

CT Scan of the Foot in Patients with Chronic Non-Healing Diabetic Foot Ulcer

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Abstract

Background: Diabetes mellitus is a chronic disease where there is an increased blood sugar level in the body which is either caused due to inability of the pancreas to secrete insulin or the body's inability to utilize it. The prevalence of diabetes mellitus is growing rapidly worldwide. Statistics show that in the year 2014, there were a total of 422 million cases of DM. Diabetes mellitus is a major cause of heart attacks, kidney failure, blindness and leg amputations. Diabetic foot ulcers are quite common and are estimated to affect nearly 15% of all diabetic patients during their lifetime. In long standing diabetic patients with chronic non-healing ulcers, bony changes or deformities are not uncommon. These bony changes can be identified using CT scans. **Materials and Methods:** An observational study was conducted on a total of 40 patients with chronic non-healing ulcer attending the surgery outpatient department of Saveetha Medical College, Chennai, Tamilnadu. The CT-scans of their foot were observed for deformities or bony changes. **Results:** Out of 40 patients, 67.5% were males and 32.5% were females. A maximum number of subjects fell under the age group of 51 - 60 years. The most common site of the ulcer was found to be in the plantar surface of big toe (53%). Among the 40 patients, 33 of them were found to have bony abnormalities on the CT scan of foot and no apparent changes were seen in the rest. Bone erosions (35%), osteopenic changes (22.5%), Charcot's joint (2.5%), osteophyte formation (12.5) and reduced joint space (10%) were the predominant changes observed on the CT scans of the study population.

Keywords

Diabetic Foot Ulcer, Bony Abnormalities, CT Scan, Bone Erosions, Charcot's Joint, Osteophyte Formation, Reduced Joint Space, Osteopenic Changes, Plantar Surface of Big Toe

1. Introduction

The prevalence of diabetes mellitus is rapidly increasing all over the world. Diabetes mellitus is classified as Type 1 and Type 2. Type 1 is the inability of the body to synthesize insulin and Type 2 is an insulin resistant state. Few of the common comorbidities are stroke, coronary artery disease, peripheral vascular disease and neuropathy. Diabetic patients are more susceptible to foot ulcers during their lifetime. The common locations of diabetic foot ulcer are plantar surface of big toe, heel of the foot and proximal interphalangeal joint.

Diabetic foot can be divided into two broad types-the neuropathic foot (neuropathy is the dominant feature) and the neuroischemic foot (occlusive vascular disease is the dominant feature). Diabetic neuropathy can lead to fissures, oedema and Charcot's joint, whereas ischemia causes pain, ulcers, digital necrosis and gangrene [1]. Type 1 and Type 2 DM influence bone health in many ways.

In the case of Type 1 DM, as there is decreased depletion of glucose, which results in its reaction with proteins and fats and causes accumulation of noxious substances called advanced glycation products (AGEs). The resultant AGE causes death of mesenchymal stem cells which stops the differentiation of osteoblasts, cartilage and adipocytes. Increased glucose levels in blood hinders protein osteocalcin synthesis which eventually leads to poor bone formation. Persistent diabetes mellitus affects the process of osteoblast maturation and increases marrow adipogenesis which is correlated with osteoporosis and increased fracture risk. Bone structure or architecture of the bone is affected by low bone mineral density (BMD) caused due to Type 1 DM. According to recent studies, around 20% of people with Type 1 DM in the age group of 20 - 60 years are in the risk of developing osteoporosis because of decreased bone formation and increased bone resorption [1]. Oral hypoglycemic drugs have also shown to have varied effects on bone health. In a study conducted recently which comprised of 22 randomised control trials, pioglitazone which is a thiazolidinedione anti-diabetic drug showed decreased bone formation and increased incidence of bone resorption and fractures. On the other hand, metformin (insulin sensitizer) use showed reduction in fracture risk.

There is a high prevalence of musculoskeletal disorders associated with diabetes mellitus. Few common disorders seen are Charcot's osteoarthropathy, osteoarthritis, carpal tunnel syndrome and osteoporosis. The cycle of osteopenia, osteolysis, abnormal loading and bone instabilities increases fracture risk. Hypoparathyroidism may coexist with hyperglycemia. Hypoparathyroidism causes bone resorption and reduced bone mineral density which in turn leads to impairment and difficulty in the healing of fractures. Another dreadful complication of hyperglycemia is osmotic diuresis which results in natriuresis and hypercalciuria. Hypercalciuria gives rise to negative calcium balance and nephropathy [1].

Diabetes is known to cause delayed wound healing. The reasons attributed to it are decreased production of new blood vessels, weakened skin barrier, reduced

collagen production and incompetency of WBCs to fight bacteria. Vitamin D and calcium intake have been proved to be related inversely to the risk of Type 2 Diabetes [1].

Computed tomography is a sensitive tool in identifying bony changes associated with diabetic foot such as reduced joint space, osteopenic changes, osteophyte formation and Charcot's joint. CT scan helps in identifying osteomyelitis in their early stage unlike X-ray where osteomyelitis can't be picked up until the disease has advanced. Unfortunately, CT scans are quite expensive, so patients belonging to low socioeconomic status are not able to afford it [2].

2. Aim of the Study

- 1) To look at the clinical presentation of diabetic foot ulcer patients who have bony changes.
- 2) To analyze the various CT changes on the foot in patients with diabetic foot ulcer.
- 3) To look at the demographic profile of these patients.

3. Materials and Methods

3.1. Study Design

It is an observational, prospective study conducted on patients with chronic non-healing diabetic foot ulcer attending surgery outpatient department of Saveetha Medical College Hospital in Chennai. The CT scan taken of their foot was observed for bony changes associated with diabetic foot ulcer. A convenient sampling methodology was adopted.

3.2. Data Collection

The study was started during the month of March 2020 and ended in April 2020. The study was conducted for a period of one month. A total of 40 patients who came to the surgery outpatient department with history of chronic non-healing diabetic foot ulcer were included in the study. The criteria which was used to select patients was the presence of diabetic foot ulcer for a duration of 3 months or more which did not heal after off-loading, debridement and medication. Informed consent was obtained from all the subjects. The CT scan pictures of the selected subjects were requested from the department of radiology using the patient's unique hospital ID and were analyzed. The study was approved by the Institutional Review Board of Saveetha Medical College and Hospital.

3.3. Statistical Analysis

Name, age and gender were included in demographic details. The location of the foot ulcer was noted. Presence or absence of characteristic bony changes associated with diabetic foot was recorded. The prevalence of disease in a particular age group, male: female ratio, common site of foot ulcer, characteristic bony changes were assessed. The data obtained was analyzed using Microsoft excel.

4. Result

A total of 40 subjects who had a chronic non-healing diabetic foot ulcer for which they attended the outpatient department of Saveetha Medical college were included in the study.

Out of the 40 subjects, 25 (67.5%) subjects were males and 15 (32.5%) were females. We had a maximum clustering of patients in the 6th decade of life and 60% of this subgroup were males [Figure 1]. We had a maximum clustering of patients in the 6th decade of life and 60% of this subgroup were males which has been outlined in Table 1.

Location of ulcer

The common locations of diabetic foot ulcer observed in the subjects were plantar surface of big toe (53%), heel of the foot (31.4%) and proximal interphalangeal joint (15.6%). Among areas mentioned above, the ball of big toe was the commonest site of ulceration [Figure 2].

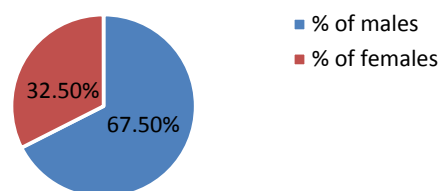


Figure 1. Percentage of males and females amongst the study population.

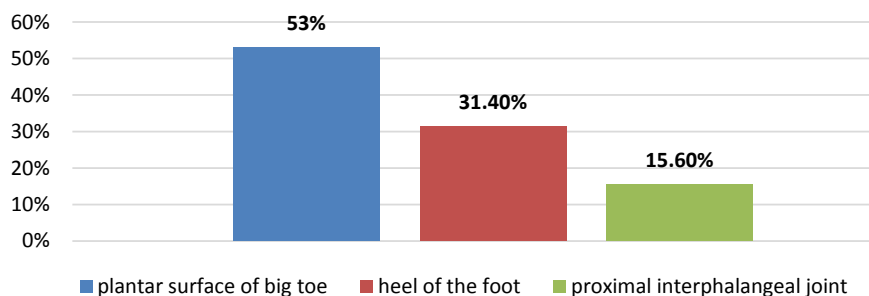


Figure 2. Location of foot ulcer.

Table 1. Age distribution of the study population.

Age (in years)	Number of cases		Total cases
	Males	Females	
0 - 10	0	0	0
11 - 20	0	0	0
21 - 30	0	0	0
31 - 40	2	0	2
41 - 50	5	4	9
51 - 60	12	8	20
61 - 70	8	1	9

Changes on CT Scan

Out of 40 patients with diabetic foot ulcer, 33 subjects were found to have bony abnormalities and the rest of them showed normal bone structure and density [Figure 3] which has been outlined in Table 2. The changes observed were reduced joint space (10%), bone erosions (35%), osteopenic changes (22.5%), Charcot's joint (2.5%), osteophyte formation (12.5%).

5. Discussion

On including long-standing diabetic patients in the study, we found that increased glucose content in the body causes diabetic foot ulcer followed by bone abnormalities or deformities.

When we analyzed the demographic details of the subjects included in the study, we found that the number of males were higher than that of females.

The most common location of the ulcer was in the plantar surface of big toe (53%) followed by heel of foot.

While analyzing the CT scan findings of their foot, we identified bony changes in 33 subjects (82.5%) and no change in 7 subjects (17.5%).

The bony changes observed in subjects with chronic non-healing ulcer were found to be high in the age group of 51 - 60 years.

The common CT changes observed were reduced joint space [Figure 4(a)]

Table 2. Changes observed on CT scan of foot.

Variable	Yes (n)	Yes (%)	No (n)	No (%)
Bone erosions	14	35	26	65
Osteopenic changes	9	22.5	31	77.5
Charcot's joint	1	2.5	39	97.5
Osteophyte formation	5	12.5	35	87.5
Reduced joint space	4	10	36	90
No change	7	17.5	33	82.5

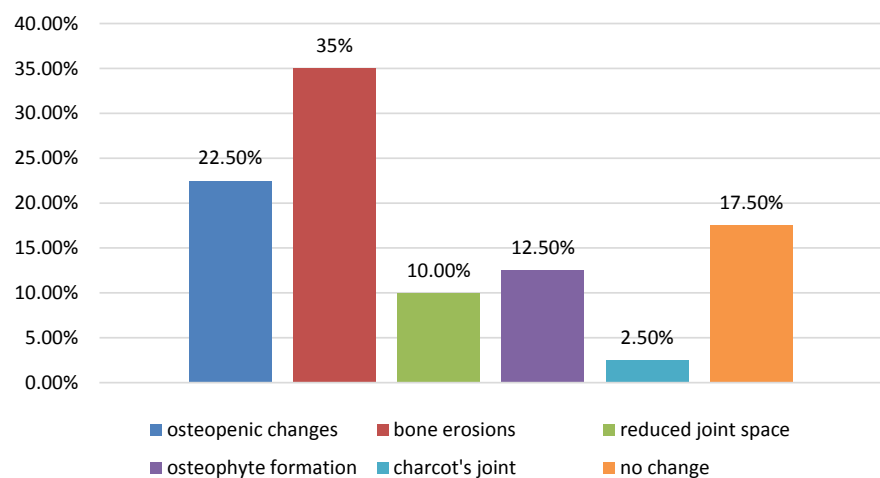


Figure 3. Percentage of various changes observed on CT scan of foot.

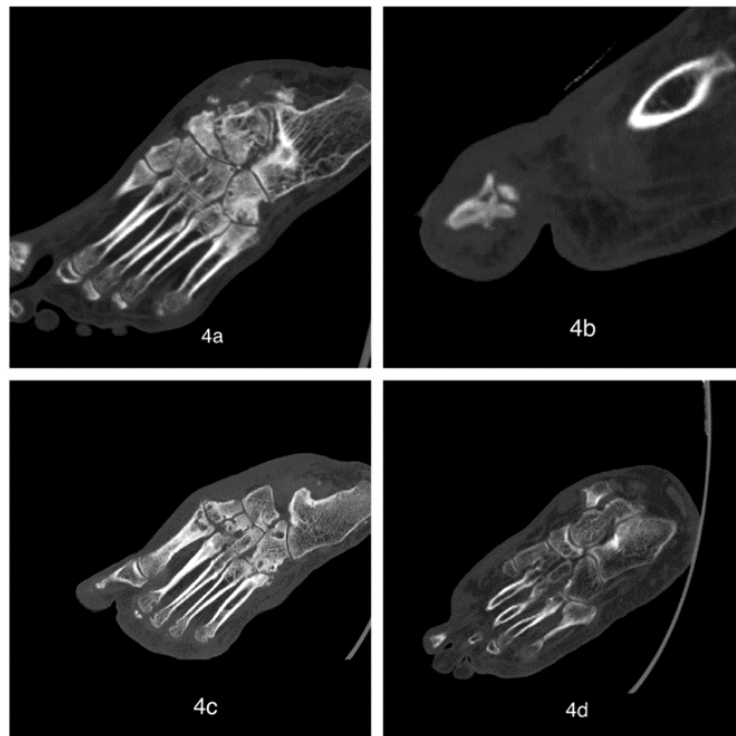


Figure 4. Shows various CT changes seen in diabetic foot referred to in the article.

(10%), osteophyte formation [Figure 4(b)] (12.5%), bone erosions [Figure 4(b)] (35%), osteopenic changes [Figure 4(d)] (22.5%) and Charcot's joint (2.5%).

The importance of this study is to understand the prevalence of bony changes seen in long standing diabetic foot ulcer patients which may cause a disability in the future. Knowledge about possible bony deformities helps in early diagnosis and treatment. Diabetic foot ulcers pose a major risk for amputation which impairs the quality of life. CT scan aids the diagnosis of bony changes in the early stage of the disease and thus can be intervened to prevent morbidity and mortality. Studies have been conducted in the past to study the efficiency of CT scans in diagnosing bone abnormalities in the acute stage of a disease. It has been proved that CT scan is more efficacious when compared to plain radiography.

There is a higher prevalence of musculoskeletal disorders associated with diabetes. Fibro proliferative disorders like adhesive capsulitis (frozen shoulder) and carpal tunnel syndrome may affect diabetics.

Disorders of the joint are not uncommon among diabetics. Charcot's joint or Charcot osteoarthropathy is a progressive, degenerative disease of the ankle joints and foot. Charcot's joint manifests as swelling, warmth, acute inflammation, erythema in the foot, when left untreated, it can cause loss of joint function, ulceration, osteomyelitis, fever and subsequent sepsis.

A peculiar "rocker bottom" appearance is seen in the middle part of the foot in this condition. Osteoarthritis is also a joint disorder which has a correlation with obesity. A person with Type 2 Diabetes mellitus and obesity are at a higher risk of developing this condition.

Risk of developing Osteoporosis increases with duration of diabetes mellitus. The factors contributing to the development of osteoporosis are decreased bone mineral density and increased frequency of falls or traumas.

Advanced Glycation Products (AGE) accumulated due to diminished utilization of glucose in blood and their reaction with proteins and fats in turn make the bones vulnerable to fracture [1].

Osmotic diuresis and hypoparathyroidism are a consequence of hyperglycemia which in turn leads to negative calcium balance and nephropathy.

Nephropathy causes abnormal Vitamin-D metabolism leading to decreased bone mineral density (BMD) and difficulty in the healing of fracture [1].

Wound healing is delayed in diabetic patients. Insulin is needed for cells to uptake glucose for energy. Increased blood glucose impairs WBC function which makes them incompetent to fight bacteria and thus results in delayed wound closure. Decreased collagen production, weakened skin barrier and decreased production and repair of new blood vessels are a few other factors which cause delayed wound healing [1].

Diabetic foot ulcers are predominantly found in the plantar aspect of toes, toe tips and heel of foot. The underlying causes of ulcer namely neuroischemia and neuropathy also affect their location [3].

Various studies have been conducted to understand the effect of Vitamin D and calcium intake on diabetes. According to a recent study conducted to examine the association between vitamin D and calcium intake and risk of diabetes, it was proved that women who consumed > 1200 mg/day of calcium and >800 IU of total vitamin D per day had 21% and 23% lower risk of developing type 2 diabetes mellitus in the future respectively.

X-rays are being used as the first line of investigation in various countries. X-ray findings become evident only during the later stages of the disease, which makes it less effective than CT scans [4]. In the later stages of osteomyelitis, signs like soft tissue swelling, periosteal reaction, periosteal new bone formation, osteolytic lesions and cortical bone destruction are seen. These X-ray findings are confirmative of acute osteomyelitis. Plain radiographs are also helpful in identifying soft tissue and bone changes caused due to neuroarthropathy and they serve as route map for other imaging modalities by ruling out postsurgical changes and foot deformities [4].

CT scan is a better tool when compared to X-ray in detecting any deformity or disease of the bone which follows diabetic foot ulcer. X-ray is useful only during the later stages of the disease where about 40% - 70% of bone resorption had already been taken place [2]. The bony changes seen in osteomyelitis become evident on an X-ray only after about 10 - 15 days of infection. In order to intervene and treat the deformity, early diagnosis of the disease is crucial.

Computed Tomography facilitates early diagnosis of changes like reduced joint space, Charcot's joint and osteomyelitis [2]. CT can be used as the first line investigation in developed countries to rule out bone pathologies instead of X-rays which are useful only in the later stages of the disease.

Unfortunately, CT scans are expensive and in resource poor countries like India, they cannot be used as the first line investigation. Early diagnosis plays a major role in treating the limb for the underlying pathology and hence amputation of the limb can be prevented. Lack of awareness about the comorbidities associated with uncontrolled diabetes mellitus leads to amputation of the limbs in the later stages hence reduced quality of life. People diagnosed with diabetes must be informed and educated about the risks associated with it and how improper treatment could become a threat to their life.

6. Limitations of the Study

- 1) The sample size of this observational study is small.
- 2) Factors that influence the bone health of diabetic patients like serum calcium level, phosphorous level and the glycemic control were not considered in the study.
- 3) The co-relation between extent of bone changes with vitamin D levels was not taken into account.

7. Conclusion

From the study, we conclude by saying that the percentage of males was higher (62.5%). Maximum number of subjects fell under the age group of 51 - 60 years. The most common site of ulcer was in the plantar aspect of the big toe (53%). Bony erosion [Figure 4(b)] which was seen in 53% of subjects was the commonest change observed on the CT scan of foot in patients with diabetic foot ulcer followed by osteopenic changes [Figure 4(c) and Figure 4(d)] with 22.5%.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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