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**Dr. Luai Farhan Zghair**

MBCHB, DGS, FICMS, CABS,  
Senior and Assist Prof in general  
surgery at Medical College, AL-  
Iraqia University, Baghdad, Iraq

## Management of diabetic foot, an interventional study

**Dr. Luai Farhan Zghair**

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### Abstract

The diabetic foot is a group of diseases in which neuropathy, ischemia, and infection lead to tissue breakdown resulting in morbidity, possible amputation and mortality. The aim of the study to identify the risk factors for amputation in diabetic patients hospitalized for foot infection. Seventy patients with diabetic foot infection were studied. The frequency for foot amputation in diabetic foot patients was significantly affected by many factors. Smoking was significantly associated with increased frequency of amputations by 10 times. Those with coronary heart disease are predisposed to amputations 5 times those who are healthy. The less the Wagner grade of foot ulcer, the less possibility for foot amputations. 74.1% of those with ulcers of Wagner grade of 4 were exposed to foot amputation, while only 25% of those of grades 2 or 3 had their foot been amputated. Similarly, Control of blood glucose level is associated with less possibility for diabetic foot amputation. Foot was amputated in 70.5% of those with blood glucose level of  $\geq 7.77$  mmol/l, while only 11.1% of those with blood glucose level of  $< 7.77$  mmol/l exposed to foot amputation. Diabetic foot amputation is a preventable disabling complication of diabetes mellitus and diabetic foot care must aim to prevent and manage risk factors for amputation in order to improve the squeals of diabetes mellitus. Stopping smoking is the important way to decrease the likelihood for amputation. Controlling coronary heart disease is must be for diabetic foot lesions to get better. Local wound care is an important step in the process of diabetic foot care. Control of blood sugar is the cornerstone in the project of diabetic foot amputation prevention. Management of diabetic foot needs a multidisciplinary approach in order to target all predictors and risk factors for foot amputation aiming at decrease community disabilities and health costs.

**Keywords:** diabetic foot, amputation, blood sugar, smoking

### Introduction

The foot supports the body weight and provides leverage for walking and running. It is unique in that it is constructed in the form of arches, which enable it to adapt its shape to uneven surfaces. It also serves as a resilient spring to absorb shocks, such as in jumping. In anatomical terms, the foot is called pes. The superior aspect or top of the foot is the dorsum of the foot. The inferior aspect or bottom of the foot is the sole or ventral side or plantar side. The big toe or great toe is digit 1 or the hallux. The skin of the sole of the foot is hairless and thick. It is firmly bound down to the underlying deep fascia by numerous fibrous bands. The skin shows a few flexure creases at the sites of skin movement. Sweat glands are present in huge numbers. The skin on the dorsum of the foot is hairy and thin, and freely mobile on the underlying structures. The sensory nerve supply to the skin on the dorsum of the foot is derived from the superficial fibular (peroneal) nerve, assisted mainly by the deep fibular (peroneal), sural and saphenous, nerves. The greater part of the blood from the whole foot drains into the dorsal venous arch via digital veins and communicating veins from the sole, which pass through the interosseous spaces. The dorsal venous arch lies in the subcutaneous tissue over the heads of the metatarsal bones. It drains on the medial side into the great saphenous vein and on the lateral side into the small saphenous vein. The great saphenous vein leaves the dorsum of the foot by ascending into the leg in front of the medial malleolus. The small saphenous vein ascends into the leg behind the lateral malleolus. The extensor digitorum brevis is the sole intrinsic muscle on the dorsum of the foot. The muscle sends a long tendon to the big toe (effectively an extensor hallucis brevis) but does not run to the fifth digit. The tendon of extensor digitorum longus passes deep to the superior extensor retinaculum and through the inferior extensor retinaculum, in company with the fibularis tertius muscle. The tendon divides into four, which fan out over the dorsum of the foot and pass to the lateral four toes. Opposite the metatarsophalangeal joints of the second,

**Corresponding Author:**

**Dr. Luai Farhan Zghair**

MBCHB, DGS, FICMS, CABS,  
Senior and Assist Prof in general  
surgery at Medical College, AL-  
Iraqia University, Baghdad, Iraq

third, and fourth toes, each tendon is joined on its lateral side by a tendon of extensor digitorum brevis. On the dorsal surface of each toe, the extensor tendon joins the fascial expansion called the extensor (dorsal) expansion. Near the proximal interphalangeal joint, the extensor expansion splits into three parts: a central part, which is inserted into the base of the middle phalanx, and two lateral parts, which converge to insert into the base of the distal phalanx. The extensor expansion, as in the fingers, receives the tendons of insertion of the interosseous and lumbrical muscles. The dorsal artery of the foot (dorsalis pedis artery) is the continuation of the anterior tibial artery and supplies the superior aspect of the foot. It starts in front of the ankle joint at an imaginary line connecting the two malleoli. It is superficial in position and is crossed by the inferior extensor retinaculum and the first tendon of extensor digitorum brevis. On its lateral side lie the terminal part of the deep fibular (peroneal) nerve and the extensor digitorum longus tendons. On the medial side lies the tendon of extensor hallucis longus. Its pulsations can easily be felt in this location. The vessel terminates by passing into the sole, where it joins the lateral plantar artery and completes the plantar arch. The plantar aponeurosis is a thickening of the deep fascia in the sole of the foot. The muscles of the sole are described in 4 layers from superficial to deep. The 1<sup>st</sup> layer contains the abductor hallucis, flexor digitorum brevis, and abductor digiti minimi. The 2<sup>nd</sup> layer includes the quadratus plantae, lumbricals, flexor digitorum longus tendon, and flexor hallucis longus tendon. The 3<sup>rd</sup> layer consists of the flexor hallucis brevis, adductor hallucis, and flexor digiti minimi brevis. The 4<sup>th</sup> layer contains the interossei, fibularis longus tendon, and tibialis posterior tendon. The posterior tibial artery passes behind the medial malleolus and terminates by dividing into the medial and lateral plantar arteries, which supply the sole. The lateral plantar artery forms the plantar arterial arch, which supplies the digits and also anastomoses with the deep plantar artery from the dorsum of the foot. The tibial nerve passes behind the medial malleolus and terminates by dividing into the medial and lateral plantar nerves, which supply the sole. The superficial fibular nerve is the main cutaneous nerve to the dorsum of the foot. The deep fibular nerve supplies a small zone between the first two digits. The saphenous nerve supplies the skin along the medial side of the foot, whereas the sural nerve supplies the lateral margin of the foot. The greater part of the blood from the whole foot drains into the dorsal venous arch. This drains on the medial side into the great saphenous vein and on the lateral side into the small saphenous vein. The great saphenous vein leaves the dorsum of the foot by ascending into the leg in front of the medial malleolus. The small saphenous vein ascends into the leg behind the lateral malleolus. The extensor digitorum brevis is the sole intrinsic muscle on the dorsum of the foot. The dorsalis pedis artery is the continuation of the anterior tibial artery and supplies the dorsum of the foot. Its pulsations can easily be felt [1]. The diabetic foot may be defined as a group of diseases in which neuropathy, ischemia, and infection lead to tissue breakdown resulting in morbidity and possible amputation [2]. Worldwide, every thirty second a limb is lost due to diabetes. Global prevalence of diabetes in 2003 was estimated to be 194 million. According to the World Health Organization, lower Extremity Amputation (LEA) are ten times more common in people with diabetes than in persons who do not have diabetes [3, 4]. In the U.S. Medicare population, the incidence of diabetic foot ulcers is six per hundred individuals with diabetes per year and the incidence of LEA is four per thousand persons with diabetes per year. Many researchers have reported a large increase in the

incidence of death among LEA patients. The surgical procedure itself is associated with a risk of death that is based on the American Society of Anesthesiologist physical status classification system and is not dependent on risks inherent to the procedure. However, thirty days postoperative mortality can approach ten percent, with most mortality associated with those receiving an LEA as an emergency procedure or with the presence of preoperative sepsis. Previous reports have estimated that the 1- year post- LEA mortality rate in people with diabetes is between ten and fifty percent, and the five year mortality rate post- LEA is between thirty and eighty percent. More specifically, in the U.S. Medicare population mortality within a year after an incident LEA was 23.1% in 2006, 21.8% in 2007, and 20.6% in 2008. In the U.K., up to eighty percent will die within five years of an LEA. In general, those with diabetes with an LEA are two to three times more likely to die at any given time point than those with diabetes who have not had an LEA. For perspective, the five year death rate after diagnosis of malignancy in the U.S. was thirty two percent in 2010 [3]. Diabetes occurs either because of a lack of insulin or because of the presence of factors that oppose the action of insulin. The result of insufficient action of insulin is an increase in blood glucose concentration (hyperglycemia). Many other metabolic abnormalities occur, notably an increase in ketone bodies in the blood when there is a severe lack of insulin. Insulin treated patients still have a considerably reduced life expectancy. The major cause of death in treated patients is due to cardiovascular problems (seventy percent) followed by renal failure (ten percent) and infections (six percent). There is no doubt that the duration and degree of hyperglycemia play a major role in the production of complications. Diabetes Mellitus complications can be viewed in two contexts; macrovascular and microvascular complications.

- Macrovascular complications.....
- 1-Coronary Heart Disease.....
- 2-Cerebrovascular disease.....
- 3-Peripheral vascular disease.....
- Microvascular complications.....
- 1-Retinopathy 2-Nephropathy 3-Neuropathy

For practical purposes, the diabetic foot can be divided into two distinct entities: the neuropathic foot (figure 1) and the neuro-ischemic foot (figure 2).Neuropathy is nearly always found in association with ischemia, so the ischemic foot is best called the neuro- ischemic foot. In rare cases the foot may clinically be ischemic without signs of neuropathy, but in practice, the diabetic ischemic foot is treated in the same way as the neuro-ischemic foot.



**Fig 1:** The neuropathic ulcer; the ulceration mostly occurs on the pressure areas.



**Fig 2:** The neuro- ischemic ulcer; the ulceration mostly occurs on the foot edges

After classification of the diabetic foot, it is necessary to make the appropriate staging in its natural history. The natural history of the diabetic foot can be divided into six stages as shown:

1. Stage 1: Normal foot
2. Stage 2: High- risk foot
3. Stage 3: Ulcerated foot
4. Stage 4: Infected foot
5. Stage 5: Necrotic foot
6. Stage 6: Unsalvageable foot

Classification of diabetic foot ulcer: The classification system most often used was described and popularized by Wagner. It is well-known and validated for foot ulcers [2].

**Wagner classification system Grade Lesion**

- Grade 0- No open lesions, may have deformity or cellulitis.
- Grade 1- Superficial ulcer.
- Grade 2- Deep ulcer to tendon or joint capsule.
- Grade 3- Deep ulcer with abscess, osteomyelitis, or joint sepsis.
- Grade 4- Local gangrene- forefoot or heel.
- Grade 5- Gangrene of entire foot.

The aim in managing diabetic foot problems is always to keep the patient at as low a stage as possible. At each stage of the diabetic foot it is necessary to take control of the foot to prevent further progression and management will be considered under the following headings [5].

1. Mechanical control
2. Wound control
3. Microbiological control
4. Vascular control
5. Metabolic control
6. Educational control

**Patients and Methods**

Seventy patients were diagnosed with infected diabetic foot were studied.

**Results**

Seventy patients were studied, twenty four females, forty six males, the age were ranged from thirty years to eighty two years (median: fifty two years), and the mean age of 55.2 years. Most patients were male (65.7%), and smokers are (74.3%).

**Table 1:** Distribution of patients with diabetes by their socio-demographic characteristics and outcomes for diabetic foot amputation.

Characteristics	Amputation			P
	No. n (%)	No. n (%)	Yes n (%)	
Gender				
Male	46 (65.7)	16 ( 34.8 )	30 ( 65.2 )	0.640
Female	24 (34.3)	10 ( 40.6 )	14 ( 59.4 )	
Smoking				
Yes	52 (74.3)	12 ( 23.1 )	40 ( 76.9 )	<0.001
No	18 (25.7)	14 ( 77.8 )	4 ( 22.2 )	

In regard of years patient had suffered from diabetes mellitus, most them has their diabetes diagnosed before less than 15 years (67.1%) with the remaining (32.9%) has diabetes for more than 15 years.

**Table 2:** Distribution of patients with diabetes by age, and time since the diagnosis of diabetes mellitus in relation to foot amputation.

Characteristics	Amputation			P
	No. N (%)	No. N (%)	Yes. N (%)	
Age at diagnosis				
<40	12 (17.1)	4 (33.3)	8 (66.7)	0.714
40-59	39 (55.7)	15 (38.5)	24 (61.5)	
≥60	19 (27.2)	7 (36.8)	12 (63.2)	
Time since Dx (years)				
<15	47 (67.1)	21 (44.7)	26 (55.3)	0.063
≥15	23 (32.9)	5 (21.7)	18 (78.3)	

When we take a look on the diabetes mellitus complications we can see that the most common complication was peripheral vascular disease (80%). Additionally, hypertension was observed in (75.7%) of our patients. Coronary heart disease is an important complication in diabetes mellitus. In our study, 61.4% of our patients were diagnosed with coronary heart disease. Diabetes mellitus has negative effects on neurons. Neuropathy was noticed in 62.9% of our patients.

**Table 3:** Distribution of patients with diabetes by comorbidity occurrence in relation to diabetic foot amputation.

Characteristics	Amputation			P
	No. N (%)	No. N (%)	Yes N (%)	
CHD				
Yes	43 (61.4)	13 (30.2)	30(69.8)	0.005
No	27 (38.6)	13 (48.1)	14 (51.9)	
HTN				
Yes	53 (75.7)	18 (34)	35 (66)	0.338
No	17 (24.3)	8 (47.1)	9 (52.9)	
Neuropathy				
Yes	44 (62.9)	15 (34.1)	29 (65.9)	0.499
No	26 (37.1)	11 (42.3)	15 (57.7)	
PVD				
Yes	56 (80)	18 (32.1)	38 (67.9)	0.086
No	14 (20)	8 (57.1)	6 (42.9)	

We did classify our patients according to their foot ulcer stage depending on Wagner criteria and we found that most of them were belong to stage 4 disease (77.1%), while others' ulcers were of either grade 2 or 3 (22.9%). Most of patients did not undergo any previous amputations (64.3%), although the remaining (35.7%) was involved in amputations in the context of either minor or major ones. Two thirds of patients have only one limb involved in the process of diabetic foot infection

(60%), while the rest (40%) have both limbs involved. An important observation that was involved in our study is the level of blood glucose at the time of admission. The majority of

patients admitted with a random blood sugar level of  $\geq 7.77$ mmol/l (87.1%), although only 12.9% were admitted with  $<7.77$ mmol/l level of random blood sugar.

**Table 4:** Distribution of patients with diabetes by disease characteristics at admission in relation to foot amputation.

Characteristics	Amputation			P
	No N (%)	No N (%)	Yes N (%)	
Wagner criteria				
2 or 3	16 (22.9)	12 (75)	4 (25)	<0.001
4	54 (77.1)	14(25.9)	40 (74.1)	
Previous amputation				
Yes	25 (35.7)	8 (32)	17 (68)	0.514
No	45 (64.3)	18 (40)	27 (60)	
DF characteristics				
Neuropathic	5 (7.1)	2 (40)	3 (60)	0.695
Ischemic	9 (12.9)	4 (44.4)	5 (55.6)	
Neuroischemic	56 (80)	20 (35.7)	36 (64.3)	
Glucose level at admission				
$<7.77$ mmol/l (140mg/dl)	9 (12.9)	8 (88.9)	1 (11.1)	0.031
$\geq 7.77$ mmol/l (140mg/dl)	61 (87.1)	18 (29.5)	43 (70.5)	
Involvement of the other lower limb				
Yes	28 (40)	9 (32.1)	19 (67.9)	0.487
No	42 (60)	17 (40.5)	25 (59.5)	

No statistically significant differences were observed in the frequency of diabetic foot amputation with regard to gender. On the other hand, smoking was significantly associated with increased risk for foot amputation ( $p < 0.001$ ; table 1). The age of patients at the time of diagnosis did not affect their probability for getting their foot amputated. The duration of diabetes also had no any significant impact on the risk for foot amputations. Chronic co-morbidities associated with diabetes showed no proved evidence of increasing risk for diabetic foot amputation except for coronary heart disease which was associated with a statistically important association ( $p = 0.005$ ; table 3). Increasing stage of diabetic foot ulcer according to Wagner criteria was an important variable in deciding the likelihood for foot amputation with increasing risk when the ulcer upgraded from stage 3 to stage 4 ( $p < 0.001$ ; table 4). Although there were no difference in the frequency of foot amputation regarding the diabetic foot classification nor the involvement of one or both lower limbs. The random blood sugar level of patients at admission ranged from 5.92mmol/l to 16.54mmol/l (median = 10.62) with a mean of 10.33mmol/l and standard deviation of 2.37. Non-surprisingly, the level of random blood sugar was associated with significant difference in the amputation rates with higher frequencies in patients with random blood sugar of  $> 7.77$ mmo/l ( $p < 0.031$ ; table4). As we see in table 5, Smoking, and coronary heart disease are associated with higher incidence of foot amputation. On the other hand, low Wagner grade and low blood glucose level are associated with lower frequency of amputation and they can be considered as protective variables.

**Table 5:** Significant variable and their odds ratio.

Variable	Odds ratio	95% confidence interval	
		Lower	Upper
Smoking	11.667	3.228	42.166
Coronary heart disease	4.5	1.52	13.322
Wagner criteria	0.117	0.032	0.422
Blood sugar level	0.052	0.006	0.449

## Discussion

Foot complications in diabetics are on the rise and this is attributable to many reasons. Amputations and the ulcers that

precede limb loss are largely preventable. Health education and organized foot care programs are required to check this public health problem. Diabetes mellitus affects every system in the body and it can be well said "knowing diabetes, is like knowing entire medicine". Every diabetic needs to know in detail about the changes in the foot. The metabolic complications namely raised blood sugar, are now easily controlled while the foot, kidney, eye and heart are targets of long-term complications [6]. Blood sugar values just tell you the state of diabetes but every cell in the body relentlessly undergoes changes which are reflected in long-term complications. Among all the long-term complications foot involvement is the foremost complication. Diabetic patients with foot ulcers constitute the majority of hospital admissions [5]. The number of admissions to hospitals for foot related complications is increasing and the limbs amputated are more than those lost in both world wars. This is of great socioeconomic importance as majority of them are in the prime earning age group and are poor. The treatment of foot ulcers needs surgical consultations, use of antibiotics, investigations, surgical procedures. And may be Hospital admissions. These eventual foot loss are largely preventable and adequate foot care prevents foot loss. Treatment of diabetes is very important. This needs the expertise of diabetic physician, vascular surgeon, orthopedist, neurologist, and general surgeon and may be plastic surgeon. Ulceration of the foot is the most frequent cause of admission to the hospital among diabetic patients and lower extremity amputation is the most complication of foot ulceration. Our study showed that diabetic patients who are smoke are more likely to undergo amputation than the non- smokers. Smoking is very bad for everyone, and it's especially risky in patients have diabetes. The nicotine in cigarettes makes blood vessels harden and narrow, curbing blood flow around the body. So smoking and diabetes makes more likely to get heart disease, and increased risk of Peripheral arterial disease. And Peripheral arterial disease was the most common co-morbidity associated with diabetic foot ulceration (80%) followed by hypertension (75%). So vascular examination is an important step in the evaluation of diabetic foot ulcer patient and targeting peripheral arterial disease is an important step in the treatment of diabetic foot especially those of ischemic and neuro-ischemic types. Management of



hypertension also important in controlling diabetic foot ulceration progression and amputation. We used Wagner criteria to classify our patients' ulcers. The higher the grade, the more risk for amputation (57% for grade 4 vs. 5.7% for grade 2 or 3). This is an evidence that the aim of diabetic foot ulcer care is to downgrading the ulcer so that to decrease the likelihood for amputation. Wound control of diabetic foot ulcer is based upon good debridement of the ulcer, dressings, the use of advanced wound healing products, supplementary wound healing techniques, and topical treatment. The level of blood sugar is the most predictor for foot amputation in diabetic patients, and its control is a major requirement for good care of foot ulcers. Also we must use Treatment regimens that reduced average HbA1c less than 7. The preventive effect of good glycemic control on diabetic foot complications especially amputations was approved by Abolfazl Shojaiefard *et al.* by a case-control study that was published in 2008 which shows the odds ratio of 3 for those with fasting blood sugar >11mmol/l [7]. Similarly in our study, we found that high blood sugar level at admission ( $\geq 7.77$ mmol/l) is associated with increased risk for amputations.

### Conclusion

Diabetic foot amputation is a preventable disabling complication of diabetes mellitus and diabetic foot care must aim to prevent and manage risk factors for amputation in order to improve the sequels of diabetes mellitus. Stopping smoking is the important way to decrease the likelihood for amputation. Controlling coronary heart disease is must be for diabetic foot lesions to get better. Local wound care is an important step in the process of diabetic foot care. Control of blood sugar is the cornerstone in the project of diabetic foot amputation prevention. Management of diabetic foot needs a multidisciplinary approach in order to target all predictors and risk factors for foot amputation aiming at decrease community disabilities and health costs.

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