

**Role of ultrasound and color Doppler in evaluation of peripheral arterial occlusive disease in diabetic foot**

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**Abstract**

**Background:** Doppler ultrasound is a non-invasive, inexpensive tool that complements the role of computed tomography, magnetic resonance imaging, and catheter digital angiography in the diagnosis, and monitoring of vascular disease.

**Objectives:** The main purpose of this study was to evaluate the lower limb arterial system in diabetic foot patients and to analyze the role of color Doppler in the diagnosis of diabetic arteriopathy.

**Patients and methods:** This is a case-control study conducted at Qena University Hospital, South Valley University, Qena. Group I: 40 healthy people were included in the control group. Group II: 40 patients known to be diabetic in the duration between August 2019 to August 2020.

**Results:** There was no significant difference between the two groups regarding the flow lumen diameter of the right / left dorsalis pedis artery and the right / left posterior tibial artery. There was a significant difference between the two groups regarding the vessel wall thickness of the right / left dorsalis pedis artery and right / left posterior tibial artery. The majority of patients had biphasic flow patterns in both the dorsalis pedis artery and posterior tibial artery, and blood flow parameters (PSV, PI, RI) for PDA and PTA were found to be significantly higher in the diabetic group and the EDV was found significantly lower in the diabetic group.

**Conclusion:** Doppler ultrasound has a high diagnostic yield in depicting abnormalities in patients with clinical features of peripheral arterial disease.

**Keywords:** Diabetes; Doppler Ultrasound; Peripheral Arteries; Dorsalis Pedis Artery; Diabetic Foot.

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## Introduction

Diabetic foot disease is one of the most important and devastating complications of diabetes. It is defined as an ulcerated foot associated with lower extremity neuropathy and / or peripheral arterial disease in a diabetic patients (Alexiadou et al., 2012)

The term 'diabetic foot disease' also refers to a combination of diseases such as diabetic neuropathy, vascular peripheral ulcers, osteomyelitis, and probably preventable limb amputation. (Khanolkar et al., 2013)

Foot problems in patients with diabetes remain a public health concern and are the most common causes for hospitalization of people with diabetes. (Centers for Disease Control and Prevention, 2005)

The prevalence of diabetic foot ulceration in the diabetic population is 4–10% (Centers for Disease Control and Prevention, 2005).

Approximately 5% of all diabetic patients have a history of leg ulcers, compared with a 15% lifetime risk for diabetic patients . (Kruse et al., 2006)

Most leg injuries (60-80%) will heal, 10-15% of which remain active, and 5-24% lead to amputation in 6-18 months. (Lauterbach et al., 2010)

Peripheral arterial disease is a contributing factor in the development of leg ulcers in 50% of cases. It usually affects the calf peroneal arteries and tibial arteries. Persistent hyperglycemic conditions result in loss of endothelial cell function and smooth cell abnormalities in peripheral arteries. (Zochodne and Douglas, 2008)

As a result of hyperglycemia there is a decrease in endothelial vasodilators leading to constriction . Furthermore, hyperglycemia in diabetes is associated with an increase in thromboxane A<sub>2</sub>, a vasoconstrictor, and platelet aggregation agonist, which increases the risk of

hypercoagulability in plasma. It is also possible to change the extracellular matrix, which causes arterial stenosis. (Paraskevas et al., 2008)

Ultrasound imaging is a non-invasive tool for assessment of blood flow in the arteries of the lower extremities and is recognized as a valuable diagnostic technique. (Park, 2005)

Gray-scale images identify plaques and thrombi ; color mode allows rapid localization of arterial stenosis and occlusion. This allows arterial disease to be assessed, classified, and tracked by accurate vascular imaging. Color doppler is a safe, common, low-cost, reproducible, and non-invasive method for assessing lower extremity arteries. (Kavitha, 2011).

The aim of the work was to evaluate the arterial system of the lower limb in diabetic foot patients and was to analyze the role of color Doppler in diagnosis of diabetic arteriopathy.

## Patients and methods

This was a case-control study at Qena University Hospital, South Valley University, Egypt. The sample size was 40 patients between August 2019 and August 2020

### Study subjects

**a. Inclusion criteria:** All patients with diabetes mellitus type I and II, diabetic patients complaining of foot ulcers, patients with peripheral neuropathy

**b. Exclusion criteria:** Patients with connective tissue disorders, corticosteroids or immunosuppressive drugs. Patients with skin diseases that disrupt skin integrity and unable to follow the instructions or apply the product .

### Methods

Patients with a history of trauma, chronic renal failure, or lactic acidosis are not included.

All patients were subjected to the following :

- **Personal history:** including name, age, gender, and occupation .
- **History of the present condition,** including onset, duration before presentation, history of trauma (type and mechanism).
- **Past history of diabetes** (onset, duration, control, treatment), hypertension, heart disease (ischemic or rheumatic) or kidney disease, ischemic symptoms (intermittent cramping or resting pain).
- **Past history:** of any lower extremity vascular surgery (debridement , drainage, amputation)
- **Clinical examination:** includes general examination with special attention to the lower extremity vascularity as regarding pulsation and refilling .
- **Routine laboratory tests:** (blood urea, serum creatinine, fasting blood glucose)

All patients were informed about the procedure and ensured to remain anonymous. Informed consent was obtained from all patients. The study was approved by the Medical Ethics Committee of the Qena University Hospital and approved by the South Valley and patients.

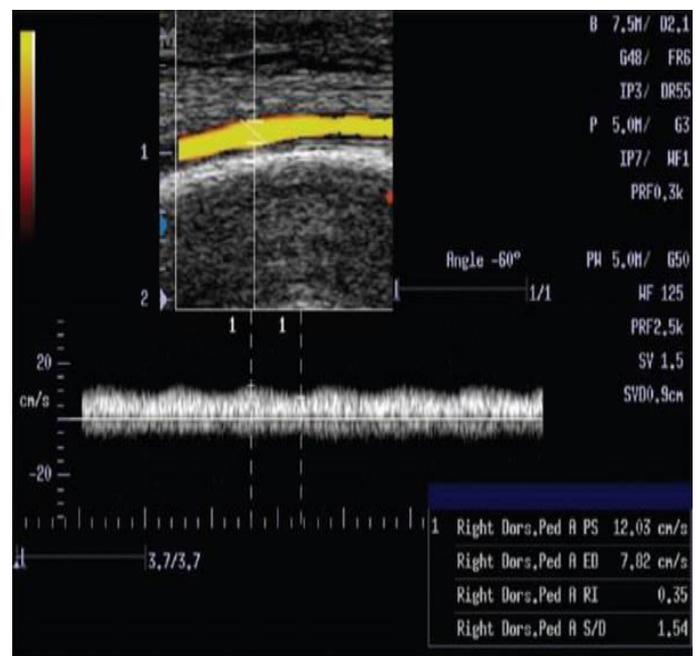
### **Doppler ultrasonography**

The relevant limb examination (whether upper , lower, right or left) was performed using a 7.5 MHz linear transmitter connected to the GE Health Care digital ultrasound imaging system (Model : P9 and P6 pro) while the patient was lying supine or prone (depending on the specific artery).

Occasionally, obese patients and people with severe subcutaneous edema a 3.5 MHz convex probe of the same device is used (for depth optimization) . After application of the water-soluble gel, the ultrasound was started with gray scale to scan lumen clarity , intima media thickness (IMT) , and the presence (or absence) of calcifications .

Then color Doppler is used (with or without PW doppler) to document the vessel filling and the direction of flow. Spectral Doppler is then used on the examined arteries and after application of the angel with sample volume correction with sampling gate at the center of color map, then spectral measurements is obtained. Furthermore, lowest filter measurement is set with high gain below the noise level and optimum scale is used to avoid aliasing.

The scan is considered normal if the artery shows a normal caliber, 1 mm (or less) IMT, uniform color flow, and typical triphasic appearance of the waveform (**Fig.1**).



**Fig.1. Duplex Doppler ultrasound scan (using power Doppler protocol) of the right dorsalis pedis artery, showing dwarf systolic peak (velocity of 12.03 cm/s), spectral broadening and significant diastolic blood flow (end diastolic velocity of 7.83 cm/s)**

All examinations were performed with patients lying calmly on the examination table and each examination was conducted over a minimum of 20 min.

\* **Investigations:** including HBA1c, Random Blood Sugar and Fasting and 2hrs post prandial blood sugar levels

### Statistical Analysis

All data were collected, tabulated and statistically analyzed using SPSS 22.0 for windows (SPSS Inc., Chicago, IL, USA) & MedCalc 13 for windows (MedCalc Software bvba, Ostend, Belgium). All statistical comparisons were two tailed with significance Level of P-value  $\leq 0.05$  indicates significant,  $p < 0.001$  indicates highly significant difference while,  $P > 0.05$  indicates Non-significant difference.

### Results

There are significant differences between the age and BMI of the two study groups, (Table.1)

There are significant differences between the two groups in terms of CRP, (Table.2)

There are significant differences between the two groups in the study in terms of the diameter of the right / left dorsalis pedis artery and the right / left posterior tibial artery regarding there diameters , (Table.3)

There is no significant difference between the two groups considering the diameter of the right / left dorsalis pedis artery and the right / left posterior dorsal artery flow lumen diameters,(Table.4)

There was a significant difference between the two study groups in terms of the wall thickness of the right / left dorsalis pedis artery and the right / left posterior artery, (Table.5)

For PDA and PTA, blood flow parameters (PSV, PI, and RI) were found to be significantly higher in the diabetic group than in the control group, while EDV was found to be relatively low in the diabetic group compared to the control group, (Table .6)

Most patients had a biphasic flow pattern in both the dorsalis pedis and the posterior tibial arteries. (Table.7)

**Table 1. Demographic data of the two studied groups**

Variables	Group I (N=40)	Group II (N=40)	t / $\chi^2$	P
Age (years)	48.67 $\pm$ 13.19	55.73 $\pm$ 15.07	<b>2.23</b>	<b>.029</b>
Sex	Male	25 (62.5%)	.219	.639
	Female	15 (37.5%)		
BMI (kg/m <sup>2</sup> )	24.36 $\pm$ 1.32	28.88 $\pm$ 1.46	<b>14.5</b>	<b>.000</b>
Smoker	17 (42.5%)	15 (37.5%)	.208	.648

**Table 2. Laboratory parameters of the two studied groups**

Variables	Group I (N=40)	Group II (N=40)	t	P
Hb (g/dL)	12.14 $\pm$ 2.15	11.59 $\pm$ 2.08	1.16	.249
Creatinine (mg/dL)	0.822 $\pm$ 0.193	0.903 $\pm$ 0.235	.168	.096
CRP (U/L)	4.33 $\pm$ 1.08	86.45 $\pm$ 27.71	<b>18.7</b>	<b>.000</b>
INR	1.01 $\pm$ 0.329	1.15 $\pm$ 0.476	1.53	.131

**Table 3. Ultrasound B-mode assessment of the diameter of the dorsalis pedis artery (DPA) and posterior tibial artery (PTA) of the two studied groups**

Variables	Group I (N=40)	Group II (N=40)	t	p
Right DPA diameter (mm)	2.35 ± 0.506	2.62 ± 0.388	<b>2.68</b>	<b>.009</b>
Left DPA diameter (mm)	2.29 ± 0.402	2.52 ± 0.537	<b>2.17</b>	<b>.033</b>
Right PTA diameter (mm)	2.47 ± 0.4	2.73 ± 0.479	<b>2.63</b>	<b>.010</b>
Left PTA diameter (mm)	2.46 ± 0.391	2.74 ± 0.596	<b>2.48</b>	<b>.015</b>

**Table 4. Assessment of flow lumen diameter in color Doppler of the dorsalis pedis artery (DPA) and posterior tibial artery (PTA) of the two studied groups**

Flow lumen diameter	Group I (N=40)	Group II (N=40)	t	p
Right DPA (mm)	2.01 ± 0.397	2.05 ± 0.382	.233	.818
Left DPA (mm)	1.97 ± 0.435	1.94 ± 0.477	.144	.886
Right PTA (mm)	2.16 ± 0.386	2.21 ± 0.459	.254	.801
Left PTA (mm)	2.13 ± 0.361	2.18 ± 0.434	.269	.789

**Table 5. Assessment of vessel wall thickness of the dorsalis pedis artery (DPA) and posterior tibial artery (PTA) of the two studied groups**

Vessel wall thickness	Group I (N=40)	Group II (N=40)	MW	p
Right DPA (mm)	0.355 ± 0.251	0.561 ± 0.286	<b>3.77</b>	<b>.001</b>
Left DPA (mm)	0.342 ± 0.237	0.502 ± 0.3	<b>2.81</b>	<b>.008</b>
Right PTA (mm)	0.352 ± 0.254	0.604 ± 0.289	<b>4.23</b>	<b>.0001</b>
Left PTA (mm)	0.337 ± 0.242	0.557 ± 0.293	<b>3.81</b>	<b>.001</b>

**Table 5. Blood flow parameters assessed by Doppler of the dorsalis pedis artery (DPA) and posterior tibial artery (PTA) of the two studied groups**

Parameters		Group I (N=40)	Group II (N=40)	t	p
DPA	PSV (cm/s)	38.45 ± 8.21	54.35 ± 32.42	<b>3.01</b>	<b>.004</b>
	EDV (cm/s)	6.45 ± 1.81	4.63 ± 1.21	<b>5.29</b>	<b>.000</b>
	PI	2.51 ± 0.477	7.15 ± 9.31	<b>3.15</b>	<b>.002</b>
	RI	0.731 ± 0.164	0.872 ± 0.314	<b>2.52</b>	<b>.014</b>
PTA	PSV (cm/s)	37.97 ± 8.53	51.76 ± 18.23	<b>4.33</b>	<b>.000</b>
	EDV (cm/s)	6.33 ± 1.76	4.47 ± 1.19	<b>5.54</b>	<b>.000</b>
	PI	2.3 ± 0.413	8.49 ± 12.58	<b>3.11</b>	<b>.003</b>
	RI	0.751 ± 0.164	0.963 ± 0.597	<b>2.17</b>	<b>.033</b>

PSV: Peak Systolic Velocity

EDV: End-Diastolic Velocity

PI: Pulsatility Index

RI: Resistance Index

**Table 7. Flow pattern on US Doppler of the dorsalis pedis artery (DPA) and posterior tibial artery (PTA) of the diabetics group**

Variables	Group II (N=40)				Total limbs
	Triphasic	Biphasic	Monophasic	Nil	
<b>Dorsalis pedis artery</b>	28 (35%)	30 (37.5%)	18 (22.5%)	4 (5%)	80 (100%)
<b>Posterior tibial artery</b>	24 (30%)	36 (45%)	16 (20%)	4 (5%)	80 (100%)

## Discussion

Although non-invasive and simple diagnostic tests are available, PAD remains underestimated and untreatable due to lack of symptoms and underutilization of screening tools. The American Diabetes Association consensus statement recommends screening for diabetic patients with signs and symptoms of diabetes by ankle brachial index (ABI). However, the accuracy of ABI in the evaluation of calcified, uncompressed blood vessels in elderly patients with medial sclerosis is controversial. In patients with moderate aorto-iliac stenosis or extensive colorectal symptoms, ABI may be false negative. (American Diabetes Association, 2018).

The aim of this study was to assess the arterial system of the lower extremities in diabetic foot patients and to analyze the role of color Doppler in the diagnosis of diabetic arteriopathy.

A prospective case control study was conducted at Qena university hospital, South Valley University, Qena involving Group I: 40 healthy individuals as control group. Group II: 40 patients known diabetic in the duration between August 2019 till August 2020.

There was a significant difference in the age and BMI of the two study groups.

However It was reported that there was no age difference between the study group and the control group. The mean body mass indices of the study group of patients with diabetes was much higher than that of the control group. (Leoniuk study et al., 2014)

Another study analyzed a total of 324 patients (male: female = 192: 132). The mean age of all participants was  $62.5 \pm 7.3$  years and the BMI was  $24.5 \pm 2.9$  kg / m<sup>2</sup>. Clinical features of people with or without PAD. The PAD group was

more likely to be older and male, and had a lower BMI. (Hur et al., 2018)

Current study shows that there were significant differences between the two groups studied in terms of CRP. There was significant difference between the two groups studied for RBS and HbA1c. There was significant difference in TC, TG, LDL, and HDL between the two groups in the study.

The mean duration of diabetes was  $12.03 \pm 6.96$  years, and the mean duration of HbA1c was  $7.23 \pm 1.57$ . (Seth et al., 2017)

It was found that HbA1c glycemic revealing the glycemic control during the last 2-3 months was available among 68% of cases . With a mean value of  $8.4 \pm 1.4$  gm / dl, fifty-three cases (77%) showed controlled blood sugar levels, i.e., HbA1c <10 gm / dl, and 15 cases (22%) showed uncontrolled blood sugar levels, i.e.> 10 gm/dl. (Shaheen et al., 2010)

It was found that fasting plasma glucose levels and lipid levels did not differ significantly between patients with or without PAD. (Hur et al., 2018)

There was a linear correlation between glycated hemoglobin content, diabetes-related mortality, and complications of micro- and macroangiopathy. Although the mean level of HbA1c oscillated around the normal value, a correlation was observed between the value of this parameter and the flow resistance index (RI): the increase in HbA1c in all studied vessels was associated with increased flow resistance measured by RI. This may suggest changes in the vessel wall (wall hardening) that affect the flow parameters manifested by gradual increased in the flow resistance . (Ma et al., 2011)

In this study, there were significant differences between the two study groups in terms of the diameter of the right / left dorsalis pedis artery and the right / left posterior posterior artery. There were significant differences between the two study groups in terms of the wall thickness of the right / left lumbar pedis artery and the right / left posterior artery.

Compared to the study group, the overall diameter of the vessel, as well as the wall thickness were of higher values observed on gray ultrasound with no statistically significant difference in the lumen diameter. (Leoniuk et al., 2014)

Using a 10 MHz probe there was decrease in arterial diameter and an increase in peripheral arterial flow resistance (RI) in patients with diabetes mellitus. (Zhang et al., 2013)

Light narrowing with unevenly irregular wall calcifications were more common in the dorsalis pedis arteries more at left side (36% on the right and 41% on the left). Anterior tibial arteries (30% on the right and 31% on the left) and the posterior tibial arteries (30% on the right and 31% on the left) were the next most common arteries to show light narrowing with irregular wall calcifications. (Das G et al., 2015)

By Doppler ultrasound, the most affected arteries being ATA in 18 patients, the second affected artery being SFA in 15 patients, and the least affected arteries being PFA. could not be evaluated. (KHALED et al., 2019)

CDS found 545 (32.4%) positive segments out of a total of 1680 vessel segments, with a wall thickness of 222 (13.7%) and a wall calcification of 120. (7.4%), occlusion 101 (6.0%), thrombus 102 (6.0%) [Table 2], compared to CTA which was able to detect 732 (43.5%) of which wall thickening were 202 (12.0%), wall calcification were 178 (10.9%), occlusion were 168 (10.3%), and thrombus were 182 (10.8%), CT detected 11.1% more number of positive cases on overall. (Kondeti et al., 2020)

The mean caliber of CFA, SFA, POP artery, ATA, PTA and dorsalis pedis artery in the arterial Doppler was  $0.66 \pm 0.43$ . cm,  $0.56 \pm$

$0.37$  cm,  $0.48 \pm 0.13$  cm,  $0.23 \pm 0.10$  cm,  $0.22 \pm 0.09$  cm, and  $0.18 \pm 0.08$  cm respectively. The proximal vessels of the lower extremities have largest caliber. (Seth et al., 2017),

A study of 43 patients with Doppler and MDCTA showed that the number of segments with 50% stenosis was 27 (3.49%) and 35 (4.52%) on DUS and MDCTA. respectively. The number of segments with occlusion was 59 (7.62%) and 95 (12.27%) on DUS and MDCTA was respectively. In generally, these results show that a comparison of DUS and MDCTA shows that MDCTA detects more stenotic or occluded arteries in the supra-popliteal, infra-popliteal and and whole leg arteries. (Kayhan et al., 2012)

Doppler methods are very accurate in making diagnostic interpretations. Doppler color diagnosis is a non-invasive and accurate method of assessing patients with peripheral ischemia. (Huljev et al., 1994)

Duplex sonography is now the main investigation used to study the location and extent of the disease. Good for diagnosing occlusions and differentiate between large (> 50%) and small (<50%) stenosis. Compared to arteriography, duplex sonography has a sensitivity of 71-98% and a specificity of 91-100%. In routine clinical practice, duplex scanning reduces the need for arteriography in patients management including whom requires intervention. Doppler ultrasound studies provide direct information about arterial disease by analyzing arterial flow hemodynamic changes of significant stenosis including velocity, velocity pulse wave contour and interruption of the laminar flow and turbulence. (Katsilambros et al., 1996)

The current study has found that blood flow parameters (PSV, PI, and RI) for DPA and PTA were significantly higher in the diabetic group than in the control group, while EDV is was found lower in the diabetic group than in the control group. Most patients had a biphasic flow pattern in both dorsalis pedis artery and posterior tibial artery.

Changes in biphasic spectral waveform was observed in 41/148 arteries in diabetic patients (27.7%), while monophasic wave form

were observed in only 4/148 cases (2.7%). For blood flow parameters (PSV, EDV, PI, RI), no statistical differences between groups were assessed by spectral doppler sonography . (Leoniuk et al., 2014),

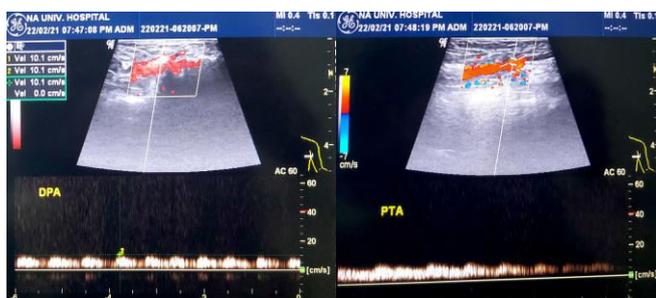
Distal ischemia of low resistance pattern was observed in the dorsalis pedis artery (25.5%), followed by anterior tibial (23%) and posterior tibial (21.5%) arteries. (Das et al., 2015)

In 38 cases there was normal blood flow with typical triphasic waveform pattern . Spectral window broadening of the spectral waveform was observed in 41 cases with 15 cases of mild stenosis (24%), 21 cases with moderate stenosis (33.8%), and five cases with severe stenosis (8%). Biphasic flow patterns were observed in 15 cases (36%) and monophasic flow in 26 cases (63.4%). (Shaheen et al., 2010)

UCD (Ultrasound Color Doppler) showed that the above knee arteries had good color filling and triphasic flow while the below knee arteries had spectrum broadening with monophasic flow . Dorsalis pedis artery had the lowest systolic velocity ( $58.44 \pm 39.59$  cm / s) and resistive index ( $0.82 \pm 0.31$ ) . Atheromatous plaques predominated in all vessels . On CTA , occlusion was observed more in PTA (n = 40/130), while calcification was predominant in the femoral artery (n = 59/130) . Collateral was present in 36.9% of the organs. On logistic regression, a low resistance index and biphasic flow of the dorsalis pedis artery on the UCD and calcifications in the peroneal artery CTA could predict a higher rate of minor amputation . (Seth et al., 2017),

**Cases:**

**Case No. 1**



**Fig.2. Male patient 65 yrs complaining of left diabetic foot and left foot rest pain with history of being diabetic (type II) from 24 yrs ago .**

**Doppler US revealed :**

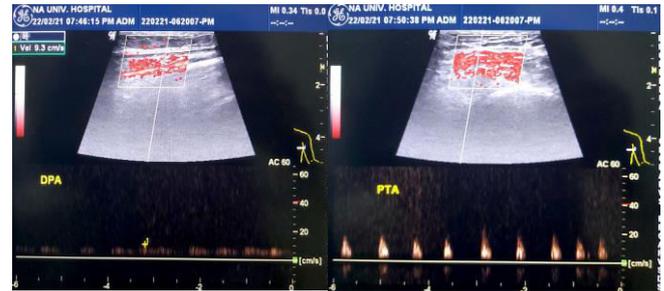
	DPA	PTA
<b>B-mode</b>	Increased IM complex thickness Median layer sclerosis	Increased IM complex thickness Median layer sclerosis
<b>Color mode</b>	Monophasic color flow	Monophasic color flow
<b>PW mode</b>	Monophasic waveform (tardus parvus) PSV +/- 10 cm/sec .	Monophasic waveform (tardus parvus) PSV +/- 10.5 cm/sec .

\* The CFA , SFA , POP A and peroneal artery show biphasic arterial wave form with atherosclerotic changes in the form of increased IM complex thickness with median layer sclerosis .

\* The middle third of PTA and distal third of the ATA are near totally occluded by echogenic thrombus .

\* Poor distal run off as described

**Case No. 2**



**Fig.3. Female patient 55 yrs complaining of unhealed right foot ulcer , right foot rest pain and intermittent claudication . The patient is diabetic type II from 15 yrs .**

**Doppler US revealed :**

	DPA	PTA
<b>B-mode</b>	Increased IM complex thickness Multiple wall calcications	Increased IM complex thickness Multiple wall calcications
<b>Color mode</b>	Monophasic color flow	Monophasic color flow
<b>PW mode</b>	Monophasic waveform (tardus parvus) PSV +/- 9.3 cm/sec .	Monophasic high resistance waveform (narrow spectral window with

		<i>rapid RT ) PSV +/- 17.5 cm/sec .</i>
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\* The CFA , SFA , POP A and peroneal artery show biphasic arterial wave form with atherosclerotic changes in the form of increased IM complex thickness with median layer sclerosis with multiple calcified and non calcified non significant plaques in the arterial tree of the examined limb more pronounced at the ATA and PTA . Noted echogenic calcified plaque at the origin of the SFA causing non significant stenosis (49%),

\* The middle third of the ATA are near totally occluded by echogenic thrombus .

\* Poor distal run off (regarding the DPA) as described in the previous table . (*figure 2*)

### Conclusion

Peripheral vascular insufficiency was a significant finding in diabetic patients for 1–10 years. The dorsalis pedis artery was the most common site. Routine Doppler studies almost rule out significant hemodynamic damage and help prevent unnecessary interference. Doppler ultrasound is a non-invasive procedure and is an easy procedure. Color Doppler is a useful tool for detecting PAD in T2DM patients.

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