International Journal of Research in Orthopaedics
Oladiran AB et al. Int J Res Orthop. 2025 May;11(3):471-476
http://www.ijoro.org

Original Research Article

DOI: https://dx.doi.org/10.18203/issn.2455-4510.IntJResOrthop20251121

Assessing the efficacy of doppler ultrasound in determining the level of amputation amongst diabetic foot patients: a 2-year retrospective study

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Received: 01 February 2025
Revised: 20 March 2025
Accepted: 01 April 2025

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ABSTRACT

Background: Diabetic foot complications leading to amputation represent a significant healthcare burden, particularly in elderly populations. Understanding the patterns, procedures, and outcomes of these amputations is crucial for improving patient care.
Methods: A retrospective observational study of 33 patients who underwent diabetic foot amputation was conducted. Data collected included demographic characteristics, clinical parameters, surgical procedures, and outcomes. Doppler ultrasound was requested for all the patients to confirm the level of amputation that had been determined clinically.
Results: The mean age was 68.8±8.9 years, with a slight male predominance (51.5%). Most patients (78.8%) belonged to the low socioeconomic class, and 63.6% had only primary education. Below knee amputation was the most common procedure (81.9%), and 66.7% of patients presented with grade 4 diabetic foot. Doppler ultrasound was requested for all patients, but only 18.2% underwent the investigation. Comorbidities were present in 69.7% of cases, with hypertension being the most prevalent (45.5%). The mean HbA1c was 9.742±4.9267. A significant improvement in PCV was observed post-operatively (31.6±4.9% versus 26.3±6.7%, p=0.001).
Conclusions: The correlation between Doppler USS and intra-op findings is statistically significant. Doppler USS remains important investigation in determining level of amputation following clinical assessment of diabetic foot patients.

Keywords: Amputation, Comorbidities, Diabetic foot, Elderly, Packed cell volume, Surgical outcomes

INTRODUCTION

Diabetes mellitus (DM) is a common health condition worldwide, with the prevalence among all age groups rising from 2.8% in 2000 to an estimated 4.4% by the year 2030. The total number of people with diabetes has been projected to rise from 171 million in 2000 to 366 million in 2030, a projected rise of more than double the previous value in 30 years.[1] The rate of rise of diabetes mellitus (DM) has however been exponential, and it has been reported by the World Health Organization that the estimated number of patients with diabetes was nearly 425 million in 2017, thereby, increasing the number complications that come with the condition.[2]

Diabetes significantly impacts the older populations so the highest estimated prevalence is seen in people older than 65. The estimated number of people with diabetes aged 65-99 years is 135.6 million (19.3%) in 2019. If this rate of rise continues, it is estimated that the number of people above 65 years (65-99 years) with diabetes will be 195.2 million in 2030 and 276.2 million in 2045.[2] Complications such as neuropathy, retinopathy, nephropathy and atherosclerosis contribute to the morbidity and mortality of this multisystemic disease. Peripheral vascular disease in lower extremities range from being asymptomatic to critical limb ischemia in the presence of DM.[1]

Among complications, diabetic foot ulcer (DFU) is particularly prevalent, which is a kind of pathology related to neuropathy and/or peripheral arterial disorder of the lower extremities and with infection, ulceration, and destruction of deep tissues in diabetic patients, as a result of the interaction of factors caused by prolonged and uncontrolled elevated blood glucose.[2] It is estimated that 15-25% of diabetic patients will be affected by a foot ulcer at some points in their lives. Patients with a diabetic foot ulcer face a mortality risk over five years that is 2.5 times higher compared to patients without diabetic foot ulcers. Therefore, prevention of foot ulcers is of utmost importance and has long been recognized as a priority by the International Working Group on the diabetic foot (IWGDF). Apart from death, lower extremity amputation (LEA) is perhaps the most feared potential result of a diabetic foot ulcer. Indeed, diabetes mellitus and peripheral arterial disease are the predominant causes of major lower limb amputation. In studies carried out recently, it was reported that PAD and DM accounted for 61.0-92.5% of major lower limb amputations (MLLAs) while in some others, DM was the cause of major lower limb amputation in 40-50% of the patients.[3]

The annual incidence of amputation varies among countries with an incidence of 0.3% in the US, Japan, and Ireland, 0.6% in the Netherlands and in Mexican and non-Mexican Americans. The incidence rate of amputation is significantly increased when the ulcer of diabetic patients occurs. The annual incidence and 7-year average incidence of amputation for DFU patients was 9.9% respectively in China. Interestingly, one tertiary healthcare facility in Nigeria reported an alarming amputation rate of up to 52% among hospitalized patients with diabetic foot ulcers.[4]

Amputation is the surgical removal of all or part of a limb or extremity. It is dismembering of a limb cutting through bone. Similarly, disarticulation is a type of amputation through a joint without cutting through bone.[5]

Amputation of the leg is among the oldest surgical procedures known to man and has been used since prehistoric times.[5] However, in the early 196Os, calls for the evaluation of the outcomes of leg amputations were being voiced. Concerns were raised for high rate of mortality associated with above knee amputations, rehabilitation difficulties and challenges of above knee amputees and complications that arise when below-knee amputations failed to heal resulting in either a revision of the surgery or re-amputation.[6]

Initially, the procedure was fraught with complications and less than desirable outcome of the patients from hemorrhage and infection. Due to lack of adequate pain control and narcotics, the operation had to take only a few minutes. Over time, the surgeons improved the operative technique with evolution of the appropriate instruments, pain control, infection control, and wound coverage. Obtaining experience, the procedure was refined and morbidity reduced significantly.[5]

Amputation surgery is 75% more prevalent in men with 80-85% of these amputations involving the lower extremities. The most common cause of non-traumatic lower extremity amputation is diabetes and peripheral arterial disease. Peripheral vascular disease occurs due to many pathologies affecting the vascular structure, such as diabetes.[7]

There are estimated to be over 100,000 major lower limb amputations undertaken every year in the US alone.[8] Similar figures were found out in a study carried out by Yao et al which showed that about 115,000 lower extremity amputations were performed each year in the United States.[9]

For the patient, a failed lower limb amputation is a catastrophic event that could lead to prolonged hospitalization, disabling illness or even death. For the surgeon, needing to revise an amputation is seen as a partial failure in diagnosis and treatment. The central question of any debate or discussion on selection of a site for healing of a lower limb amputation must address the question: "will an amputation below the knee give primary and satisfactory healing?".[10] There is however an agreement that rehabilitation after amputation of the lower extremity is greatly enhanced by the preservation of the knee joint.[9] Below knee amputees typically experience better energy efficiency, trunk stability and overall lifestyle improvements in terms of independence and daily activities.

Despite this, it is hugely important that the appropriate amputation level is determined. Amputation surgery is an important treatment modality to remove necrotic tissue from the body, reduce metabolic burden, and enable the patient for mobilization. The goal of this surgical procedure is to obtain a limb stump that is painless, functional, and as long as possible. At this stage, it is important to determine the most appropriate amputation level. Failure to determine the appropriate primary amputation level is one of the main reasons for reamputation, and reamputation rates of 15-40% have been reported.[7] Reamputation is an undesired outcome but crucial to perform when necessary following MLLA. There are studies in the literature reporting that 18.8-49.1% of patients undergoing MLLA require reamputation. In these studies, it was revealed that incorrect determination of the amputation level is a risk factor for reamputation.[3] The rate of need for reamputation reported in patients with DM can range up to 60% also, the financial burden on the patient for prolonged hospitalization as a result of improper choice of amputation level can be massive. It is therefore important that a technique that will predict the optimal amputation level in the lower extremity be consistently utilized.[9]

Clinical criteria, such as pulse status, limb color and temperature, trophic changes, infection, necrosis, and wound bleeding, have been inconsistent guides to the outcome of amputation. Although clinical assessment and

operative expertise remain the standards for success of amputation, there is a need for more objective measures of selecting the most appropriate distal level of amputation compatible with wound healing. In one study, it was stated that physical examination alone is unreliable in determining the level of amputation, and the use of Doppler ultrasonography (D-USG) significantly reduces the reamputation rates in amputations performed above the knee level.[3]

In a study carried out by Bignol et al, it was found that compared to doppler ultrasound, findings obtained from physical examinations of the femoral and popliteal pulsations were inconsistent and unreliable at rates of 25% and 64% respectively and imaging methods must definitely be used. In the current study, D-USG and CTA were used to determine the level of amputation, and according to these two imaging methods, the most distal point with healthy circulation in the extremity was considered as the amputation level. It was found that the use of D-USG in determining the level of amputation statistically reduced the need for reamputation and D-USG was a reliable method for determining the level of amputation.[3]

In a study carried out by Xavier et al among 244 patients to assess whether ultrasound arterial mapping could be used alone to determine options to treat critical lower-limb ischemia in diabetic patients, it was found that duplex can be used safely for decision making in CLI, both in diabetic and nondiabetic patients and it was revealed that the therapeutic decision reached after ultrasound arterial mapping matched the final therapeutic decision reached 92.2% of the time.[11]

A study carried out by Adiyeke et al among 166 subjects showed that despite the limitation of doppler ultrasound in that the method is unable to assess all arterial structures (deep-seated arterial structures in obese patients) and the need for a very careful and long-term examination to detect the presence of complete occlusion and severe stenosis, it remains a reliable tool in determining the appropriate amputation level.[7]

The results of C-DUS and CT angiography were also evaluated separately, and it was found that there was no difference between the two methods in determining the level of amputation, nor was there a difference in reamputation rates depending on the level determined. Martinelli et al. compared CT angiography and C-DUS for distal flow assessment in patients with critical lower extremity ischemia and found that RDUSG assessments performed by well-trained operators could be an alternative to CT angiography.[7]

This study assessed Doppler ultrasound's effectiveness in determining appropriate amputation levels for diabetic foot patients. The two-year retrospective analysis at University College Hospital, Ibadan examined the correlation between Doppler findings and actual vascular status during surgery. Researchers analyzed patient demographics, clinical features, and surgical outcomes, focusing particularly on healing and reamputation rates. By comparing clinically determined amputation levels with Doppler recommendations, the study aimed to develop evidence-based guidelines for preoperative assessment that could improve outcomes and rehabilitation for diabetic patients needing lower limb amputation.

METHODS

This retrospective observational study examined patients aged 45-60 years and above who underwent diabetic foot amputation at University College Hospital, Ibadan within 2years (January-2022 to December-2024). The study included 33 participants and analyzed their demographic, clinical, and surgical outcomes.

Inclusion criteria encompassed patients with diabetic foot complications requiring amputation. The study categorized diabetic foot severity using a 5-point grading system, with most patients presenting as grade 4 or 5.

Patients were excluded from the study if their amputation was due to non-diabetic causes such as trauma, congenital abnormalities, or malignancy. The study also excluded patients with incomplete medical records where essential data points such as demographic information, clinical parameters, or surgical details were missing. Additionally, patients who underwent amputation procedures at facilities other than University College Hospital, Ibadan during the study period (January 2022 to December 2024) were not included in the analysis.

Ethical approval was not sought for this study as it was designed as a retrospective review of routine clinical care data. The research utilized existing medical records without requiring additional patient contact or intervention. Patient identifiers were removed during data extraction, and the analysis was conducted using anonymized data to ensure patient confidentiality and privacy. As a quality improvement initiative examining standard clinical practices and outcomes, this study fell under the category of institutional audit rather than primary research requiring formal ethical review. The hospital administration granted permission to access the medical records for the purpose of this retrospective analysis, with the understanding that findings would be used to improve clinical protocols for diabetic foot management.

The comprehensive demographic data included age, sex, educational level, and socioeconomic status. Clinical parameters included HbA1c levels, presence of comorbidities, previous amputation history, and initial care patterns. Surgical data encompassed amputation level, anesthesia type, ASA classification, use of tourniquets, and blood transfusion requirements.

Pre-operative assessment included Doppler ultrasound requests for all patients to evaluate vascular status. Packed cell volume (PCV) was measured both at admission and post-operatively.

All procedures were performed under spinal anesthesia. surgical approaches included below knee amputation (BKA) and above knee amputation (AKA) on both right and left lower extremities.

Statistical analysis included descriptive statistics for demographic and clinical characteristics. Paired t-tests were used to compare pre- and post-operative PCV values. Results were considered statistically significant at $p<0.05$.

However, several limitations should be noted. The study was constrained by its relatively small sample size of only 33 patients and was conducted at a single center, potentially limiting the generalizability of the findings. Despite universal requests for Doppler ultrasound, its utilization was limited.

RESULTS

The study included 33 participants with a mean age of 68.8±8.9 years, ranging from 60 to 90 years old. Most participants (57.6%) were between 60-69 years old. There was an even gender distribution, with slightly more males (51.5%) than females (48.5%). Most participants had only primary education (63.6%), and the majority fell into the low level of socioeconomic class (78.8%). As shown in Table 1.

Table 1: Demographic characteristics of the participants (n=33).

Variables	Classification	Frequency	Percent
Age (years)	60-69	19	57.6
	70-79	8	24.2
	79-80	5	15.2
	90-99	1	3.0
Mean±SD [range]	68.8±8.9 [60.0-90]		
Sex	Male	17	51.5
	Female	16	48.5
Level of education	No formal education	6	18.2
	Primary	21	63.6
	Secondary	3	9.1
	Tertiary	3	9.1
Socioeconomic class	Low	26	78.8
	MIDDLE	7	21.2

Regarding surgical procedures, below knee amputation (BKA) was the most common surgery type, with the right BKA accounting for 27.3% and left BKA for 15.2% of cases. Above knee amputation (AKA) was less common. Most patients (66.7%) were classified as grade 4 diabetics, with all procedures performed under spinal anesthesia. Most patients were classified as ASA III (39.4%), though notably, 27.3% of cases had no documented ASA classification.

Table 2: Level of amputation.

Level of amputation (clinically)	Level of amputation (clinically + Doppler USS)
L AKA=1	L AKA=2
L BKA*=10	L AKA*= 1
	L BKA=10
R AKA=3	R AKA=3
R BKA=16	R BKA=16

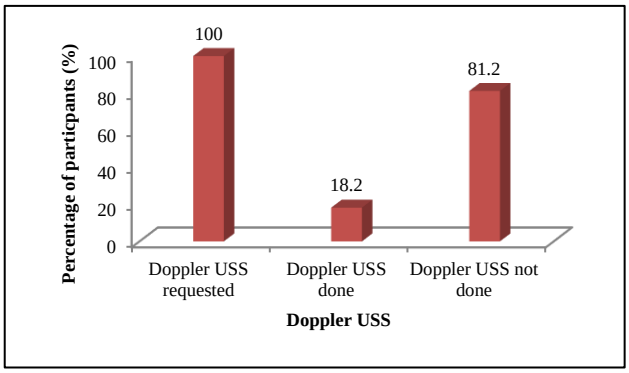

Figure 1: Status of Doppler USS.

While Doppler ultrasound was requested for all patients (100%), it was only performed in 18.2% of cases. Many patients (90.9%) had initially received home-based care before seeking hospital treatment, and 75.8% had no initial treatment rejection (Figure 1).

Regarding previous amputations, most patients (93.9%) had no prior procedures. Comorbidities were present in 69.7% of cases, with hypertension being the most common (45.5%). Various combinations of hypertension with other conditions were also noted, including chronic hepatitis B, glaucoma, and stroke.

Tourniquet use was minimal (6.1%), and only two patients (6.1%) required revisit surgery- one for stump revision to AKA and another for debridement and stump refashioning.

Table 2 shows how surgeons decided on amputation levels using two assessment methods: clinical examination and Doppler ultrasound (USS). Out of 33 total cases, 27 (81.8%) were assessed clinically while only 6 (18.2%) had Doppler USS evaluation despite requests from all the participants. Among the 6 participants that did doppler USS one was initially assessed clinically for BKA but following the doppler result review, the level of amputation was changed to AKA.

The study found significant differences in pre- and post-operative packed cell volume (PCV). The mean post-operative PCV was 31.6±4.9%, while the admitting PCV

was 26.3±6.7%, showing a statistically significant difference (p=0.001). Blood transfusion requirements varied, with 54.5% of patients receiving pre-operative transfusion, 42.4% receiving intraoperative transfusion, and 15.2% requiring post-operative transfusion.

Table 3: Clinical procedure (n=33).

Variables	Classification	Frequency	Percent
Level of amputation	L BKA	18	54.6
	L AKA	4	12.1
	R AKA	2	6.1
	R BKA	9	27.3
Grade of DM	3.00	1	3.0
	4.00	22	66.7
	5.00	10	30.3

The average HbA1c level among participants was 9.742±4.9267, with values ranging from 4.0 to 28.9.

DISCUSSION

The study's demographic profile, with a mean age of 68.8 years and slight male predominance (51.5%), aligns with previous research on diabetic foot amputations. Similar age distributions were found, that is, older adults are particularly vulnerable to diabetic foot complications requiring amputation.[12]

The high prevalence of lower educational attainment (63.6% with primary education) and low socioeconomic status (78.8%) correlates with findings suggesting these factors may influence delayed presentation and poor outcomes in diabetic foot care.[13] This is further supported by the study's finding that 90.9% of patients initially received home-based care rather than professional medical attention.

The predominance of below knee amputation (BKA) in this cohort mirrors international trends that have shown that BKA generally offers better functional outcomes and rehabilitation potential compared to above knee amputation (AKA).[14] However, the study's high proportion of Grade 4 diabetic foot cases (66.7%) indicates advanced disease at presentation, consistent with observations about delayed medical intervention in developing countries.[15]

The limited use of Doppler ultrasound (18.2% despite 100% request rate) represents a significant deviation from standard practice guidelines. The International Working Group on the diabetic foot strongly recommends vascular assessment before amputation to optimize level selection and healing potential.[16] These may be explained by most of the patients belonging to low socioeconomic class and payment for health facility is majorly out of pocket in this part of the world.

The high prevalence of comorbidities (69.7%), particularly hypertension (45.5%), aligns with findings from a study which identified cardiovascular comorbidities as significant risk factors for amputation in diabetic patients.[17] The study's mean HbA1c of 9.742% indicates poor glycemic control, exceeding the American Diabetes Association's recommended target of <7% for most adults with diabetes.[18]

The significant improvement in packed cell volume post-operatively (p=0.001) and the pattern of blood transfusion requirements suggest effective perioperative management, though comparison with international standards is limited by varying institutional protocols and resource availability.

The low revision surgery rate (6.1%) compares favorably with international data, though longer follow-up periods might be needed for definitive comparison with previous studies which reported revision rates over extended periods.

These findings underscore the complex interplay of socioeconomic factors, healthcare access, and clinical management in diabetic foot amputation outcomes, highlighting areas for potential intervention and improvement in care delivery.

CONCLUSION

Amputation for diabetic foot gangrene is commoner in the lower socioeconomic group, due to late presentation in advanced stages. The financial challenges and out of pocket mode of payment makes compliance with Doppler USS low. The correlation of the Doppler findings and eventual level of amputation in patients who do Doppler USS is very high. It is therefore recommended that routine use of Doppler USS should be further encouraged.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

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Cite this article as: Oladiran AB, Morhason-bello JO, Adebayo AM, Balogun MJ, Aremu OA. Assessing the efficacy of doppler ultrasound in determining the level of amputation amongst diabetic foot patients: a 2-year retrospective study. Int J Res Orthop 2025;11:471-6.