INTRODUCTION

Foot ulcers are a common and serious complication of diabetes mellitus. Diabetic foot ulcers (DFUs) are estimated to affect 15% of people with diabetes during their lifetime. Ulcer is often due to combination of diabetic neuropathy and peripheral vascular disease which decreases supply of oxygen to the affected extremity. So they can be classified as either neuropathic (found in 80-85% of all patients) and ischemic which is involved in 50% of lower extremity amputations. Epidemiologic data suggest that foot ulcers precede 85% of amputations and 9-20% of diabetic patients undergo a second ipsilateral or controlateral amputation within 1 year after amputation ***(Fife et al., 2007 and Wu, 2010).***

The decrease in sensory input from lower limbs due to neuropathy will increase foot injury and reinjury. Pedal injury can come from sources of heat or cold as well as poorly fitting shoes. Once the foot is injured, the ulcer becomes chronic because of re-injury hypoxia. Microvascular and macrovascular complications of diabetes diminish blood flow to the extremities, limiting the gradient of oxygen pressure in the tissue. Oxygen is an essential controlling factor for bacterial killing"through enhancing phagocytosis of bacteria and inhibiting toxin formation", fibroblast growth, angiogenesis,

collagen synthesis, epithelialization and other biochemical processes essential for wound healing ***(Lyon, 2008 and Cucco, 2011).***

Quality Of Life (QOL) is a vague construct that reflects an individuals' perspective on life satisfaction regardless of the situation. It can be profoundly altered by the presence of a delayed wound healing. A review of the literature confirms that the presence of unhealed DFUs negatively affects patients' QOL.Which incorporates such variables as pain, suffering, financial healthcare costs, strain on personal resources and overall impact on life and activities of daily living ***(Spilsbury et al., 2007, King,2009 and Vissink et al., 2009)***

Hyper Baric Oxygen Therapy (HBOT) may be a noninvasive alternative for the treatment of diabetic foot ulcers. Many of the studies examining the role of HBOT in treatment of diabetic ulcers have been retrospective, non randomized and non controlled. Results of these studies suggest that it may accelerate wound healing and reduce amputation. It was defined as adjunctive treatment that involves administration of 100% oxygen at atmospheric pressure greater than 1 atmosphere absolute (ATA) within a hyperbaric chamber: monoplace chamber for one patient lying, multiplace chambers for multi patients either seated or supine ***(Rakel et al., 2006 and Kemp & Hermans, 2011).***

Inhalation of pure oxygen at higher pressure causes plasma and hemoglobin to become supersaturated, so enhancing oxygen delivery to all tissues, in addition to driving oxygen directly through skin rising oxygen level in all tissues. A typical session lasts between 60 and 90 minutes and not more than 120 minutes, with one session daily. Prescribed pressure and time will be determined by type of pathogen at wound site and other factors such as the degree of revascularization around the affected tissues ***(Heyneman & Lawless-Liday, 2002 and Londahi et al., 2011).***

History of hyperbaric medicine

Hyperbaric therapy was first documented in 1662, when Henshaw built the first hyperbaric chamber, or 'domicilium'. Since this time, reports of beneficial effects from increased pressure have increased, and by 1877, chambers were used widely for many conditions, though there was little scientific rationale or evidence. In 1879, the surgical application of hyperbaric therapy in prolonging safe anaesthesia was realized and explored ***(Fontaine, 1879; Henshaw, 1664)***

In 1927, Cunningham reported improvement in circulatory disorders at sea level and deterioration at altitude, and a patient who was grateful to Cunningham for his recovery after HBO treatment, built the huge 'steel ball hospital' chamber, but this was closed when Cunningham failed to produce evidence for its use ***(Cunningham,1927).***

Early chambers used compressed air rather than oxygen, due to early reports of oxygen toxicity. Drager was the first to explore the use of pressurized oxygen in decompression sickness, and his protocols were put into practice by Behnke and Shaw in the late 1930s ***(Lorrain-Smith, 1889; Yarbrough and Behnke, 1939).***

Research conducted by the US military after the Second World War brought greater knowledge about survivable pressures. As a result, the use of HBO increased, and throughout the late 1950s and early 1960s, HBO was used to potentiate radiotherapy effects, prolong circulatory arrest during surgery, and to treat anaerobic infections and carbon monoxide poisoning. Unfortunately, HBO has also been used without a solid evidence base in conditions such as dementia, emphysema and arthritis. Concerns about lack of scientific progress and regulation led the Undersea and Hyperbaric Medical Society (UHMS) to form a Committee on Hyperbaric Oxygen Therapy, which is now the international authority on HBO ***(Smith et al.,1962).***

When it comes to severe foot and ankle wounds, advanced wound care modalities, such as VAC therapy, skin substitutes and surgical reconstructions (flaps and grafts) are justified by clinical evidence as providing superior efficacy over conventional treatments (e.g:traditional dressing). While

HBO may appear “exotic,” this treatment is one of the safest and effective modalities for reducing major leg amputations from diabetic foot ulcers.Increasing incidences of diabetes and peripheral vascular disease, and improving primary medical care led to increasing numbers of patients who are candidates for HBO treatments. It is our duty to present this valuable adjunctive treatment to our patients as it has been proven to save limbs and lives ***(CADTH ‘Canadian Agency for Drugs and Technology in Health’, Issue 25. March 2007).***

AIM OF THE STUDY

Is to review literature regarding the effect of hyperbaric oxygen therapy in improving results of diabetic foot reconstruction.

ANATOMY OF THE FOOT

The human foot and ankle is a strong and complex mechanical structure containing exactly 26 bones, 33 joints (20 of which are actively articulated) and more than a hundred muscles, tendons, and ligaments ***(Hawes et al.,1994).***

Function of the foot:

The foot has two important functions:

A) To support the body weight in standing position.

B) To serve as a lever to propel the body forword in walking and running.

If the foot possessed a single strong bone instead of a series of small bones, it could sustain the body weight and serve as a rigid lever for forward propulsion. However, with such an arrangement , the foot could not adapt itself to uneven surfaces, and the forward propulsive action would depend entirely on the activities of the gastrocnemius and soleus muscles Because the lever is segmented with multiple joints, the foot is pliable and can adapt itself to uneven surfaces. Moreover, the long flexor muscles and the small muscles of the foot can exert their action on the bones of the forepart of the foot and toes and greatly assist the forward propulsive action of the gastrocnemius and soleus muscles ***(Richard, 2004).***

The foot can be subdivided into the hindfoot, the midfoot, and the forefoot: As shown in Figure (1)

The hindfoot is composed of the talus (or ankle bone) and the calcaneus (or heel bone). The two long bones of the lower leg, the tibia and fibula, are connected to the top of the talus to form the ankle. Connected to the talus at the subtalar joint, the calcaneus, the largest bone of the foot, is cushioned inferiorly by a layer of fat ***(Hawes et al.,1994).***

The five irregular bones of the midfoot, the cuboid, navicular and three cuneiform bones, form the arches of the foot which serves as a shock absorber. The midfoot is connected to the hind- and fore-foot by muscles and the plantar fascia ***(Hawes et al.,1994).***

The forefoot is composed of five toes and the corresponding five proximal long bones forming the metatarsus. Similar to the fingers of the hand, the bones of the toes are called phalanges and the big toe has two phalanges while the other four toes have three phalanges. The joints between the phalanges are called interphalangeal and those between the metatarsus and phalanges are called metatarsophalangeal (MTP) ***(Hawes et al.,1994).***

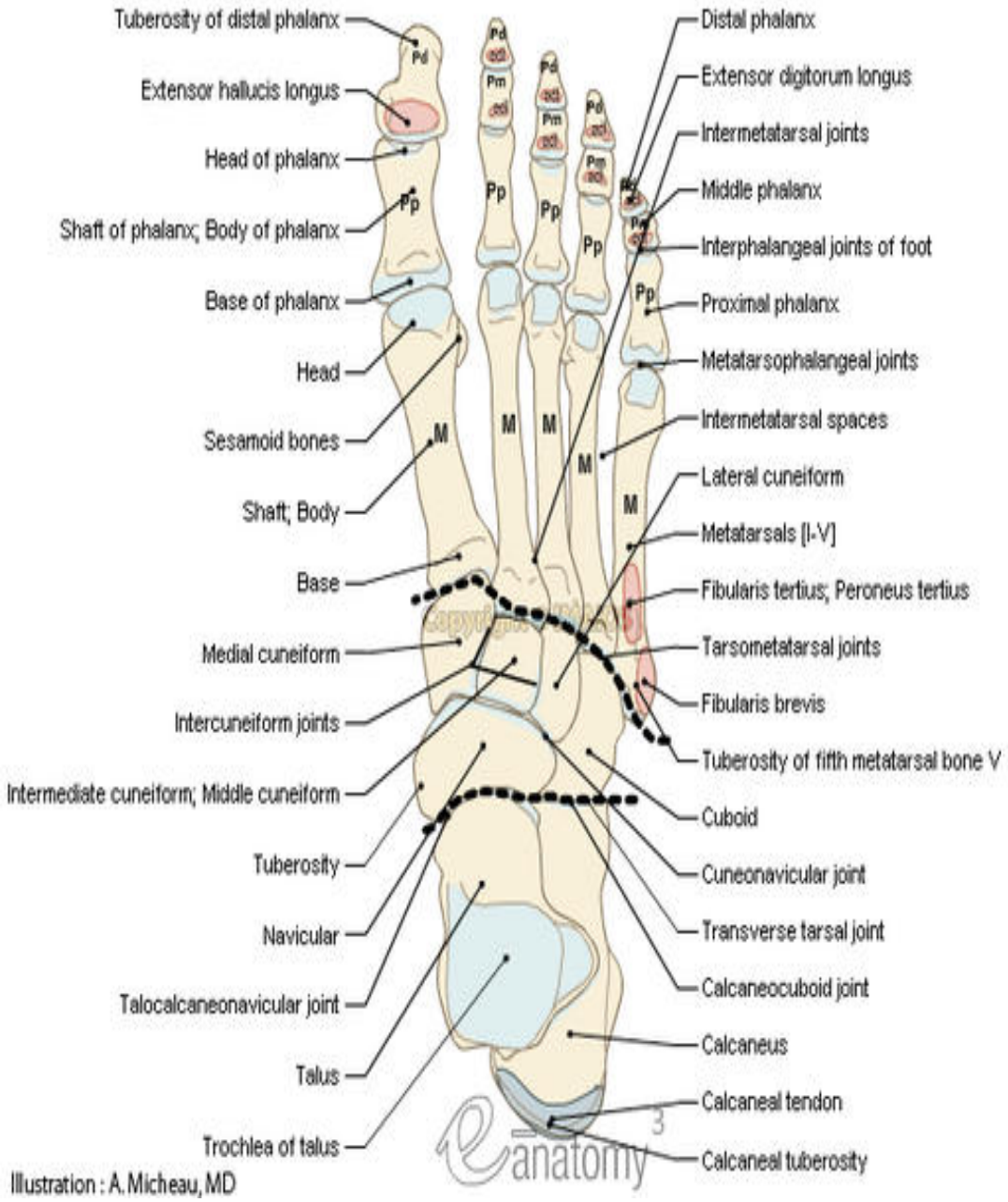
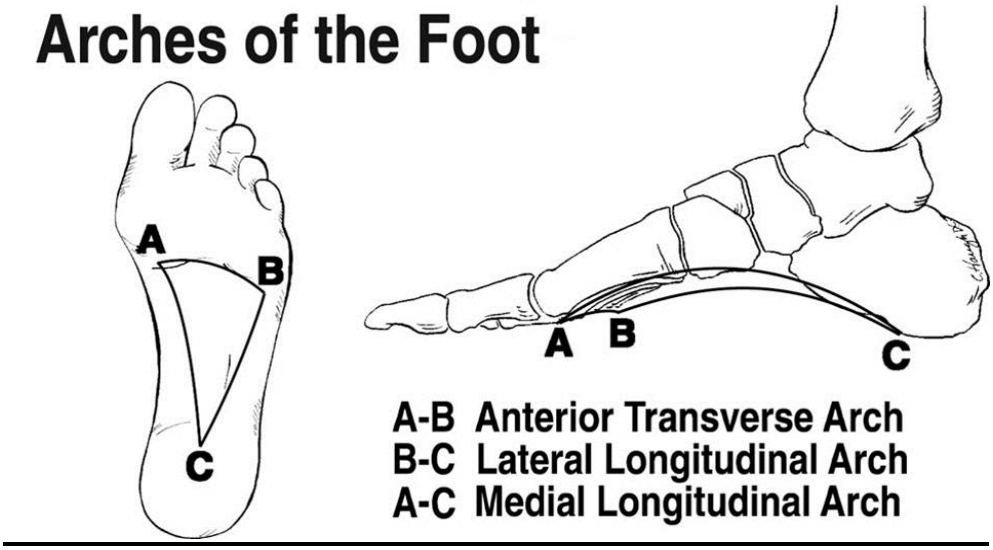


Figure (1): *Dorsum of foot - Anatomy : Bones; Skeletal system, Joints of foot http://www.imaios.com*

Arches of the foot : As shown in Figure(2)

The human foot has two longitudinal arches and a transverse arch maintained by the interlocking shapes of the foot bones, strong ligaments and pulling muscles during activity. The slight mobility of these arches when weight is applied to and removed from the foot makes walking and running more economical in terms of energy. As can be examined in a footprint, the medial longitudinal arch curves above the ground. This arch stretches from the heel bone over the "keystone" ankle bone to the three medial metatarsals. In contrast, the lateral longitudinal arch is very low. With the cuboid serving as its keystone, it redistributes part of the weight to the calcaneus and the distal end of the fifth metatarsal. The two longitudinal arches serve as pillars for the transverse arch which run obliquely across the tarsometatarsal joints. Excessive strain on the tendons and ligaments of the feet can result in fallen arches or flat feet ***(Mareb-Hoehn, 2007).***



Figure(2):*Foot arches http://the3inone.wordpress.com*

***Vascular angiosomes*:As shown in Figure (3)**

Ian Taylo first defined the angiosome as a three-dimensional anatomic unit of tissue fed by a source artery ***(Taylor et al.,1990).***

In planning any surgical procedure on the foot, or when embarking on any course of wound care treatment, it is essential that optimum blood flow is obtained in the area of tissue breakdown. By understanding the principle of angiosomes and the vascular anatomy of the foot, wound healing and foot salvage will be easier to predict. It has been reported that up to 15% of bypasses to the foot fail to heal wounds on the foot, in spite of remaining patent, simply because these bypasses failed to revascularise the affected

angiosome. It is, therefore, crucial that bypass procedures are done to the right blood vessel, if existent ischaemic ulcers are to be healed ***(Berceli et al.,1999).***

In Ian Taylor's landmark paper on angiosomes, an angiosome is defined as an anatomic unit of tissue (which has skin, subcutaneous tissue, fascia, muscle and bone), fed by a source artery. Every angiosome is linked to a neighbouring angiosome by numerous choke vessels. This ensures the provision of blood flow to an adjacent angiosome when a source artery is damaged. While the choke vessels are small connections, there are also larger arterial to arterial connections and collaterals that allow blood to flow to an angiosome even if the source artery is occluded ***(Taylor et al., 1990).***

Taylor describes at least 40 angiosomes in the body, of which 6 are found in the foot and ankle. These originate from the three main arteries in the lower extremity, the posterior tibial artery, the anterior tibial artery and the peroneal artery ***(Taylor et al., 1990).***

The foot and ankle consists of six angiosomes. The following arteries feed the angiosomes of the foot and ankle: (a) the distal anterior tibial artery feeds the anterior ankle while its continuation, the dorsalis pedis artery, supplies the dorsum of the foot; (b) the calcaneal branch of the posterior tibial artery

feeds the medial and plantar heel; (c) the calcaneal branch of the peroneal artery feeds the lateral and plantar heel, (d) the anterior perforating branch of the peroneal artery feeds the anterolateral ankle; (e) the medial plantar artery feeds the plantar and (f) the lateral plantar artery feeds the lateral plantar mid- and forefoot . Note that the plantar heel receives dual blood supply from the calcaneal branches of the posterior tibial and peroneal arteries ***(Attinger et al., 2001).***

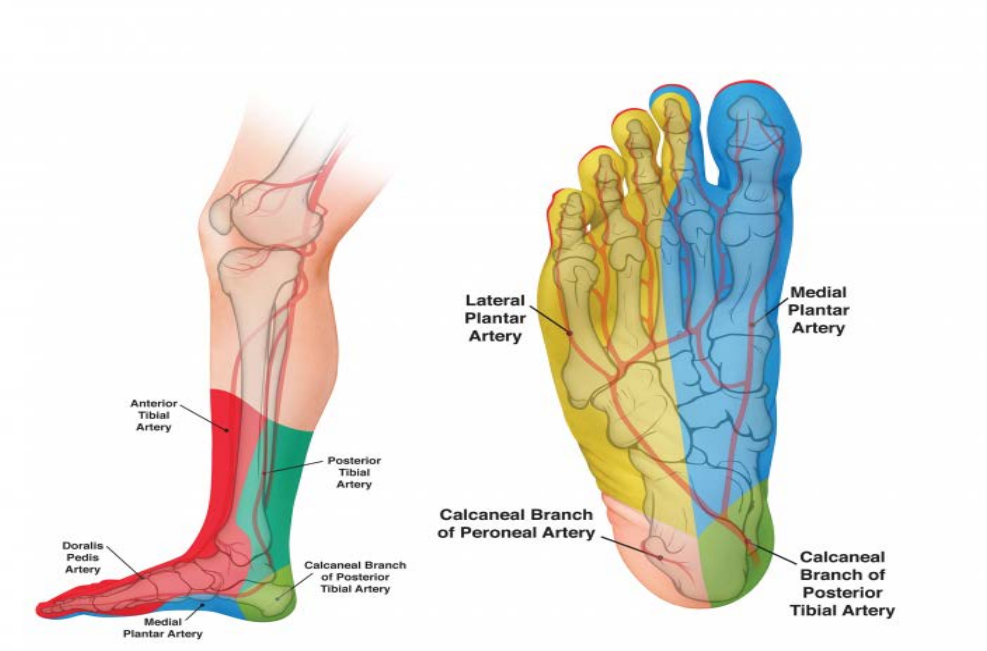


Figure (3): *Distribution of the main foot and lower ankle angiosomes*
http://www.podiatrytoday.com

Pressure areas of the foot:

Measurement of foot pressure distribution (FPD) is clinically useful because it can identify anatomical foot deformities, guide the diagnosis and treatment of gait disorders and falls, as well lead to strategies for preventing pressure ulcers in diabetes. Age-related anatomical and physiological changes in foot bone and ligament structure affect FPD during gait ***(Rodgers, 1995).***

Walking may present a challenge to elderly people, and several age-related gait changes have been identified . ***Morag et al. 1997*** found that age correlated with heel pad stiffness, but to a lesser degree with walking speed, soft tissue characteristics, and height of the medial longitudinal arch ***(Morag et al., 1999).***

Pressure values under the heel and midfoot are predominantly affected by weight bearing at the heel strike and midstance, whereas pressures in the anterior regions are determined to a greater extent by flexibility, muscle strength, and muscle recruitment ***(Kimmeskamp et al., 2001).***

DIABETIC FOOT

Diabetes is the most common metabolic disease worldwide. WHO reported increasing incidence all around the world especially in developing countries ***(Sicree et al., 2006).***

It is well known that diabetic foot ulceration is a significant end stage complication of diabetes with considerable economic and public health implication. More than 50% of nontraumatic lower extremity amputations are performed on patients with diabetes, and the relative risk of having a major amputation associated with diabetes in the Medicare population is -10 ***(Reiber et al., 2001).***

Lower-extremity problems in the diabetic patient had often in the past been referred to as "the forgotten complication," compared with eye disease and nephropathy. Much progress has been made in the last decade in the understanding of diabetes-related foot problems, as evidenced by an increasing number of publications, and presentations at major meetings in this field. Unfortunately, much of this new knowledge has not yet been adequately translated into clinical practice ***(http:// www. cdc. gov/ nchs/ products/ pubs/ pubd /hp2k/ review/ highlightshp2000.htm., 2004).***