Diabetic Foot Ulcers

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Introduction and Epidemiology of DFU

Diabetic foot ulcers(DFU) are the major complications of uncontrolled diabetes Mellitus. Each year the numbers of diabetic patients are rising. The current estimation of people with diabetes is more than 582 million worldwide, and 19% to 35% of them develop DFUs in their lifetime (McDermott, et al). Approximately, 1.6 million people suffer from DFU in the US. From 50% to 60% of ulcers will become infected, Around 20% of patients with DFUs will undergo amputation, losing from toes to above the knee, disabling patients or 10% of them die within a year. Ulceration-type complications of diabetic patients are the most difficult to treat and manage. These ulcers lower the quality of life of patients, limit daily physical activities, and increase healthcare utilization. Infected ulcers can progress into gangrene and eventually limb loss. The mortality rates of 70% of DFU patients had an above-the-knee amputation, while 30% of them died within 5 years. The direct cost and treatment is enormously high in the United States, it varies from 9 billion to 13 billion dollars (Armstrong et al., 2023).

In this paper, I will review diabetic foot ulcers and their complications such as infection, gangrene, and amputation. Also, I am interested to learn more about DFU's prevention, screening, diagnosis, treatment, and long term management applications. Additionally, I will explore the impact of medical nutrition therapy (MNT) on wound care. As a dietetic intern in hospital settings, I have observed that diabetic foot ulcers are a very common medical problem.

Pathogenesis and Risk Factors of DFU

High-risk diabetic foot can be identified with regular checks and screening, and future complications can be prevented. Peripheral artery disease, neuropathy, foot deformities, previous

amputation, repetitive mechanical pressure, poorly fitted and poor quality footwear, poor hygiene of feet, improper trimming of toenails, poor lifestyle such as smoking, alcohol consumption, sedentary lifestyle and obesity, cardiovascular disease(CVD), kidney disease, and infections are the main risk factors for developing foot ulcers.

Disparities of DFU differ among age groups, longevity of having DM, sex/gender, race/ethnicity, and social determinants (Armstrong et al). The risk of DFU increases with age, it is due to the duration of DM the person has been diagnosed. Young and middle-aged people have more advanced foot ulceration due to poor lifestyle, high A1C, higher PN, and smoking. DFU is 1.5 times higher in males than in females. Also, minor and major amputations are higher in men which is explained by underlying risk factors, access to care, screening, and treatment adherence. Black, Hispanic, and other non-white adults experience higher rates and are directly associated with structural racism and determinants of health such as access to healthcare, food insecurity, education level, and socioeconomic status (McDermott et al., 2023).

Peripheral Neuropathy

Diabetic neuropathy and peripheral vascular disease are the most common etiologic risk factors for ulceration. They may act together or just alone and with a combination of other risk factors such as mechanical pressure, microvascular disease, Charcot foot, and increased susceptibility to infections. Neuropathy is the most dangerous form of complications of diabetes mellitus Type 1 and type 2. It is a type of nerve damage that occurs gradually and it is caused by long-term hyperglycemia.

Peripheral neuropathy usually affects the upper and lower extremities. Symptoms may include tingling, numbness, pain, and burning sensation in legs and arms (Shaw et al., 1996). Onset of these symptoms may even occur before diagnosis of diabetes mellitus. This could be

explained by elevated blood sugar and nerve damage. Lack of sensation may progress into the formation of DFU. Insensitivity with a combination of mechanical pressure or sometimes in a single event such as stepping on a nail. In most patients, the trauma may be caused by wearing improper shoes (Shaw et al., 1996).

Therefore, screening the patient's feet and prescribing orthopedic comfortable shoes are the best preventative measures to avoid ulceration incidents. For diabetic patients with neuropathy, it is important to self-check their feet and legs daily. A podiatry specialist visit is a must to clip nails in the proper way to prevent any kind of infection. Using moisturizing lotions for dry skin is recommended. The most important monitoring of neuropathy is to control blood sugar, checking HbA1C every 90 days, referring diabetic patients to registered dieticians, and educating them to control blood sugar are the best preventative modalities of ulcerations (ADA).

Peripheral Vascular Disease

Peripheral vascular disease (PVD) is also another form of risk factor for diabetic foot ulceration. PVD is a blood circulation disease, so-called atherosclerosis, in which plaque builds up in the inner walls of the vessels. Plaque accumulation on the walls of the vessels prevents normal blood circulation, which leads to lower oxygen and nutrient supply to various tissues and cells. The most severe form of PAD is critical limb ischemia, defined by characteristics such as limb pain and eventually limb loss. There are numerous changeable and non-changeable risk factors for atherosclerosis. Non-changeable factors such as a person's age, history of heart disease, and family history. And, changeable factors include coronary heart disease, diabetes, high cholesterol, hypertension, sedentary lifestyle, smoking, and obesity. Studies suggest that half of the diagnosed patients do not have any symptoms. Some patients may experience leg cramps, fatigue, and weakness. Ischemia in the limb manifests by pain in rest, non-healing

wounds, and ulcerations, in many cases, it progresses into gangrene and amputation (Gul & Ganzer et al., 2023).

The treatment and management of the PVD depend on the patient's age, risk factors, severity of the disease, and functional status. Cardiovascular risk modifications are essential to lower the PVD progression. Smoking cessation significantly lowers the risk of developing cardiovascular events, along with myocardial infarction and stroke. Besides, pharmacotherapy physical activity has shown improvement in symptoms. As a part of the treatment plan monitoring a person's blood pressure, diet modification and lipid profile, weight loss, blood glucose and HbA1C less than 7%, and regular follow-up to the interdisciplinary team is a key to preventing foot ulceration, infection, gangrene formation, or amputation of lower extremities (ACC).

Medical Nutrition Therapy Applications for Patients with Diabetic Foot Ulcers

An interdisciplinary approach to treatment and wound management is needed for patients, especially those who are at high risk. Medical teams such as physicians, podiatrists, nurses, dieticians, and psychologists are the best to help patients heal diabetic foot ulcers (Alavi et al., 2014).

It is important to recognize early and preventing ulceration of diabetic foot is a key. If wounds are detected, then immediate treatment is required. Wounds are generally treated with pharmacology and surgical methods depending on the stage of the wound. Along with treatment, doctors prescribe certain items such as properly designed diabetic shoes, casts, foot braces, compression wraps, and shoe inserts.

In wound treatment, medical nutrition therapy(MNT) is one of the vital intervention strategies. Glycemic control is crucial for preventing the wounds and delaying the formation of the ulcers. Sugar control is also one of the major techniques to manage diabetes and its all other complications. Additionally, it is important to treat and monitor other risk factors such as hypertension, lipid profile, weight management for ulceration, and macrovascular complications. There are several different diets available to minimize all the risk factors. In this situation, registered dietitians help choose the diet and make it more suitable for individuals depending on their age, and gender, and considering other coexisting comorbidities of diabetic patients. Additionally, the nutritional assessment includes an evaluation of anthropometric data, nutrition-focused physical examination(NFPE), gathering biomedical and laboratory data, and considering a patient's overall diet history and fluid intake. Further, educating the patients on lifestyle change, teaching them how to control glycemic index, reassessing them, and ensuring dietary compliance are helpful to fit the normal blood glucose of patients.

Chronic and non-healing wounds are associated with certain nutrient deficiencies. The presence of wounds contributes to changing a patient's nutritional caloric and protein needs, along with certain vitamins and microelements. Protein-energy malnutrition (PEM) is one of the leading factors for non-healing wounds. PEM can develop slowly in patients with diabetic foot ulcers. This is due to inadequate energy, calories, and protein intake and other risk factors such as substance abuse, depression, inability to prepare food, dysphagia, low socioeconomic status, and food insecurity. With aging protein loss is a natural phenomenon, however, in patients with wounds it will lead to significant protein loss. However, the body has an amazing mechanism to preserve protein loss, by using free fatty acids to use a substrate for energy sources, allowing the protein to be used for tissue repair.

Lean body mass consists of 75% of the total body weight, and 50-60% is muscle mass by weight, the rest of its bones and tendons. About 15% loss of protein has a profound effect on the body's normal function. The wound injury will increase metabolic rate and nutrient demands, especially in proteins. Repeated remodeling and proliferation of the cell phases deplete the protein energy, thereby decreasing fibroblast activities, and delaying angiogenesis, which contributes to less collagen formation. The protein-energy loss decreases immune function thus making diabetic feet susceptible more to infection (Bowker & Pfeifer., 2008).

Proteins are also the main component of the cell structure of the muscle, viscera, red blood cells, and connective tissue. Most enzymes that maintain whole bodies' biochemical processes and immune functions are also made from proteins. In malnourished patients with significant protein loss, glucose as an energy comes from amino acids which occur via gluconeogenesis. That's because when levels of glucose in the blood are decreased, glucagon increases, which will try to regulate blood sugar by converting other noncarbohydrate macronutrients into glucose. Also, stress hormones such as cortisol and catecholamine will try to elevate blood sugar by breaking down amino acids and converting them into glucose. Amino acids will be obtained from muscle tissues of the body. Amino acids enter the TCA or citric cycle, then will be converted into acetyl-CoA, then into pyruvate, and finally pyruvate into glucose molecules. Thus, catabolism of the body protein can be reflected in decreased levels of plasma albumin, and prealbumin, which are laboratory indicators of malnutrition caused by muscle loss. In diabetic patients with PEM, acute injury, or other coexisting illnesses, the presence of wound inflammation may lead to hypermetabolism or increased catabolism of lean body mass (Wallace & Schwartz, 1997). Therefore, patients with DFU need more calorie and protein intake to prevent weight loss.

Assessment of Calorie Needs and Recommendations

Assessment and calorie needs can be calculated by using several calculation methods. For instance, energy expenditure can be calculated by the energy expenditure of the individual depending on one's age, sex, physical activity, and stress factor caused by acute injury, surgery, major or chronic disease, stress level, and surgery by using Harris-Benedict equation (Harris-Benedict, 1918). This method's accuracy has been studied by numerous researchers and it is more suitable for a healthy, well-nourished person, however, for malnourished patients could underestimate the resting energy expenditure. Also, in most healthcare settings like hospitals can be used to determine energy needs. Approximately 25 kcal and 30 kcal per kilogram of body weight can meet basal metabolic needs. The energy needs of patients with DFU are also based on body weight and the current wound status of the patient (Basiri et al., 2022). According to older studies by Breslow (1993) reported that 40 kcals per kilogram of body weight in nursing patients showed positive outcomes.

Assessment of Protein Needs and Recommendations

The human body does not store proteins compared to other macronutrients like fats and carbohydrates. Every single protein in the body has a significant role and function, therefore, low protein intake and energy intake will lead to lean body tissue breakdown for energy sources. Food and Nutrition Board (1989) recommends for healthy adults from 0.6 grams (females) to 0.8 grams(males) of protein per kilogram of body weight to maintain normal homeostasis. However, healthy elderly patients need 1.0 grams of protein for a kilogram of body weight. It is explained that elderly people break down more proteins and need higher protein synthesis. If patients are stressed or injured then even more up to 2 grams of protein is needed for a kilogram of body weight.

The AHRQ *Guidelines for the Treatment of Pressure Ulcers* recommended 1.25 to 1.50 grams of protein per kilogram of body for patients with pressure ulcers who are malnourished. Chernow and his colleagues (1990) in their pilot study found that prescribing up to 1.8 grams of protein helps wounds heal faster.

Amino-acids

Current research recommends wound-healing amino acids like L-arginine and L-glutamine. Arginine is a precursor for nitric oxide and proline, which stimulate collagen synthesis and decrease inflammation at injured cellular sites. Arginine also stimulates growth hormone and the activation of T-cells. The dosage recommendation is 4.5 grams per day for better outcomes. While L-Glutamine plays an important role in the immune system. Glutamine Is a precursor of glutathione, which is a major antioxidant and cofactor for many enzymatic reactions. Thus, it protects the cellular membrane damage and helps to cross amino acids across the membrane into the cell for further biochemical processes. Also, glutamine helps the healing of wounds by regulating cellular apoptosis, phagocytosis, and superoxide production(Barchita et al., 2019). There are many types of protein powders and mixtures available for patients with ulcers without increasing the total volume of food volume. In hospital settings, Abbot's high protein powders are known by the brand name Juven.

Macro and micronutrients recommendations for DFU

Dehydration is very common in patients with diabetic wounds, especially in geriatric patients. Adequate hydration status will provide an optimal environment for wound healing. The fluid intake recommendations depend on the patient's health status. For patients with wounds 1ml per estimated calorie intake if patients do not have End Stage of Renal Disease of Congestive Heart Failure(CHF).

Vitamin C and Zinc supplementation together showed better results in wound healing. Vitamin C as an antioxidant prevents cellular damage by free radicals. It also helps with collagen production and forms extra bonds within the collagen matrix. The current recommendation for vitamin C ranges from 500mg/per day, but for patients with diabetic foot ulcers, the range will increase up to 2 per day.

Zinc is an essential trace mineral that is involved in cellular protein synthesis, replication, collagen synthesis, and overall immune health. Zinc deficiency was associated with poor wound healing. The pilot researchers like Norris and Reynolds(1967), Haggard and colleagues(1999), Hallbook and Lanner(1972), and Wilkinson and Hawke(1998) all reported the positive effects and healing power of zinc supplementation in wound healing. The DRI for Zinc for male and female adults is 11g/day. Patients with wound or diabetic foot ulcers can achieve a need for Zinc by taking multivitamins as well.

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