be designed. It is important to realize that the lesions typical of early failure are also commonly seen during the later period either because they were not addressed in a timely fashion or because the lesions have progressed and are now the source of dysfunction. The parameters of this study were the blood flow velocity, anteroposterior diameter of feeding vein, brachial artery resistive index and reduction in diameter of the vessel lumen.

Methodology

The sample size was calculated using 95% confidence level, with an expected sensitivity of color Doppler as 81% with 9% margin of error, specificity as 79% with 10% margin of error taking an expected percentage of AV fistula complications in 50%. Patients admitted in Nephrology department of Jinnah Hospital, Lahore from November 2014 to March 2016 and referred by clinicians to the radiology department of either gender aged 20-70 years having mature fistulas of more than 12 weeks recent onset maturation were included in the study. Patients with acute hemodialysis, receiving hemodialysis through AV graft and those who were hemodynamic unstable (Blood pressure < 60/50 mmHg and Heart rate < 60/ min) were excluded. 105 subjects fulfilling these criteria constituted the study population.

After taking informed written consent and relevant history, blood flow and luminal diameter of AV fistula were assessed by color Doppler ultrasound. CDS of all patients was performed by one of the researchers to minimize variability in data collection. The blood flow velocity (> 500 ml/sec) and diameter of feeding vessel (>4 mm) was noted and recorded on the proforma. The patients then underwent DSA and the percentage of stenosis of the feeding vessels was measured and compared with the adjacent vessel. If the stenosis was more than 50%, it was considered significant.

Results

The age range in this study was from 20-70 years with a mean age of 42.08 ± 11.90 years. Out of these 105 patients, 73 (69.52%) were males and 32 (30.48%) were females with ratio of 2.28:1. Mean blood flow velocity was 489.23 ± 187.41 ml/sec and mean reduction in luminal diameter was 46.38 ± 13.62%.

All the patients were subjected to Color Doppler Ultrasound of AVF. CDS scan supported the diagnosis of AVF stenosis in 64 (60.95%) patients and no AVF stenosis in 41 (39.05%) patients. DSA findings confirmed AVF stenosis in 69 (65.71%) patients and no AVF stenosis in 36 (34.29%) patients. In CDS positive

patients, 58 (True Positive) had AVF stenosis and 06 (False Positive) had no AVF stenosis on DSA. Among 41, CDS negative patients, 30 (False Negative) had AVF stenosis on DSA whereas 11 (True Negative) had no AVF stenosis on DSA.

Overall sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy of CDS for the detection of AVF stenosis, taking DSA as gold standard was 84.06%, 83.33%, 90.62%, 73.17% and 83.81% respectively (Figure I).

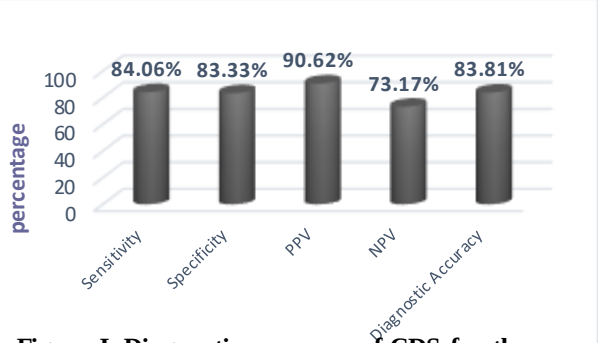

Figure I. Diagnostic accuracy of CDS for the detection of AVF stenosis.

Discussion

Access is the lifeline for the ESRD patients, but its creation and maintenance is a difficult undertaking. The AVF has long been recognized as the preferred access in such patients.[9] Preoperative evaluation of upper extremity with duplex ultrasound is a useful adjunct to physical examination, especially in obese, those with multiple previous access surgeries or those with vascular disease.[10] After the creation of the access, prolonged functional patency may prove elusive due to the development of stenotic lesions leading to thrombosis or failure to mature. The failure rate of HD access in the first year is high. After fistula maturation and use, subsequent failure is frequently associated with thrombosis secondary to underlying focal stenosis, most commonly at site of the anastomosis. Clinical monitoring of AVF function is recommended to detect deterioration in function before thrombosis occurs. AVFs are most commonly placed in the upper extremity, either in the forearm or upper arm. A forearm AVF directly connects radial artery to a cepahalic at the wrist or distal forearm. This increases flow in the draining vein. This results in dilatation and wall thickening of the vein, allowing for frequent cannulation for hemodialysis. An upper arm AVF is typically created at the antecubital fossa and connects the brachial artery to the cephalic vein or at the basilic vein, which is usually transposed more anterolaterally for easier access and is called a basilic vein transposition fistula.[19]

The superficial high frequency probe is used with minimal pressure to limit deforming the veins. For anatomical localization of an abnormality, the words cranial and caudal are used. The arterial inflow and venous outflow is evaluated. Transverse diameters of the arteries and veins are taken. Turbulant flow, stenotic flow, presence of plaque or thrombus are noted. The depth of the AVF from skin is also documented. Brachial artery resistive index is documented. The artery supplying the anastomosis is the feeding artery. Hallmark of the access dysfunction on USG is decreased blood flow. Gray scale evaluation must preceed the Doppler study. In case a stenotic segment is detected, the pre and post stenotic velocities are measured. In addition, any visible narrowing in the draining vein on gray scale or any area of aliasing is further assessed with velocity measurements on spectral Doppler. Poststenotic arterial waveforms with parvus and tardus characteristics are considered abnormal in the feeding artery. Failure to document velocity elevation in the presence of luminal narrowing on grayscale may indicate inflow stenosis or low systemic pressure. If there is no anastomotic stenosis, but the vein flow is sluggish, downstream cranial venous system may be stenotic or thrombosed. It is extremely important to keep the Doppler angle accurate as incorrect Doppler settings can contribute to velocity measurement errors. Doppler angle of insonation should be maintained at $\leq 60°$ and the angle correction is parallel to the vessel wall.[18]

The treatment of AVF stenosis is balloon angioplasty.[24] In case dysfunction persists 2-3 weeks after angioplasty, CDS is repeated for second look into an undetected abnormality or for insufficient balloon dilatation.[20] If there is evidence of accessory dilated veins, they are treated with surgical ligation or percutaneously occluded with image-guided ligation.[22] Deep draining vein stenosis is treated with superficialization or lipectomy.[16]

The role that CDS plays as part of a surveillance program is clear.[11,12] CDS imaging lends itself well to the evaluation of hemodialysis access as grafts and fistulas are superficial structures. This modality allows the identification and localization of abnormalities, which may potentially threaten the access function and patency.

Identification and correction of access abnormalities at early stages may improve longevity and function as blood flow <500/cc/min or stenosis >50% identified on the duplex exam has been correlated with access thrombosis within 6 months.[13] So, in this study, we have determined the diagnostic accuracy of color Doppler sonography for the detection of AVF stenosis, taking DSA as a gold standard.

In our study, all the patients were subjected to color Doppler ultrasound of AVF. CDS scan supported the diagnosis of AVF stenosis in 64 (60.95%) patients and no AVF stenosis in 41 (39.05%) patients. DSA findings confirmed AVF stenosis in 69 (65.71%) patients and no AVF stenosis in 36 (34.29%) patients. A study done on AVF revealed that the diagnosis of anastomotic stenosis was possible with a diagnostic accuracy of 81%, a sensitivity of 79% and a specificity of 84%.[14]

Ultrasound can clearly differentiate between extrinsic compression, intramural problems, and intraluminal causes. It also allows the observer to evaluate the state of collateral vessels available to plan for remedial surgeries. Thus, the duplex Doppler ultrasound is an ideal tool to complement clinical evaluation of dysfunctional arteriovenous access.[15] So, on the whole, our study concluded that color Doppler sonography (CDS) is a highly sensitive and accurate non-invasive modality for detecting AVF stenosis, and should be used routinely in order to reduce invasive digital subtraction angiography (DSA). Although angiography is the most sensitive and specific imaging modality to identify and characterize stenotic vascular lesions, it is expensive and invasive.[23] For screening, noninvasive assessment is preferred to first identify fistulas with a high likelihood of stenosis. AVFs with sufficiently abnormal screening tests would then undergo diagnostic angiography and, if indicated, treatment. Clinical monitoring and surveillance are currently used to screen for vascular stenotic lesions.[21]

Conclusion

Color Doppler sonography (CDS) is a highly sensitive and accurate non-invasive modality for detecting AVF stenosis, and has the potential to dramatically improve our ability of accurate diagnosis of stenosis in mature fistulas of recent onset. Digital Subtraction Angiography (DSA) which is an invasive procedure requiring higher expertise, contrast injection, intervention and a long time of study can be avoided by using CDS. So, we recommend that Color Doppler sonography (CDS) should be used routinely as a prime modality for detecting AVF stenosis which will result in proper and timely management for reducing the morbidity of these patients.

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