Mycetoma control and prevention

INTRODUCTION

Mycetoma is a slow progressing chronic inflammatory tropical disease caused by actinomycetoma bacteria and eumycetoma fungi found in soil and water [1] . These bacteria and fungi enter the body through open wounds or abrasions on the skin. Symptoms appear as firm painless nodules under the skin, in the subcutaneous tissue, and develop into granulose oozing sores over time [1] . Mycetoma lesions extend into the subcutaneous tissue and bone, leading to devastating deformities, disability, negative and surgical amputation in the most advanced cases. The majority of mycetoma cases present in the extremities, with nearly 70% of cases occurring in the feet, followed by hands (12%), legs (10%) and torso (6%). The disease is common among manual field workers who walk barefooted in rural endemic areas and have frequent direct contact with the outdoor environment. The Male to female ratio is 6: 1, with most cases commonly reported in adults aged 20-40 years old [1-3] . The disease is endemic to tropical and subtropical regions known as the ‘ mycetoma belt’ which stretch between 30°N and 15°S of the equator. Countries within the mycetoma belt include Sudan, Somalia, Senegal, India, Yemen, Mexico, Venezuela, Colombia, Brazil. and Argentina, with the majority of mycetoma cases being reported from Mexico, Sudan, and India [3] .

Mycetoma is not a notifiable condition, and it was only recently added to the WHO Neglected Tropical Disease List in 2016 [4] . It’s true annual incidence and prevalence rates globally are currently unknown. Because of this, there is a lack of accurate data on the number of reported cases in each country per year [9] . In Sudan, research conducted in mycetoma-endemic states suggest a prevalence rate of 14. 5 per 1, 000 individuals [4] . However, this is a gross underestimation, as most patients tend to present to health facilities in more advanced stages of disease. Treatment of mycetoma is long and challenging with poor outcomes. The infection is slow-progressing and painless; the incubation period varies from 3 months to 9 years [5] . For this reason, diagnosis and treatment of mycetoma is delayed and the number of reported cases only reflect more advanced cases of disease. There are currently no viable control or prevention programs for mycetoma. This is due to the fact that mycetoma is endemic in low-income and resource-limited countries with inadequate medical and healthcare infrastructure, surveillance systems, and diagnostic and treatment facilities [9] . As such, prevention at the primary level is key to reducing the incidence of mycetoma and the socio-economic dislocation caused by the disease. Prevention through synthesized antifungal microbial materials in the form of integrated products such as shoes, socks, gloves etc. can greatly minimize exposure inexpensively, thus reducing the new contracted cases of mycetoma. As a proposed solution, Sana Protective Shoes and Work Gear is cost-effective lightweight, breathable and antibacterial/antifungal functional products that will work to neutralize exposure and effectively reduce the risk of contracting mycetoma and like diseases.

ETIOLOGY OF DISEASE

Mycetoma is classified into actinomycoma, caused by a bacterial agent, and eumycetoma caused by fungus. The global incidence of actinomycetoma and eumycetoma vary by country and region [9] . Actinomycetoma is more prevalent in drier regions in South and Central America where eumycetoma is more common in humid regions in Africa [5] . This climate contributes to the breeding and survival of mycetoma agent and is characterized by short rainy seasons (4-6 months), and longer dry seasons (6-8 months) where the temperature fluctuations vary between 45-60oC to 15-18oC daily [5] . There are more than 56 fungal and bacterial species that cause mycetoma. The most frequent actimomycetoma cases are caused by S. Somaliensis, A. Madurae, A. pelletieri, N. Brasiliensis and N. Asteroides. Approximately 50% of all mycetoma cases are classified as eumycetoma, 70% of which are caused by Madurella mycetomatis [6] . The pathology of mycetoma and mode of transmission are not clearly understood. There are no known vectors or animal reservoirs for the disease [6] . The mycetoma agent is found primarily in soil and animal manure and can enter the body through an infected thorn prick, wood splinter, cut, or abrasion. Once the pathogen is introduced to the wound track it injects itself into the underlying skin and begins to create microcolonies of small aggregate grains called sclerotia [7] . As the infection spreads, grain clusters grow into hard painless nodules that secrete pus, blood and fungal grains that vary in size, color and consistency [10] . The infection can spread deep into the tissue and infect the underlying bone. The disease is seen to be more invasive and fast progressing among patients with malnutrition, poor general health status, immunosuppression and associated illnesses like malaria and HIV/AIDS. However, there is no definite conclusion about the relationship between a patient’s immune status and the progression of disease [7] .

BIOLOGY OF DISEASE

The role of the host's immune system and effects of the mycetoma agent on immunocompromised systems are not well known. Some studies have been conducted on the role of the immune system in fighting mycetoma in vitro and in animals, but very few have been performed on humans [10]. The body's innate immune system is triggered as a first line of defense in an attempt to engulf and inactivate the organism. Complement-dependent chemotaxis of polymorphonuclear leukocytes is induced once the bacteria and fungi antigens are introduced to the body [10]. Once the organism begins to organize itself into grains, the immune system responds in three different ways. In the first, neutrophil degranulation occurs. Neutrophils migrate from the bloodstream to the site of infection in response to chemical signals released from the mycetoma agent [10]. Secondly, macrophages and monocytes are called in to clear away neutrophil debris and mycetoma grains. Monocytes present to the inflammation site as a precursor of macrophages and begin phagocytic activity. Macrophages leave the bloodstream, enter the infected tissue, and attach to the pathogen. Once its attached itself to the pathogen, the macrophage engulfs the pathogen into a vesicle inside the cell where digestive enzymes break the mycetoma pathogen down [10]. Digestible material is used as nutrients within the phagocyte and undigestible material is removed from the cell via exocytosis. Finally, epithelioid cell granulomas are formed to protect the infection from further spread [10].

Innate immunity is ineffective in stopping the infection from spreading. A study conducted in 1978 by Melendro et al, found that virulent N. Basiliensis bacteria were able to escape oxygen-dependent microbicidal activity and continue to multiply after engulfment into the phagocytic cell [10] . Research also suggests that mycetoma agents produce anesthetic substances, which explains why the disease is usually asymptomatic and painless. The pain characterized in the late stages of disease is related to the nerve damage associated with the tissue damage, expansion of the bone and vasoconstriction to the infected area [10] .

APPROACHES TO DISEASE PREVENTION AND CONTROL

The lack of a global prevention or control program for mycetoma is due to our limited understanding of the basic epidemiological characteristics of mycetoma [9] . Because of this, the only available methods to control and eliminate disease lie in strengthening disease advocacy and scaling up access to interventions and community-level activities through disease mapping, early case detection and treatment [6] . The Mycetoma Research Centre (MRC), a WHO Collaborating Centre, is a globally recognized leader in public-health management of mycetoma and the driving force behind the WHO resolution to add mycetoma to the Neglected Tropical Disease List in 2016 [5] . The MRC plays an active role in epidemiological mapping of disease, treatment and management of mycetoma cases, and the development of new field diagnostic tools [6] . While MRC conducts regular medical missions in endemic regions throughout the year, disease mapping for mycetoma is generally incomplete, and the number of people at risk for the disease is unknown. There is an urgent need to consolidate existing country data into a structured mycetoma database as well as conduct mapping for mycetoma where the same is required to determine its distribution.

Complete cure in mycetoma is difficult and reoccurrence of infection post-surgical treatment is common. According to the MRC, cure rates with antibiotic therapy are only 43% for actinomycetoma and 25% for eumycetoma. The average cost of treatment in Sudan can go up to as much as $330USD, while monthly income averages only $60USD. More than 50% of patients end up discontinuing treatment due to lack of progress and high costs [6] . At the community level, MRC conducts health education campaigns in schools, local community centers and religious institutions, as well as, hosts radio and T. V informercials and Q&A sessions in order to train community members to detect, document, and refer cases of mycetoma to local health facilities. House to house surveys are conducted in endemic villages and suspected patient's demographic information is registered and samples are taken to confirm diagnosis [5] . In addition, MRC conducts shoe drives and distributes animal cages to improve village hygiene and reduce contact with animal manure [5] . However, there is a gross lack of infrastructure to support the operational logistics necessary to carrying out these activities on a larger national scale. Additionally, there is a lack of access to healthcare services in remote rural areas where mycetoma is endemic. The MRC is the only specialized treatment center for mycetoma in the country. The Ministry of Health needs to allocate more resources to establishing more satellite offices and regional centers in endemic areas.

Patients are often discouraged from travelling long distances to Khartoum to seek treatment and often present in more advanced stages of disease.

PROPOSED SOLUTIONS

As a proposed solution, using Sana Protective Shoe and Work Gear may help prevent exposure to mycetoma pathogen. Sana Protective workwear is made using 3D printed technology and is functionally designed to be worn by the rural farming and agricultural community. The work gear is synthesized using a graphene-oxide silver-nitrate nanoparticle compound infused within the rubber material. The graphene-oxide material is considered to be the world's thinnest, strongest, and stiffest material [8] . It is a low costing material, easily accessible and scalable, and versatile in its ability to be synthesized with other compounds [8] . The material has gained considerable interest in the medical field because of its antimicrobial properties as well as its thermal conductivity and high hydrophobic properties [8] . The material properties of the Sana shoe are antifungal and antibacterial, providing a method to neutralize exposure while farmers conduct the day to day activities that put them in harm's way and effectively reduce the risk of employees contracting mycetoma. The Sana Protective Work Gear is water, heat and chemical resistant and designed to keep feet dry, comfortable, and provide breathability throughout the day. The shoe is designed with an elastic collar and front pull tab that make it easy to slip on and off. The thick-density sole is designed to facilitate the farmer's natural gait and protects them from harsh surfaces. Sana Gloves and functional dermis coverings are cut, puncture and abrasion resistant, lightweight, breathable, and water, chemical, and heat resistant. Controlled laboratory test for dermal exposure against a hyper-exposed environment yielded a less than 0. 1% exposure rate to synthetic tissues sheathed with the Gen. 1 material compound. At a 99% protective coverage rate, printing of Gen 1 Sana Shoes for distribution pilot is satisfactory. We are currently completing our second year of clinical research trials into the effectiveness of Sana Gear in protection against mycetoma among rural agricultural workers in Sennar, Sudan, a highly endemic region for mycetoma.

Sana is the most effective product of its kind within the wider genre of agricultural protective gear. Being first-to-market carries its inherent advantages for Sana. Its pioneering technology and manufacturing procedures create a new foothold in the PPE market. Sana’s synthesis, material needs, and production process are all mostly in-house. The advantages of 3D printing as opposed to traditional apparel manufacturing will streamline production at very low cost and use of material. Production cost is estimated to be $1. 70USD per pair of Sana Protective Shoes. The projected cost to scale at higher tiers tier lowers production cost to $0. 63USD, with a suggested sales point of $5. 40USD to $6. 50USD per pair. These price points are much lower than current far less-effective products in this genre. The majority of competitive products specific to our customer bases’ work safety needs are classified as generic and lack most of Sana’s qualities.

We are working with the WHO, MRC, and the National Ministry of Health to implement the region’s first Occupational Health and Safety PPE mandate for rural farm workers. Corporate agricultural businesses and commercial farmers in Sudan will be required to supply their workers with protective gear to reduce the incidence of mycetoma and like diseases associated with these trades. Additionally, our firm is working with MRC to provide health education campaigns and mass distribute Sana PPE materials to rural communities targeted during MRC research and medical interventions.

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