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## ORIGINAL RESEARCH

# A Comparative Study of Lower-Limb Arterial Blood Flow Pattern in Diabetic Patients with and without Foot Ulcer

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**Abstract**

**Background:** In this study, we wanted to evaluate the lower-limb arterial blood flow pattern in diabetic patients with and without foot ulcer.

**Materials and methods:** This was a hospital based cross-sectional study conducted among 50 patients of diabetes mellitus who presented with ischemic symptoms with foot ulcer and without foot ulcer to the Department of Surgery OPD of PSG Hospitals, from November 2019 to May 2021, after obtaining clearance from Institutional Ethics Committee and written informed consent from the study participants.

**Results:** Males were at higher risk of getting a diabetic foot ulcer compared to females. Also, older patients with age more than 60 were mostly affected and were at high risk as opposed to younger patients. Among the patients with symptoms, pain, numbness, colour change and absent or weak pulses were significantly associated with ulcer. The qualitative wave form analysis showed that anterior tibial, posterior tibial, and dorsalispedis were also significantly diseased in patients with ulcer.

**Conclusion:** Proper management of diabetic foot problems with thorough clinical evaluation of the patient, including proper assessment for vascular involvement is important. This is followed by early treatment with an emphasis on preventative strategies.

**Keywords:** Diabetes Mellitus, Foot Ulcer, Doppler Imaging

## Introduction

At the beginning of the 21st Century, diabetic foot problems, although eminently preventable, represented one of the commonest causes of hospital inpatient admissions in western countries. In 2005, the International Diabetes Federation realized the global importance of diabetic foot disease and chose to focus their campaign during the whole year on raising awareness with a worldwide campaign to-put feet first‖ and highlight the common problem of amputation amongst diabetic patients throughout the world. To coincide with World Diabetes Day 2005 (November 14, birth date of Frederick Banting), the Lancet elected to dedicate a whole issue to diabetic foot problems. The global term-diabetic foot‖ refers to the variety of pathological conditions that might affect the feet in patients with diabetes. Foot ulcers are defined as lesions involving a skin break with loss of epithelium they can extend into the dermis and deeper layers sometimes involving bone and muscle.

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Amputation is defined as- the removal of a terminal, non-viable portion of the limb‖. The life time risk of a diabetic patient developing a foot ulcer (DFU) has been estimated to be as high as 25%. The suffering of affected individuals and the cost of DFUs are both equally staggering. Those patients with DFUs usually have other complications of diabetes including nephropathy. The study of the epidemiology of diabetic foot disease has been beset by numerous problems relating to both diagnostic tests used and population selected. However, studies from the Western countries reported that the annual incidence of foot problems amongst the diabetic population is just less than 2%. Similarly, when discussing amputations, the figures vary widely again due to diagnostic criteria as well as regional differences. It must be remembered that many patients at diagnosis of type 2 diabetes have significant neuropathy. With respect to ethnicity, studies suggest that foot ulcers and amputations appear to be less common in Asian patients of Indian subcontinent origin and Afro-Caribbean men. In contrast, reports from the USA suggests that amputation rates are more common amongst African Americans with diabetes than amongst white Americans. Diabetic foot ulcers are among the most common complications of patients who have diabetes mellitus which is not well controlled. It is usually the result of poor glycemic control, underlying neuropathy, peripheral vascular disease, or poor foot care. It is also one of the common cause for osteomyelitis of the foot and amputation of lower extremities. These ulcers are usually in the areas of the foot which encounters repetitive trauma and pressure sensations. Staphylococcus is the common infective organism. The disease is typically chronic, and an inter professional approach will have the best outcome. The combined involvement of podiatrist, endocrinologist, primary care physician, vascular surgeon, and an infectious disease specialist is extremely beneficial. It is a commonly encountered scenario in both outpatient settings and inpatients. Diabetic foot ulcers are responsible for more admissions than any other diabetic complication. Today, diabetes is the leading cause of non-traumatic amputations all over the world. Overall, about 5% of patients with diabetes mellitus develop foot ulcers and 1% end up with an amputation. Educating the patient about the complication and the need for proper medical care will reduce the risk of complications and good compliance. The aetiology for diabetic foot ulcer is multifactorial. The common underlying causes are poor glycemic control, calluses, foot deformities, improper foot care, ill-fitting footwear, underlying peripheral neuropathy and poor circulation, dry skin, etc. About 60% of diabetics will develop neuropathy, eventually leading to a foot ulcer. The risk of a foot ulcer is increased in individuals with a flat foot as they have disproportionate stress across the foot, leading to tissue inflammation in high risk areas of the foot. Imaging modalities for evaluating peripheral arterial disease in the lower extremities includes computed tomography (CT) angiography, conventional angiography, and Doppler ultrasonography (US). Three dimensional CT angiography provides information about atherosclerotic calcifications and the extent of stenosis or occlusion of the arteries. CT angiography has some advantages, such as shorter examination time, the ability to evaluate the iliac artery, and the fact that it is less affected by the operator‘s experience. Conventional angiography is used for vascular interventions such as angioplasty or stent application, as well as in the diagnosis of peripheral arterial disease. Doppler US is the only non-invasive technique that does not require contrast enhancement, preparation of the patient before the study, or radiation exposure. Doppler US is a good method for screening and follow-up, as well as for the definitive diagnosis of peripheral arterial disease. Color Doppler US can easily identify arteries by finding round objects with regular pulsation and can be used to detect stenotic or occluded segments. Pulsed-wave Doppler US can show the exact flow velocity of each arterial segment and determine the degree of severity of the stenosis based on an analysis of the pulsed-wave Doppler spectral waveform. Knowledge of the ultra sonographic anatomy of the lower

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extremity arteries and the corresponding anatomical landmarks is essential for performing Doppler US.

**Aims and objectives**

To differentiate blood flow pattern in diabetic patients, with and without foot ulcer.
To study the types of blood flow in lower extremities in diabetic patients.

**Materials and methods**

This was a hospital based cross-sectional study conducted among 50 patients of diabetes mellitus who presented with ischemic symptoms with foot ulcer and without foot ulcer to the Department of Surgery OPD of PSG Hospitals, from November 2019 to May 2021 after obtaining clearance from Institutional Ethics Committee and written informed consent from the study participants.

**Inclusion criteria**

Diabetes mellitus with more than 5 years of duration.
Age 18 to 80 years.
Cellulitis.
Intermittent claudication pain.
Gangrene (WET AND DRY).
Diabetic foot ulcers.
Lower-limb swelling.
Rest pain.
Patients consenting to take part in the study.

**Exclusion criteria**

Patients who have less than 5 years of diabetes mellitus.
Gas gangrene.
Patients not willing to take part in the study.
Trauma patients.

**Statistical methods**

Frequency and percentage were reported for gender, age and clinical presentation.
Doppler study of lower limb arteries was studied. Chi square test was used to test the significance between the variables and complications of ulcer and p value less than 0.05 was taken as statistically significant.
Statistical analysis was done using Statistical Package for Social Sciences (SPSS) Software version.

**Results**

| **Age Category** | **Ulcer Present N (%)** | **Ulcer Absent N (%)** |
|---|---|---|
| Less than 60 years | 8 (32) | 17 (68) |
| More than 60 years | 17 (68) | 8 (32) |
| *Age Distribution* | | |
| Sex | Number (N) | Percentage (%) |
| Males | 28 | 56 |
| Females | 22 | 44 |
| *Sex Distribution* | | |

***Table 1: Demographic Distribution***

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32% and 68% of the study participants belonged to age category less than 60 years and more than 60 years respectively in those having the ulcer and in those without ulcer, 68% and 32% of them belonged to less than 60 years and more than 60 years' categories respectively. Males constituted 56% and females 44% of the total population.

| S. No | Variable | Category | Ulcer Absent (%) | Ulcer Present (%) | Odds Ratio (95 % CI) | P Value |
|---|---|---|---|---|---|---|
| 1 | Age | Less than 60 years | 17 (68) | 8 (32) | 4.156 (1.376- 14.820) | 0.011 |
| | | 60 years and above | 8 (32) | 17 (68) | | |
| 2 | Duration | 5-10 | 19 (52.8) | 17 (47.2) | 1.490 (0.429- 5.172) | 0.529 |
| | | More than 10 | 16 (42.9) | 8 (57.1) | | |
| 3 | Sex | Female | 15 (68.2) | 7 (31.8) | 3.857 (1.180-12.606) | 0.023 |
| | | Male | 10 (35.7) | 18 (64.3) | | |
| 4 | Side | Left | 11(50) | 11 (50) | 1 | 1 |
| | | Right | 14 (50) | 14 (50) | | |

***Table 2 :Association of Variables with Ulcer***

Association between age, duration of diabetes, gender and side with ulcer. Those who were 60 years and above were 4.156 times at risk of developing ulcer and males were 3.857 times at risk of developing ulcer. There was statistically significant association between elder age and ulcer, male and ulcer with p value of 0.01 and 0.023 respectively.

| S. No | Variable | Category | Ulcer Present (%) | Ulcer Absent (%) | Odds Ratio (95 % CI) | P Value |
|---|---|---|---|---|---|---|
| 1 | Pain | Present | 24 (96) | 8 (32) | 51 (5.825- 446.546) | <0.001 |
| | | Absent | 17 (4) | 1 (68) | | |
| 2 | Numbness | Present | 9 (36) | 2 (8) | 6.469 (1.230- 34.012) | 0.017 |
| | | Absent | 16 (64) | 23 (92) | | |
| 3 | Fatiguability | Present | 2 (8) | 0 | 2.089(1.554- 2.803) | 0.149 |
| | | Absent | 23 (92) | 25 (100) | | |
| 4 | Colour Change | Present | 6 (24) | 0 | 2.316 (1.650- 3.250) | 0.009 |
| | | Absent | 19 (76) | 25 (100) | | |
| 5 | Pulses | Weakly Palpable | 9 (36) | 3 (12) | 4.125 (1.96 – 17.704) | 0.047 |
| | | Palpable | 16 (64) | 22 (88) | | |

***Table 3: Association of Symptoms with Ulcer***

Among diabetics with ulcer, 96% had pain, 36% had numbness, 8% had fatiguability, 24% had colour change and 36% had weakly palpable pulse. There was statistically significant association between ulcer and presence of pain, numbness, colour change and weakly palpable pulse with p value of <0.05. Those with ulcer had 51 times high chance of pain, 6.46 times high chance of numbness, 2.316 times increased chance of colour change and 4.12 times high risk of weak pulse.

| S. No | Variable | Category | Ulcer Present(%) | Ulcer Absent (%) | P Value |
|---|---|---|---|---|---|
| 1 | Common Femoral Artery | Monophasic | 2 (8) | 0 | 0.149 |
| | | Triphasic | 23 (92) | 25 (100) | |
| 2 | Superficial Femoral Artery | Biphasic | 0 | 2 (8) | 0.308 |
| | | Monophasic | 2 (8) | 1 (4) | |
| | | Triphasic | 23 (92) | 22 (88) | |
| 3 | Popliteal Artery | Biphasic | 2 (8) | 0 | 0.355 |

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| | | | | | |
|---|---|---|---|---|---|
| | | Monophasic | 3 (12) | 3 (12) | |
| | | Narrowing | 1 (4) | 0 | |
| | | Stenosis | 1 (4) | 0 | |
| | | Triphasic | 18 (72) | 22(88) | |
| 4 | Anterior Tibial | Biphasic | 3 (12) | 3 (12) | 0.038 |
| | | Monophasic | 11 (44) | 3 (12) | |
| | | Narrowing | 1 (4) | 0 | |
| | | Stenosis | 1 (4) | 0 | |
| | | Triphasic | 9 (36) | 19 (76) | |
| 5 | Posterior Tibial | Biphasic | 6 (24) | 5 (20) | 0.047 |
| | | Monophasic | 7 (28) | 1 (4) | |
| | | Narrowing | 2 (8) | 0 | |
| | | Stenosis | 3 (12) | 4 (16) | |
| | | Triphasic | 7 (28) | 15 (60) | |
| 6 | DorsalisPedis | Biphasic | 2 (8) | 3 (12) | 0.002 |
| | | Monophasic | 15 (60) | 5 (20) | |
| | | Narrowing | 1 (4) | 0 | |
| | | Stenosis | 3 (12) | 0 | |
| | | Triphasic | 4 (16) | 17 (68) | |

***Table 4: Association of Doppler Wave Forms of Lower Limb Arteries with Ulcer***

The findings of Doppler wave pattern in diabetics with and without foot ulcer are as follows. In common femoral artery, majority of diabetics with and without ulcer had triphasic wave pattern, few with ulcer had monophasic pattern. In superficial femoral artery, majority of diabetics with and without ulcer had triphasic wave pattern, followed by monophasic pattern. In popliteal artery, majority of diabetics with and without ulcer had triphasic wave pattern, followed by monophasic pattern. In addition, few of those with ulcer had biphasic, narrowing and stenosis pattern.

The flow pattern in the anterior tibial artery, posterior tibial artery and dorsalispedis artery was different in diabetics with and without ulcer with p value of <0.05. In anterior tibial artery, majority of those with ulcer had monophasic pattern (44%), followed by triphasic (36%) and biphasic pattern (12%), 4% had narrowing and 4% had stenosis. Whereas majority of those without ulcer had triphasic pattern (76%), followed by biphasic (12%) and monophasic pattern (12%).

In posterior tibial artery, 28% of those with ulcer had triphasic and monophasic pattern (44%), followed by biphasic pattern (24%), 8% had narrowing and 12% had stenosis. Whereas majority of those without ulcer had triphasic pattern (60%), followed by biphasic (20%), stenosis (16%) and monophasic pattern (4%). In dorsalispedis artery, majority of those with ulcer had monophasic pattern (60%), followed by triphasic (16%), stenosis 12%, biphasic pattern 8% and narrowing 4%. Whereas majority of those without ulcer had triphasic pattern (68%), followed by monophasic (20%) and biphasic pattern (12%).

| **Variable** | **Category** | **Ulcer Present (%)** | **Ulcer Absent(%)** | **P Value** |
|---|---|---|---|---|
| Atheromatous changes | Diffuse atheromatous wall calcification | 19 (76) | 15 (60) | 0.183 |
| | Minimal Atheromatous wall calcification | 4 (16) | 3 (12) | |

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| | | | | |
|---|---|---|---|---|
| | No atheromatous wall calcification | 2 (8) | 7 (28) | |

***Table 5 : Association of Atheromatous Change with Ulcer***

There was no difference between atheromatous change and presence of ulcer.

**Discussion**

In our cross-sectional study, we have studied 25 patients of diabetes mellitus with ischemic symptoms complicated with foot ulcers and 25 without foot ulcer. Of these patients, 44% were females and 56% were males. Among the patients with foot ulcer, 64.3% were males and only the rest 31.8% were females. There was a significant association between gender and ulcer (p=0.023, Odds=3.857). A similar result was observed in a study conducted by Ratnakar et al. in which the authors found that 60% were male and only 40% were females. The predominance of males over females has been highlighted in epidemiological studies of diabetic foot, which in general have consensus that males are relatively at a higher risk of diabetic foot ulceration as compared to females.

Among the patients with foot ulcers, 68% of the patients were in the age group of 60 years and above. The prevalence of diabetic foot ulceration in the diabetic population was more frequently seen in elderly patients. The association between age and ulcer (p=0.011, Odds=4.156) was found to be significant. In a study conducted by Daba Abdissa et al. the mean age of the respondents was 50.1±14.28 and 53.8% was above the age of 50 years. Also, in a study done by Ali M Al Amriet al. there was significant association between diabetic foot and age (with p=0.004). Age is one of the most common risk factors for diabetic foot. The prevention of diabetic foot is crucial, considering the negative impact on a patient‘s quality of life and the associated economic burden on the patient as well as the healthcare system.

The risk of foot ulceration and limb amputation also increases with the duration of diabetes. In a study conducted by Shashank Shekhar Tripathi et al. in 2019 the maximum duration of disease was 16 years and the mean duration of disease was 9.6 years. However, in this study, the duration of diabetes was not significantly associated with ulcer (p=0.529, Odds=1.490). Among the patients with ulcer, 68% were in the group of 5 - 10 years of the disease, and only 32% were in patients with more than 10 years of the duration of the disease.

It was also found in our study, that there was no significant association between the side and the occurrence of the ulcer. Among the patients with ulcer, 44% were on the left side and 56% were on the right side (p value=1, Odds=1). We have found ischaemic symptoms significantly associated with patients who had ulcers than those without ulcer. Pain, numbness, colour change and weak or absent pulses were these symptoms. Among patients with ulcers, 96% had pain, 36% had numbness, 8% had fatigue ability, 24% had colour change and 36% had weakly palpable pulse.

Diabetic neuropathy is the common factor in almost 90% of diabetic foot ulcers. Nerve damage in diabetes affects the motor, sensory, and autonomic fibres. Motor neuropathy causes muscle weakness, atrophy, and paresis. Sensory neuropathy leads to loss of the protective sensation of pain, pressure, and heat. In our study, pain was significantly associated with ulcer (p<0.001, Odds=51). Also, numbness, colour change, absent or weak pulses were associated with patients with ulcer (p=0.017, p=0.009 and p=0.047 respectively). Ratnakar et al. in 2017 conducted a study of diabetic foot ulcer patients admitted at a tertiary centre in Rohilkhand region of Uttar Pradesh, India. It describes the epidemiology, risk factors, clinical symptoms and extent of lesions in these patients. Pain (72.00%) was the most common presenting feature, followed by history of trauma (70.00%), ulcer (40.00%), claudication (24.00%) and recurrent infection (16.00%). Hypertension was noticed as co-morbidity in 14% patients whereas peripheral neuropathy was noticed in 30% patients. Doppler scanning is a very useful technique for screening and follow-up, for the authoritative

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identification of peripheral arterial disease. This technique is widely preferred as it is simple, versatile and handy. Doppler USG is the main non-invasive procedure with many advantages. The modality doesn't need administration of any contrast; any pre-procedure planning and most important of all, there is no risk of radiation exposure. It is a simple, non-invasive, and an affordable method allowing anatomical and hemodynamic vascular assessments, regardless of calcifications in the arteries. In diabetics without ischemic symptoms, most of the Doppler wave patterns are triphasic and biphasic, while in diabetics with ischemic symptoms, biphasic and monophasic waves are predominantly seen. The Doppler waveform analysis provides further information; a triphasic waveform reflects a normal hemodynamic state and then the absence of LEAD (lower extremity arterial disease). The presence of monophasic or biphasic waveforms has good negative predictive value. This technique is particularly helpful to establish the diagnosis of vascular insufficiency in clinically suspected cases of vascular disease and to predict the therapeutic results and follow up. In our study, majority of our patients, both with and without ulcers, had triphasic wave pattern in their femoral arteries. Few of the patients with ulcer had monophasic pattern. In majority of the patients with and without ulcers, superficial femoral artery had triphasic wave pattern, followed by monophasic pattern. Likewise, in popliteal artery too, majority of the patients, again both with and without ulcers, had triphasic wave pattern, followed by monophasic pattern. In addition, few of those with ulcer had biphasic pattern. Also narrowing and stenosis of the vessels were seen. There was a significant difference in the flow pattern in the anterior tibial artery, posterior tibial artery and dorsalispedis arteries in patients with and without ulcer (p value of $<0.05$). In anterior tibial artery, majority of those with ulcer had monophasic pattern (44%), followed by triphasic (36%) and biphasic pattern (12%). 4% had narrowing and 4% had stenosis. Whereas, majority of those without ulcer had triphasic pattern (76%), followed by biphasic (12%) and monophasic pattern (12%). In posterior tibial artery, 28% of those with ulcer had triphasic and monophasic pattern (44%), followed by biphasic pattern (24%). 8% had narrowing and 12% had stenosis. Whereas, majority of those without ulcer had triphasicpattern (60%), followed by biphasic (20%), stenosis (16%) and monophasic pattern (4%). In dorsalispedis artery, majority of those with ulcer had monophasic pattern (60%), followed by triphasic (16%), stenosis 12%, biphasic pattern 8% and narrowing 4%. Whereas, majority of those without ulcer had triphasic pattern (68%), followed by monophasic (20%) and biphasic pattern (12%). Our study showed anterior tibial ($p=0.038$), posterior tibial ($p=0.047$) and dorsalispedis ($p=0.002$) patterns were significantly associated with ulcer. A study conducted at Allahabad showed that as the duration of disease increases, there is an increased probability for appearance of ischemic symptoms and foot involvement. In diabetics without ischemic symptoms, most of the Doppler wave patterns are triphasic and biphasic, while in diabetics with ischemic symptoms, biphasic and monophasic waves are predominantly seen. Diabetic foot is a major health problem in diabetic patients. And majority of the patients were males and were in older age group. Among the patients with symptoms; pain, numbness, colour change and absent or feeble pulse were significantly associated with ulcer. The qualitative wave form analysis showed that anterior tibial, posterior tibial and dorsalispedis were also significant in patients with ulcer.

**Conclusion**

The management of diabetic foot ulcers remains a major therapeutic challenge which implies an urgent need to review strategies and treatments, in order to achieve the goals and reduce the burden of care in an efficient and cost-effective way. Prevention of diabetic foot ulceration is critical to reduce the associated high morbidity and mortality rates, and the possibility of amputation. Males and elderly patients are the people mostly affected by diabetic foot ulcer, and its consequences. Pain, numbness, colour change and absent or weak

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pulses are the high-risk symptoms of diabetic foot ulcer. The aetiology of diabetic foot disease is multifactorial, and includes complications of diabetic neuropathy, vasculopathy, immunopathy and poor glycaemic control. Proper management of diabetic foot problems begins with a thorough clinical evaluation of the patient followed by early treatment with an emphasis on preventative strategies. It is essential to identify the foot at risk, through careful inspection and physical examination of the foot followed by neuropathy and vascular tests. Diabetic foot ulcers should be carefully evaluated, and the gold-standard treatments should be strictly applied in order to prevent amputation. In diabetics without ischemic symptoms, most of the Doppler wave patterns are triphasic and biphasic, while in diabetics with ischemic symptoms, biphasic and monophasic waves are predominantly seen. The Doppler waveform analysis provides further information; a triphasic waveform reflects a normal hemodynamic state and then the absence of LEAD (lower extremity arterial disease). The presence of monophasic or biphasic waveforms has good negative predictive value. This technique is particularly helpful to establish the diagnosis of vascular insufficiency in clinically suspected cases of vascular disease and to predict the therapeutic results and follow up.

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