Original Article

Doppler Sonographic Characteristics and Clinical Outcomes of Diabetic Foot Syndrome: A 5-Year Audit from a Tertiary Hospital in Northern Nigeria

Abstract

Background: Diabetes foot syndrome is one of the common complications of diabetes. Detailed information on the clinical and vascular characteristics of patients with diabetic foot disease in relation to the outcome of the care provided to these patients will be useful to policymakers and clinicians in early detection and timely interventions for the prevention of disabling complications. **Materials and Methods:** This is a review of patients with diabetic foot managed in Aminu Kano Teaching Hospital over 5 years (January 2017–May 2022). The sociodemographic characteristics, Wagner classification of the foot, Doppler sonographic characteristics and clinical outcomes, etc., were reviewed. **Results:** A total of 51 patients were reviewed. Males and females accounted for 56.8% and 43.1%, respectively. Twenty-five patients had Wagner grade 4 ulcers, and fewer patients had Wagner grade 1 and 5-foot ulcers. The mean ± standard deviation Doppler arterial intimal media thickness was 1.53 ± 0.33 (range 0.90–2.40 mm). The majority of DFS patients had Doppler sonographic lesions on the right lower limb 28 (54.9%) only, and 11 (21.6%) of the lesions were bilateral. The posterior tibial artery 11 (21.6%) was the most involved arterial segment with plaques, followed by a combination of popliteal and tibial arterial 10 (19.6%) segments. At 6 months, 45.2% had limb amputation, 17.6% healed ulcers, 17.6% delayed wound healing, and 9.8% died. **Conclusion:** There is an unacceptably high prevalence of poor treatment outcomes, thus, contributing to a huge burden of care to patients living with diabetes. There is a strong association between severe arterial stenosis detected by Doppler ultrasound and higher rates of amputations.

Keywords: *Amputation, arterial stenosis, diabetes food syndrome, doppler scan*

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Introduction

Diabetes foot syndrome (DFS), as defined by the World Health Organization, is an "ulceration of the foot (distally from the ankle and including the ankle) associated with neuropathy and different grades of ischemia and infection."[1] Diabetic foot conditions, such as ulcerations, infections, and gangrene, are the most common cause of hospitalization among diabetic patients. Routine ulcer care, treatment of infections, amputations, and hospitalizations cost billions of dollars every year and place a tremendous burden on the healthcare system. Diabetic foot syndrome is one of the common complications of diabetes mellitus in our environment; which is responsible for high morbidity, physical disability, high cost of care, and mortality; as identified by Apelqvist and Agardh as well as other authors.[2-6] The presence of diabetes foot ulcers was strongly associated with age and diabetic complications such as multiple cardiovascular diseases and nephropathy, which were important factors related to amputation and long-term disability.[1,5,7]

Early presentation of DMF ulcers coupled with aggressive wound care, control of infections, and adequate glycemic control have been found to minimize the risk of lower extremity amputation.[8]

Although the quality of care has really advanced in developed and even many developing countries, the clinical outcome of diabetic foot syndrome in our local setting is very poor due to late presentation, suboptimal vascular diagnosis, and nonavailability of endovascular therapy.[4,9]

Despite the high prevalence of diabetic complications in Nigeria,[10] there is a paucity of data describing the detailed vascular, laboratory, and microbial characteristics of patients with diabetic foot disease in relation to the outcome of

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the care provided to these patients. If available, the data will greatly assist policymakers and clinicians to update clinical care guidelines and providing necessary facilities, which will help the healthcare team to intervene earlier to prevent disabling and other life-threatening end-organ complications. Therefore, this study aimed to determine the characteristics and to audit the clinical Doppler ultrasound characteristics and outcomes of patients admitted with diabetic foot syndrome in Aminu Kano Teaching Hospital, Nigeria.

Materials and Methods

This retrospective study was conducted at Aminu Kano Teaching Hospital for the period of 5 years from January 2017 to May 2022. The study protocol was approved by the Health research ethics committee of Aminu Kano teaching hospital (reference number: NHREC/28/01/2020/AKTH/2972; approval date: February 15, 2021). The following information was extracted from the records of patients who were admitted with DFS:

1. Sociodemographic characteristics: age and gender.
2. Clinical data: duration of diabetes at presentation, the severity of the foot disease based on Wagner classification, site, and laterality of the lesion, history of a similar lesion in other parts of the body, presence of comorbidities, and other diabetes-related complications.
3. The patients had bilateral lower limb vascular ultrasound scans using the Mindray DC-6 system, equipped with high-resolution and full Doppler protocols. The examination was done from the distal abdominal aorta, iliac arteries, and both lower limbs. The scan was done by a consultant radiologist with a minimum of 2-year post-fellowship experience. The following findings were extracted from the Doppler ultrasound reports from the records of the patients: the presence of wall calcification, thickening of the intimal media, presence, location, and characteristic of atheromatous plaque, presence, length, and severity of the stenotic lesion. Detailed location of the lesions and consequences there, such as total occlusion.
4. Laboratory data: admitting random plasma glucose
5. Treatment data: such as debridement, antibiotic therapy, skin grafting, amputation, duration of hospital stay, etc.
6. Outcome data: such as complete healing, chronic ulcer, osteomyelitis, amputation, sepsis, death, etcetera.

Patients without complete records (of 1–6 above) were excluded from the study.

Operational Definitions

For the purpose of this study, the following terms were defined as stated below:

1. Stroke: stroke as a "rapidly developed clinical signs of focal (or global) disturbance of cerebral function, lasting more than 24 h or leading to death, with no apparent cause other than of vascular origin.[11]
2. Peripheral neuropathy: is defined as a syndrome characterized by sensory or combined sensory and autonomic manifestations associated with an almost entirely normal neurological examination (except for possible distal pinprick and thermal loss) or at least abnormalities solely associated with small fiber involvement.[12]
3. Renal impairment: is defined by structural or functional abnormalities of the kidney (such as microalbuminuria and elevated creatinine clearance), with or without decreased GFR or GFR <60 mL/min/1.73 m^2 for ≥3 months, with or without kidney damage.[13]
4. Heart disease: for the purpose of this study, heart disease as a diabetic complication is ischemic heart disease caused by narrowed heart (coronary) arteries that supply blood to the heart muscle, as evidenced by physiological, biochemical, or imaging features of myocardial ischemia.[14]

The results were analyzed using the International Business Machines statistical package for social sciences (IBM SPSS) software version 23.0 (IBM, Chicago, IL, USA). The results of the descriptive statistics for the quantitative variables were presented in summarizing indices (of mean and standard deviation), while the proportions of the categorical variables were expressed as proportions and percentages. A comparison between the obtained categorical variables and the outcomes of the treatment in both groups was made by the chi-square test. A *P*-value of 0.05 or less was considered a statistically significant result. Findings were presented numerically, graphically, and in tabular forms.

Results

During the 5-year audit period, a total of 69 patients were admitted with DFS. About 18 patients were excluded because they didn't have a lower limb vascular ultrasound scan at presentation due to other pressing medical emergencies such as diabetic keto-acidocis, acute stroke, or death within a few hours of admission. As a result, only records of 51 patients were extracted and therefore analyzed. They consisted of 29 (56.9%) males and 22 (43.1%) females. The mean ± standard deviation (SD) age of the study participants was 56.8 ± 11.1 years (range of 35–80 years) with a greater number of females being older (mean = 58.6 years) than men (mean = 55.5 years). The mean ± SD admission random plasma glucose level was 14.5 ± 6.4 mmol/L.

As shown in Table 1, a large proportion of these patients, 21 (41.6%) presented with Digit/Foot darkening and Leg/Foot ulceration 19 (37.3%) as their main clinical presentation, whereas only 2 (3.9%) presented with leg swelling alone at presentation. Twenty-five (49.1%) patients had Wagner grade 4, foot ulceration, while fewer patients 2 (3.9%) had

Table 1: Clinical profiles of patients with diabetes foot syndrome

Variable	Frequency	Percentage
Clinical presentation		
Claudication and ulceration	9	17.6
Digit/foot darkening	21	41.2
Leg/foot ulceration	19	37.3
Leg swelling	2	3.9
Total	51	100
Wagner grading of the patients		
Grade-1	2	3.9
Grade-2	7	13.7
Grade-3	15	29.4
Grade-4	25	49.1
Grade-5	2	3.9
Total	51	100
Renal impairment		
Present	18	35.3
Absent	33	64.7
Total	51	100
Neurologic complication		
Absent	30	58.8
Peripheral neuropathy	13	25.5
Stroke	8	15.7
Total	51	100
Cardiac complications		
Present	28	54.9
Absent	23	45.1
Total	51	100

Table 2: Sonographic findings of patients with diabetes foot syndrome

Variable	Frequency	Percentage
Side of the lesion		
Right	28	54.9
Left	12	23.5
Bilateral	11	21.6
Total	51	100
Arterial segment involved		
Aorto-iliac	4	7.8
Femoral	3	5.9
Femoro-popliteal	7	13.7
Popliteal and tibial	10	19.6
Anterior tibial	7	13.7
Posterior tibial	11	21.6
Both tibial	6	11.8
Dorsalis pedis	3	5.9
Total	51	100
Wall calcification		
Present	45	88.2
Absent	6	11.8
Total	51	100
Atheromatous plaque		
Present	38	74.5
Absent	13	25.5
Total	51	100
Stenosis severity		
None	4	7.8
Mild	7	13.7
Moderate	14	27.5
Severe	26	51.0
Total	51	100

Wagner grade 1 or 5 levels of foot ulcers. The ulcer grades of other patients are illustrated in Table 1. Regarding the presence of comorbidities, 18 (35.3%) of the patients had renal impairment. Others include peripheral neuropathy 13 (25.5%), stroke 8 (15.7%), and heart disease 28 (54.9%).

The mean ± SD Doppler arterial intimal media thickness (IMT) was 1.53 ± 0.33 (range 0.90–2.40 mm). As shown in Table 2, more than half of the patients had arterial lesions detected by Doppler sonographic lesions on the right lower limb 28 (54.9%), while 11(21.6%) of them had bilateral disease. The posterior tibial artery 11 (21.6%) was the most involved arterial segment with plaques, followed by a combined Popliteal and tibial arterial 10 (19.6%) segments. Notably, isolated femoral and dorsalis pedis segments 3 (35.9%) were the least encountered in this series. A large proportion 45 (88.2%) of DFS patients showed generalized arterial wall calcifications on sonography (as exemplified in Figure 1). As depicted in Figure 2, atheromatous plaques were present in 38 (74.5%) of DFS patient that underwent Doppler with severe arterial luminal stenosis present in slightly more than half 26 (51.0%) of DFS patients [Table 2 and Figure 3].

A total of 13 (25.5%) and 10 (19.6%) of the patients had above and below-knee amputations performed, respectively. Out of the 51 patients with DFS, three (5.9%) had maggot debridement therapy, while the remaining patients had either interphalangeal disarticulation or other forms of conservative treatments, as shown in Table 3. There were a significant number of amputations, 23 (45.2%) as treatment outcomes at 6 months among patients with DFS, mainly because of initial surgical intervention, while healed ulcers 9 (17.6%) and delayed wound healing 9 (17.6%) had the same rate of treatment outcome after 6 months of follow-up. Furthermore, a few patients, 5 (9.8%) with DFS, died after 6 months of follow-up [Table 3].

Wagner grading was significantly associated with the type of treatment received at the presentation. Those who had amputations and disarticulations having a significantly higher Wagner grading of foot ulceration (P-value = 0.003517, χ^2 = 8.5176). Overall, the presence of comorbid diseases did not significantly influence the type of treatment received among patients with DFS (P-value = >0.05, χ^2 = 0.12592). However, severe arterial stenosis was significantly associated with higher rates of amputations and disarticulations as treatment options, while moderate stenosis had a significant association with conservative treatment (P-value = 0.0002, $\chi 2$ = 14.334).

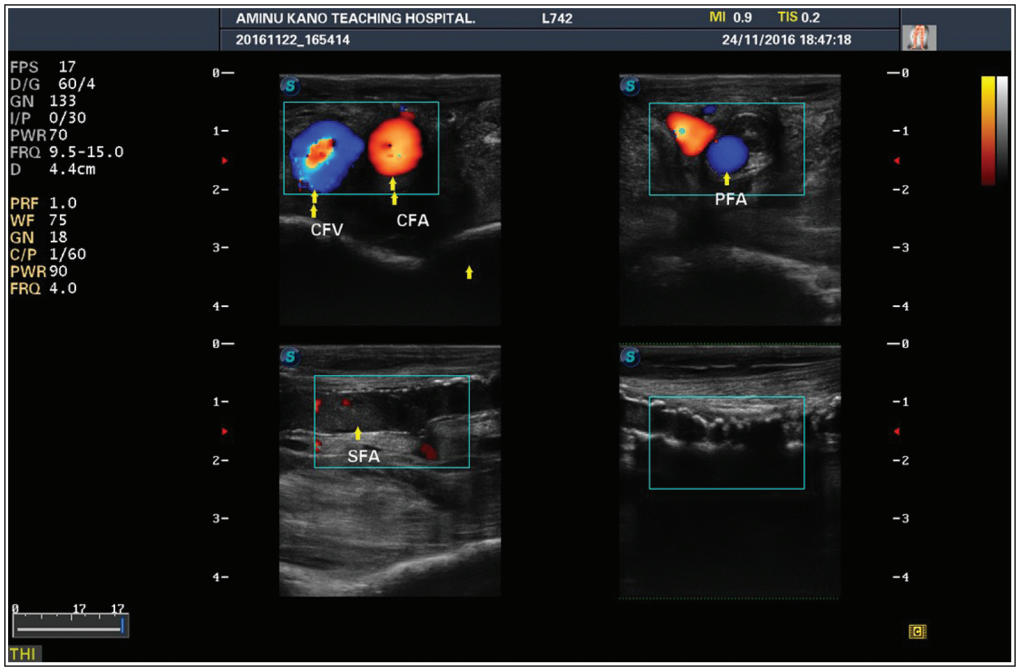

Figure 1: A high-resolution color and power Doppler sonogram of the lower limb of an elderly diabetic with Wagner's grade-3 right ischaemic ulcer. It shows absent blood flow and extensive irregular wall calcifications on the superficial femoral artery (SFA). However, there is good color flow within the common femoral artery (CFA), profunda femoral artery (PFA) and common femoral vein (CFV)

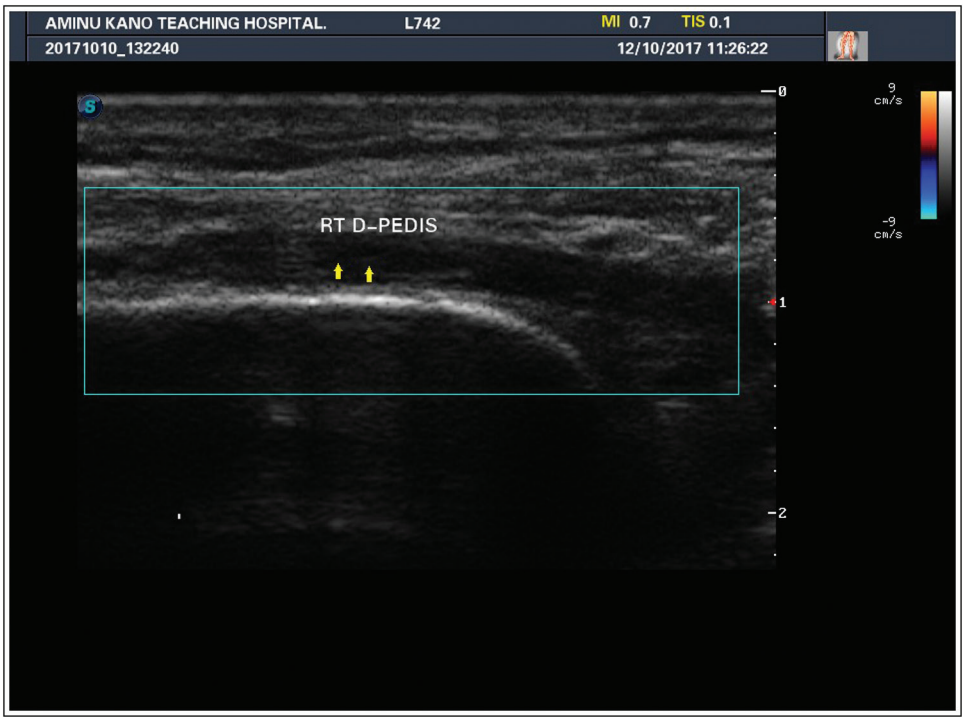

Figure 2: A colour Doppler sonogram of the right dorsalis pedis artery, showing extensive atheromatous plaque, occluding the lumen of the artery

Discussion

DFS is one of the dreaded complications of diabetes and can lead to increased morbidity and mortality in addition to the economic and financial burden it imposes on the patient.[1,7-9] Only 51 record met the eligibility criteria for this study with a slight male preponderance (56.9%). Ugwu *et al.*[4] in their multicenter study as well as Muhammad *et al.*[3] all in Nigeria found similar male preponderance. This is likely because we both studied same Nigerian populations with similar demographics.

The mean age of the patients in this study was 56.8 years. Similar mean age was reported by Muhammad *et al.*[3]

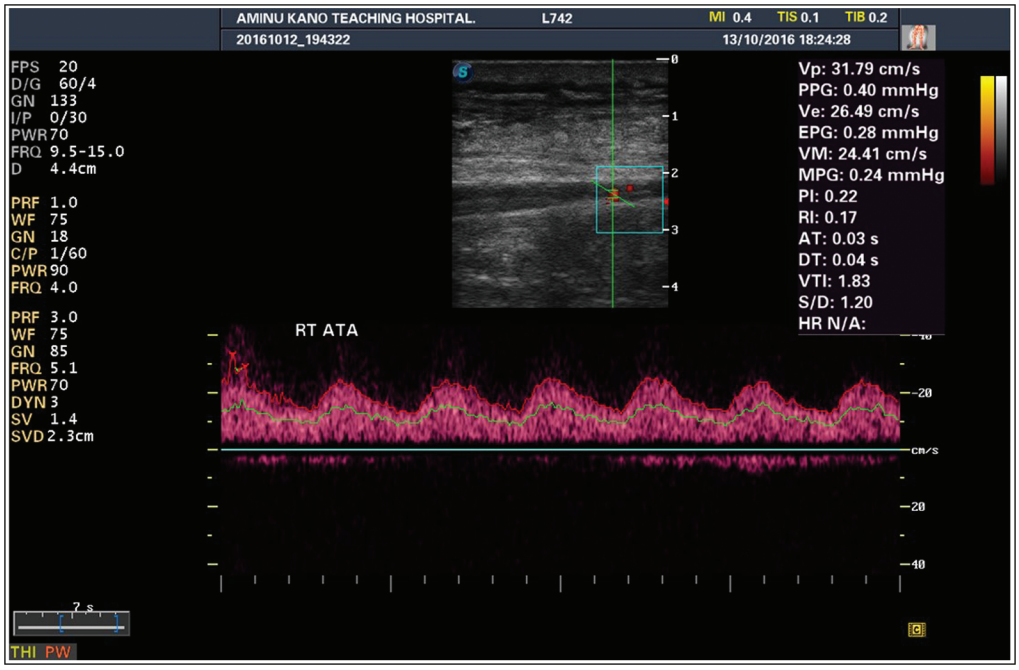

Figure 3: A spectral Doppler sonogram of the right anterior tibial artery (ATA), showing a dwarf systolic peak, spectral broadening and significant diastolic blood flow. These features a typical of the significant proximal stenotic disease

and Ugwu *et al.*[4] in their studies on diabetic foot ulcer patients in Nigeria.[3,4] The clinical presentations of the patients in this study (with digit/foot darkening, ulceration, intermittent claudication, as well as hyperglycemia) are similar to many previous reports.[8,9,15,16]

In similarity with the experience of Olubusola *et al.*,[17] this study also showed a high proportion of 82.4% presenting with at least Wagner grade 3 foot ulceration. However, an earlier study by Danmusa *et al.*[15] had a slightly lower value of 65.7% in nearby Zaria, Northwestern Nigeria. On the other hand, Apelqvist and Agardh[5] reported a much lower prevalence of 32.1% from Sweden, in their study on association between clinical risk factors and outcome of diabetic foot. The difference may be related to different geographical locations (Africa vs. Europe) and the fact that access to healthcare, funding as well as education are in favor of Swedish citizens than those in Nigeria.

The Wagner grading was significantly associated with the type of treatment received at presentation, with those who had amputations and disarticulations having a significantly higher Wagner grading (3 and above) of foot ulceration. This is similar to the findings of many researchers Worldwide.[1,4,7-9,15,16]

In evaluating patients with diabetic foot, Doppler ultrasonography is an invaluable tool that helps in assessing vascular abnormalities, neuropathies as well as infections.[2,18-20] Vascular scans can clearly show level of macroangiopathy whose severity correlates well with the level of diabetic foot. Arterial wall thickness, blood flow, calcifications, artheromatous plaque, luminal diameter as well as level of the vascular compromise can all be clearly outlined by high resolution scan.[2,18-20] In this study, all the patients had abnormal vascular scan result of the lower limbs. The increased arterial IMT of 1.53 ± 0.33 found in this study, is similar to an earlier report in Nigeria[21] but much higher than the findings of an Indian study by Das *et al.*[22] This could be related to the greater severity of the stenotic disease of our patients at presentation

Table 3: Clinical outcome of patients with diabetes foot syndrome

Variable	Frequency	Percentage
Treatment at presentation		
Above knee amputation	13	25.5
Below knee amputation	10	19.6
Disarticulation	7	13.7
Debridement and skin grafting	9	17.6
Maggot therapy	3	5.9
Conservative	9	17.6
Total	51	100
Outcome at 6 months		
Amputation	23	45.2
Healed ulcer	9	17.6
Delayed wound healing	9	17.6
Discharge against medical advice	5	9.8
Death	5	9.8
Total	51	100

In contrast to this study, Das *et al.*[22] and Okasha *et al.*[23] found the dorsalis pedis artery to show more severe disease in DFS, while this study found posterior tibial and popliteal arteries to be more commonly involved. Notably, the femoral and dorsalis pedis segments 3 (35.9%) had the least involvement. Though right-sided lesion predominates

(54.9%), with bilateral pathology accounting for 21.8% of cases, Hameed *et al.*[24] showed a left-sided predominance (46%) and a smaller proportion of bilateral disease (14%). On the other hand, an Ivorian Doppler ultrasound study reported an unusual bilateral disease of up to 62%.[25]

In this study, 88.2% of the patients had generalized arterial wall calcifications on sonography. This is in agreement with that of Bourron *et al.*[26] In contrast, the arterial wall calcification seen in this study is much higher than the Indian series reported by Swain *et al.*,[27] showing the prevalence of 42%; as well as 43.8% from Ivory Coast as reported by Kodjo *et al.*[25] In general, calcification of the arterial wall in the intima (a feature of atheroma) and in the media (mediacalcosis) contributes to an arterial occlusive process below the knee and is associated with amputation risks.[26,28] The prevalence of athermanous plaques in this study (74.5%) was much higher than what was reported by other studies (ranging 38%–45%).[22,24,25] This high burden of atheromatous plaque was found in a cohort with high prevalence of arterial luminal stenosis of 51%. These findings supported the critical contribution of peripheral artery disease (PAD) in the pathogenesis of DFS. PAD causes atherosclerotic occlusive disease of lower extremities. PAD is associated with increased risk of lower extremity amputation and is also a marker for atherothrombosis in cardiovascular, cerebrovascular and renovascular beds.[29] This fact was further stressed by the findings of this study, showing severe arterial stenosis to be significantly associated with higher rates of amputations and disarticulations, while moderate stenosis had a significant association with conservative treatment. In this study, high Wagner grade are associated with significantly increased rate of amputations and amputation. This is similar to the findings of Ugwu *et al.*[4]

From the foregoing, this study revealed that our patients are presenting with high-grade DFS, which is typically characterized by high blood glucose, IMT, arterial wall calcification, and severely stenotic lower limb arteries. In addition to the high amputation rates, those who had conservative treatment also showed a relatively delayed wound healing at 6 month. A more robust prospective study will provide better insight into the confounders and specific causes as well as predictors of poor outcomes for the purpose of long-term prevention.

Conclusion

Diabetic foot syndrome is quite common in North-Western Nigeria. There is an unacceptably high prevalence of poor treatment outcomes, thus contributing to a huge burden of care to patients living with diabetes. A multidisciplinary approach to care, improved infrastructure (human and material), as well as access to care, and appropriate policies in the management of diabetes, will go a long way in stemming the tide of the menace of DFS in Nigeria.

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Conflicts of interest

There are no conflicts of interest.

References

1. Tuttolomondo A, Maida C, Pinto A. Diabetic foot syndrome as a possible cardiovascular marker in diabetic patients. J Diabetes Res 2015;2015:1-12.
2. Kruse I, Edelman S. Evaluation and treatment of diabetic foot ulcers. Clin Diabetes 2006;24:91-3.
3. Muhammad FY, Pedro LM, Suleiman HH, Uloko AE, Gezawa ID, Adenike E, *et al*. Cost of illness of diabetic foot ulcer in a resource limited setting: A study from Northwestern Nigeria. J Diabetes Metab Disord 2018;17:93-9.
4. Ugwu E, Adeleye O, Gezawa I, Okpe I, Enamino M, Ezeani I. Burden of diabetic foot ulcer in Nigeria: Current evidence from the multicenter evaluation of diabetic foot ulcer in Nigeria. World J Diabetes 2019;10:200-11.
5. Apelqvist J, Agardh CD. The association between clinical risk factors and outcome of diabetic foot ulcers. Diabetes Res Clin Pract 1992;18:43-53.
6. Richard JL, Lavigne JP, Got I, Hartemann A, Malgrange D, Tsirtsikolou D, *et al*. Management of patients hospitalized for diabetic foot infection: Results of the French OPIDIA study. Diabetes Metab [Internet] 2011;37:208-15.
7. Sade R, Jatothu D, Taruni., Sade K, Pyadala N. Management of diabetic foot ulcers in a teaching hospital. Int Surg J 2017;4:3088.
8. Adeleye OO, Ugwu ET, Gezawa ID, Okpe I, Ezeani I, Enamino M. Predictors of intra-hospital mortality in patients with diabetic foot ulcers in Nigeria: Data from the MEDFUN study. BMC Endocr Disord 2020;20:1-10.
9. Ezeani IU, Ugwu ET, Adeleye FO, Gezawa ID, Okpe IO, Enamino MI. Determinants of wound healing in patients hospitalized for diabetic foot ulcer: Results from the MEDFUN study. Endocr Regul 2020;54:207-16.
10. Uloko AE, Ofoegbu EN, Chinenye S, Fasanmade OA, Fasanmade AA, Ogbera OA, *et al*. Profile of Nigerians with diabetes mellitus - Diabcare Nigeria study group (2008): Results of a multicenter study. Indian J Endocrinol Metab 2012;16:558-64. Erratum in: Indian J Endocrinol Metab 2012;16:981.
11. Aho K, Harmsen P, Hatano S, Marquardsen J, Smirnov VE, Strasser T. Cerebrovascular disease in the community: Results of a WHO collaborative study. Bull World Health Organ 1980;58:113-30.
12. Gondim F de AA, Barreira AA, Claudino R, Cruz MW, Cunha FMB, Freitas MRG de, *et al*. Definition and diagnosis of small fiber neuropathy: Consensus from the Peripheral Neuropathy Scientific Department of the Brazilian Academy of Neurology. Arq Neuropsiquiatr 2018;76:200-8.
13. National Kidney Foundation. K/DOQI clinical practice guidelines for chronic kidney disease: Evaluation, classification, and stratification. Am J Kidney Dis 2002;39:S1-266.
14. Heusch G. Myocardial ischemia: Lack of coronary blood flow or myocardial oxygen supply/demand imbalance? Circ Res 2016;119:194-6.
15. Danmusa UM, Terhile I, Nasir IA. Prevalence and healthcare costs associated with the management of diabetic foot ulcer in patients attending Ahmadu Bello University Teaching Hospital, Nigeria. Int J Health Sci (Qassim) 2016;10:207-15.

16. Zhang Y, Li W, Yan T, Lu C, Zhou X, Huang Y. Early detection of lesions of dorsal artery of foot in patients with type 2 diabetes mellitus by high-frequency ultrasonography. J Huazhong Univ Sci Technol Med Sci 2009;29:387-90.
17. Adeleye OO, Williams AO, Dada AO, Ugwu ET, Ogbera AO, Sodipo OO. Sequelae of hospitalization for diabetic foot ulcers at LASUTH Ikeja Lagos: A prospective observational study. Front Clin Diabetes Healthc 2022;3:889264.
18. Wu L, Zhang C. Diagnosis of blood vessel stenosis caused by arterial thrombosis of lower extremities by ultrasound based on the mobile information system. J Healthc Eng 2022;2022:9826416.
19. Wu Y, Shen Y, Sun H. Intelligent algorithm-based analysis on ultrasound image characteristics of patients with lower extremity arteriosclerosis occlusion and its correlation with diabetic mellitus foot. J Healthc Eng 2021;2021:7758206.
20. Pieruzzi L, Napoli V, Goretti C, Adami D, Iacopi E, Cicorelli A, *et al*. Ultrasound in the modern management of the diabetic foot syndrome: A multipurpose versatile toolkit. Int J Low Extrem Wounds 2020;19:315-33.
21. Ismail A, Saleh M, Tabari A, Isyaku K. Clinical and Doppler ultrasound evaluation of peripheral arterial diseases in Kano, North-western Nigeria. Niger Postgrad Med J 2015; 22:217.
22. Das G, Gupta AK, Aggarwal A. Assessment of lower limb arteries by Doppler sonography in diabetic patients. Int J Res Heal Sci 2015;3:18-23.
23. Okasha A, Mahmoud HN, Askary ZM, Abdel-naser AA. Role of ultrasound and color Doppler in evaluation of peripheral arterial occlusive disease in diabetic foot. SVU-Int J Med Sci [Internet] 2021;1:1-11.
24. Hameed SFU, Mohammed SH, Karuppasamy P. Evaluation of peripheral lower limb insufficiency among patients with diabetes mellitus using Doppler ultrasound—An prospective study. Int J Contemp Med Surg Radiol 2020;5:3-7.
25. Kodjo K, Diallo MM, Diallo AM, Dago KP, Hue A, Yao A, *et al*. Doppler ultrasound abnormalities of the lower limbs in patients with diabetic foot at the Yopougon University Hospital in Ivory Coast. Open J Endocr Metab Dis 2022;12:113-21.
26. Bourron O, Aubert CE, Liabeuf S, Cluzel P, Lajat-Kiss F, Dadon M, *et al*. Below-knee arterial calcification in type 2 diabetes: Association with receptor activator of nuclear factor κB ligand, osteoprotegerin, and neuropathy. J Clin Endocrinol Metab 2014;99:4250-8.
27. Swain J, Tiwari S, Pratyush D, Dwivedi A, Gupta B, Shukla R, *et al*. Vascular calcification in diabetic foot and its association with calcium homeostasis. Indian J Endocrinol Metab 2012;16:450.
28. Zettervall SL, Marshall AP, Fleser P, Guzman RJ. Association of arterial calcification with chronic limb ischemia in patients with peripheral artery disease. J Vasc Surg 2018;67:507-13.
29. Thiruvoipati T, Kielhorn CE, Armstrong EJ. Peripheral artery disease in patients with diabetes: Epidemiology, mechanisms, and outcomes. World J Diabetes 2015;6:961-9.