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Mucormycosis: A Double Threat to COVID-19 Patients

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Abstract
While the COVID-19 outbreak in India continues, a fatal fungal illness known as "Mucormycosis," often known as "Black Fungus," has caused a new health concern in the country. Several state governments proclaimed a pandemic after more than 11,000 instances of black fungus infection were confirmed across India. During the second wave of Coronavirus, an uncommon fungal infection appeared. Experts attribute this situation to pre-diabitic condition of coronavirus-positive patients and excessive administration of steroids. Mucormycosis was a reasonably common infection in India before the COVID-19 epidemic, compared to other nations across the world, and it expanded fast along with the pandemic. Factors that accelerated the spread of Mucormycosis are infected bed linen in the hospital, packaged foods and medications. This fungus infection, caused by opportunistic pathogenic fungi, is life-threatening in immunocompromised individuals and is increasing at a faster rate, with greater death rates. A more detailed and comprehensive study of the pathogenesis of disease will lead to well developed treatment methods.This review will focus on mechanism, symptoms, diagnosis, and treatment of Mucormycosis, or Black fungus outbreak during post COVID-19 complications in India.
Key words: COVID-19, Mucormycosis, Black Fungus, diabetic, immunosuppressed, steroids

Indian Scenario

Considering the worldwide spread of Mucormycosis infection, it was reported that before COVID-19, this rate was 70 times higher in India than in other countries. Due to the rapid progression of disease, many provincial governments in India have declared this infection an epidemic. In 2020 and 2021, infections of aspergillosis, Mucormycosis and candidiasis were reported in India due to immunosuppressive treatment modalities used in COVID-19 [4, 5]. Mucormycosis is a serious fungus that can put diabetic ketoacidosis patients at risk [6]. India has been ranked second highest for diabetes cases in the world, thus higher rate of diabetes has also been the reason, as patients with high blood sugar levels are more susceptibile to disease. Diabetes affects the body by lowering the immune defences, coronavirus makes it worse, and then steroids which are needed to fight COVID-19 act like fuel to the fire [2, 7]. Uncontrolled diabetes causes blood sugar to rise and tissues to become partially acidic, creating a suitable environment for the reproduction of Mucorales fungi. Mucormycosis infection was identified as a worldwide risk long before the COVID-19 outbreak. Studies by scientists between 2000 and 2017 have shown that 40% of all Mucormycosis reported cases have diabetes. At present, during the COVID-19 second wave, Mucormycosis or black fungus cases have been reported in 45,374 Indian patients, of which 85% had Coronavirus infection. In total, 4,332 lives have been lost due to this infection. Dr. Harsh Vardhan, Union health minister, outlined these reports to a ministerial group. According to shared data, 34,940 patients had COVID-19, but 26,187 or about 64.11% had diabetes as well. Also, 31,444 of the cases had rhino-orbital characteristics, meaning the patients had infections in the nasal cavity and area around the nose [8]. COVID-19 patients have elevated levels of inflammatory cytokines such as interleukin [IL]-2R, IL-6, IL-10, and tumour necrosis factor (TNF-α), as well as a weakened cell-mediated immune response, affecting all CD4 + T and CD8 + T cells resulting, in increased susceptibility to fungal coinfections [9]. More than half of the cases are reported from the Western states of Gujarat and Maharashtra. On average between 800-900 cases have been reported in 15 more states. Due to progression in the rise of cases, India's 28 states have been informed to declare this disease an epidemic and more states are expected to follow. The first state striked by second wave was Maharastra, which has already reported surge of 6,339 cases, which is highest in the country. Another state hit hard by COVID-19 was Gujarat, there were 5,486 cases [9].

Mucormycosis or Black Fungus

Fungi classified in the order Mucorales consist of 6 families majorly causing skin infections. Samples isolated from infected individuals with Mucormycosis often belong to the Mucoraceae family. *Rhizopus oryzae* (*Rhizopus arrhizus*) is a fungus species belonging to the Mucoraceae family and causes the highest infection in the order [10]. Mucormycosis, is caused by Mucormycetes, It is a disease also known as zygomycosis and is caused by different fungi in the "Mucorales" fungal family **(Fig. 1).** Black fungus can be found on plants, soil, or decaying organic matter, as matter of fact, people who do outdoor activities or gardening can easily carry it. Its growth can also be seen in rotten foodstuffs (bread, fruit, etc.), initially fuzzy white in color and turn dark gray over time. Condensation lines and drip ceilings are also suitable areas for black fungus growth. In short, this mushroom can be easily found everywhere in our environment.

Types of Mucormycosis

Rhinocerebral Mucormycosis (infection of the nose and brain) is a kind of infection that can spread to the brain. Particularly, kidney transplant recipients and diabetic patients are more likely susceptible Mucormycosis infection. Pulmonary (lung) Mucormycosis is the most prominent form, which is seen in

individuals who have undergone stem cell or organ transplant, as well as in cancer patients [11, 12]. The common type seen in children is Gastrointestinal Mucormycosis than in adults and is a common infection especially in premature or low birth weight babies who have undergone surgery. Cutaneous (skin) Mucormycosis is a type of infection that occurs with the invasion of fungi from the skin area and is most commonly seen in people with a weak immune system. Disseminated mucomyrcosis infection spreads to different parts in the body through bloodstream. Brain is the most commonly afflicted organ, although it can also affect the skin, heart, and spleen [13, 14].

Epidemiology and clinical presentation of Mucormycosis

Due to a lack of clinical diagnosis, exact information on the epidemiology of Mucormycosis is limited. According to autopsy reports from across the world, it is the third most frequent cause of fungal infection, after *Aspergillosis* and *Candidiasis*, with a rise in illness among adults and newborns under the age of one year [15]. Documented literature shows that Mucormycosis is at least five to ten times less common when compared to other fungal infections such as *Aspergillosis* [16, 17]. The epidimology of Mucormycosis differs between developed and developing countries. In developed countries, hematologic malignancies and hematopoietic stem cell transplantation (HSCT) are a leading cause of Mucormycosis, however uncontrolled diabetes or trauma are more prevalent in developing countries, particularly in India [18-22]. The more often people encounter Mucormycosis spores, the more are the incidences of becoming contracted. New causative agents, vulnerable population and increasing prevalence have been influential in the change of epidemiology of Mucormycosis, especially in recent times. While Mucormycosis is increasing throughout the world, its increase is particularly noteworthy in the Asian continent. After the spores of fungus are inhaled, the virus can become lodged in the sinuses or lungs such type of Mucormycosis is most commonly seen in people with weakened immune systems. Fungi can cause Mucormycosis after they reach the skin through a simple scratch or cut, or through a burn or any form of skin trauma [10, 22].

Mucormycosis is more common in people with bone marrow or solid organ transplants, uncontrolled diabetes patients, immunocompromised patients, patients suffering from the consequences of corticosteroid therapy, hematological malignancy, and trauma. The nasal and brain can both get infected by rhinocerebral Mucormycosis which can cause fever, swelling, black spots on the face, sinus congestion, and headaches. Pulmonary Mucormycosis specifically infects the lungs, causing cough, chest pain, respiratory distress and fever. In rhinocerebral murcormycosis, the sinuses and brain are infected. A fever may occur, while in cutaneous Mucormycosis, the skin is infected inducing ulcers, blisters, or redness. Gastrointestinal Mucormycosis is very common in premature newborns and not common in adults. It causes abdominal pain, nausea, vomiting, gastrointestinal bleeding. A person with Disseminated Mucormycosis who has multiple medical complications, prevents them from being able to differentiate the disease from other infectious diseases and finally, an uncommon presentation as renal infection.

Diversity of fungi caused Mucormycosis

Mucormycosis is a fungal illness that causes substantial morbidity and death and is caused by a variety of fungus. Mucormycetes are fungi belonging to the Mucorales order. The most common species causing Mucormycosis are *Rhizopus* and *Mucor* microorganisms. *Rhizopus homothallicus, Rhizopus arrhizus, Mucor irregularis, Thamnostylumluckynowense, Apophysomyces variabilis, Cunninghamella bertholletiae, Syncephalastrum* species, *Lichtheimia* and *Saxenaea* are the species that cause Mucormycosis [23, 24]

Mucormycosis pathogenesis

Host Defenses

According to clinical and experimental evidences, people without phagocytes or having reduced phagocytic activity are more likely to get infected with Mucormycosis, for instance, patients who are severely neutropenic, are at a higher risk of getting Mucormycosis. While the patients contracting with AIDS, do not appear to be at higher risk of acquiring Mucormycosis. A normal host's mononuclear and polymorphonuclear phagocytes are capable of killing mucorales, which produce the cationic peptides defensins and oxidative metabolites [25-27]. Clinical data shows that phagocytes are the primary host defensive mechanism against black fungus **(Fig. 2).** Patients with malfunctioning phagocytes are also more likely to develop Mucormycosis. Hyperglycemia and acidosis have been shown to impede phagocytes' capacity to move in a direction and destroy organisms via both oxidative and nonoxidative processes [28]. Furthermore, corticosteroid therapy impairs the capacity of mice bronchoalveolar macrophages to inhibit spore germination in in-vitro or in-vivo infection caused by intranasal inoculation.

Iron uptake

Mucorales contain a number of virulence characteristics that may make us sick, one of which being the capacity to absorb iron from the host. While iron is involved in a variety of cell activities, it is especially crucial for cell growth and development [29]. successful pathogens acquire iron from the host in a number of different mechanisms. Unbound iron levels in the blood play an important role in predisposing DKA patients to Mucormycosis. The toxic effect of iron is prevented by binding to proteins such as ferritin, lactoferrin and transferrin in mammals. Binding of iron to proteins is one of the host defense mechanisms developed against microorganisms, especially Mucorales. For example, growth of *R. oryzae* in serum medium without exogenous iron is very poor. Patients with DKA are extremely prone to black fungus. This is associated with the disease's iron intake. DKA patients have excessive amounts of free iron in their serum. [30, 31], The growth of *R. oryzae* is aided by serum at an alkaline pH(7.3-6.88) and has an adverse effect on the microorganism (7.78-8.38). In blood samples taken from healthy individuals and processed in vitro under acidic conditions shows decreased iron binding ability. This may be because acidosis impairs the iron-binding capacity of transferrin, possibly through proton-mediated displacement from transfer of ferric iron [32]. In experiments, Iron chelators, such as deferiprone and deferasirox, which Mucorales do not utilize as xenosiderophores, appear to protect mice with DKA from Mucormycosis infection. Each Mucorales species shows different sensitivity to iron chelators. According to the study of Lewis et al., the fungicide and deferasirox minimal inhibitor concentrations of *Mucor* species and *Cunninghamella bertholletiae* are higher than other *Rhizopus* species [33, 34]. Dialysis patients are highly susceptible to fatal forms of Mucormycosis when given with the iron chelator deferoxamine. According to studies, *Rhizopus* absorption of radiolabeled iron from serum deferoxamine is 8 times that of *Aspergillus fumigatus* and 40 times that of *Candida albicans*. A major factor of concern for Mucormycosis is iron overload from blood transfusions. Low-molecular-weight iron chelators and high-affinity iron permeases are used by fungi to obtain iron from their hosts [29, 35-37]. Fungi have a mechanism in place that converts high-affinity iron permeases into a more soluble form of iron. A protein complex comprised of a multicopper oxidase and an iron permease captures the reduced iron generated by the surface reductase. 6 copper oxidases, 3 ferric reductases, and 1 high-affinity iron permease have been identified after the genome sequencing of R. *oryzae*. During murine infection and inhibition of FTR1 gene expression by RNA-I, the gene encoding high affinity iron

permease (FTR1) is expressed by *R. oryzae* or the FTR1 copy number is reduced. Thus, the virulence in animal models of Mucormycosis decreases. Passive vaccination with anti-Ftr1p immune serum protected DKA mice from R. *oryzae* infection [38-40]. FTR1 is regarded as an important virulence factor for *R. oryzae*. In treatments, lethal consequences of Mucormycosis can be prevented with anti-Ftr1p passive immunotherapy method. Rhizopus secretes rhizoferrin, a polycarboxylate siderophore that provides iron to Rhizopus via a receptor-mediated, energy-dependent mechanism. Thirteen siderophore parmeases have been identified in the genome sequences of *R. oryzae*. Deferoxamine and rhizoferrin are two examples of siderophores receptors. Whether rhizoferrin transports iron by internalizing the siderophore or by releasing it out of the cell remains unclear. It is known that rhizoferrin does not have the ability to obtain iron from serum [31, 41, 42]. The impact of the organism's endogenous siderophores on virulence in a mammalian host is predicted to be low based on this information. Rhizoferrin is unable to absorb iron from the blood. The organism uses xenosiderophores such as deferoxamine to obtain iron from the host. Fungi can also obtain iron from the host by using heme [43]. Two homologues of heme oxygenase have been uncovered in the Rhizophus genome. These homologous enzymes can explain the angioinvasive nature of *R. oryzae* and enable it to obtain iron from the host hemoglobin. *R. oryzae,* which has reduced copy number of FTR1, shows late growth in environments supplemented with heme. In *R. oryzae*, FTR1 can facilitate intracellular heme absorption by acting as a cytoplasmic membrane permeability **(Fig. 3)** [44, 45].

Fungal-Endothelial Interactions

The uniform presence of extensive angioinvasion resulting in tissue necrosis and vessel thrombosis is a hallmark for Mucormycosisinfections.This angioinvasion can spread hematogenously to different target organs from the initial site of the infection. Damage and penetration of endothelial cells lining blood arteries are critical indicators of an organism's pathogenicity. In vitro, *R. oryzae* spores but not germlings may attach to subendothelial matrix proteins such as laminin and type IV collagen. The adhesion rate of *R. oryzae* hyphae to subendothelial matrix proteins is quite low compared to *R. oryzae* spores. Moreover, hyphae and spores can adhere uniformly to human umbilical vein endothelial cells. Germ tube and spores attach to subendothelial matrix proteins and damage endothelial cells independently of serum factors. Endothelial cells also perform defense by phagocytizing the microorganism [46, 47]. The *R. oryzae* microorganism does not need to be alive for damage to endothelial cells. For non-viable *R. oryzae* to pose a risk, phagocytosis is necessary. In a study, diabetic mice were given four doses of R. oryzae blastospores that were killed by the heat effect, resulting in a 40% mortality rate. The mechanism of tissue damage caused by dead *R. oryzae* has not been clarified yet. The clinical conclusion is that this microorganism is killed after its presence in the tissue is detected, the microorganism continues to damage the tissue, and perhaps the deadly antifungal agents are ineffective during the disease.

Black fungus symptoms

Mucormycosis can be found in different parts of the body. The infection often starts in the mouth or nose and progresses to the central nervous system through the eyes. The symptoms and signs of the disease depend on its location in the body [48]. The prime symptoms of the black fungus include discolouration of the oral tissues, tongue, gums, stuffy nose, severe pain, swelling of face, heaviness below the eyes, discomfort, fever and headache.

Diagnosis and treatment

Mucormycosis is characterised by nasal discharge, haemorrhage, and nasal obstruction. The presence of lumps covered by illusory black eschar (rash or dead tissue) on endoscopic imaging of the nasal cavity suggests the diagnosis. **(Fig. 4).** With the

progression of the disease, black necrotic masses that can be seen in the mouth may cause palate destruction. Protrusion of the eyeball (proptosis), loss of movement in the eyeball and related double visions can be seen. Eye pain may be followed by redness and blindness. A blockage in the blood vessels of the brain can cause paralysis, bleeding and even death [49]. People who have the disease may experience lethargy, seizures, limb weakness, headache, and death. As of the current scenario, Mucormycosis is on high rise in India, patients suffering from COVID-19 and the patients on immunosuppressants like diabetes mellitus, hematological malignancy, solid organ transplants, and corticosteroid treatment are among the long list of infectants, hence are subjected to a high mortality rate i.e. 30-50% [50]. Following clinical suspicions, CT and MRI scans of the sinuses, nose, and brain are performed. With these scans, clear information about the presence and spread of the lesion can be obtained. Features such as shortness of breath, cough and fever seen in lung Mucormycosis are same as COVID-19 and make the diagnosis of Mucormycosis difficult. If the patient does not show any improvement despite taking appropriate drugs and the disease is getting worse, fungal infection should be suspected. In addition to revealing additional lung lesions, the CT chest assists in diagnosis. The diagnosis is made by examining the bronchopulmonary lavage aspirate under a microscope. In certain situations, a reverse halo sign (RHS) is preferred over a CT scan since it is a reliable indication of pulmonary Mucormycosis [51]. In another study of patients with lung Mucormycosis, presence of RHS is common on all of them. Symptoms were centrilobular nodules, bronchial wall thickening, petribronchial consolidation with *Aspergillus* in it [52].

Early treatment due to early diagnosis is very important in the disease. According to recent studies, more efficient results can be obtained with antifungal therapy, surgical debridement of necrotic tissue, and combined treatment with reversal of the underlying disease. Isavuconazole, which has recently started to be used in treatment, closes the gaps in the treatment of patients with liver failure and kidney disease. More studies are needed for complex antifungal therapies. Due to a paucity of clinical studies, adjuvant treatments are likewise not well supported [20].

Reversal of underlying disease

In the treatment of patients with Mucormycosis, it is very important to prevent or reverse the underlying defects of the host defense. Immunosuppressive drugs, especially corticosteroids, should be administered in the lowest possible doses or the use of drugs should be discontinued. Treatment with aggressive measures that restore normal acid-base status and euglycemia rapidly are vital for diabetics with ketoacidosis.

Surgical management

With Mucormycosis, blood vessel thrombosis and tissue necrosis may limit the penetration of antifungal agents into the infected tissue. Debridement of necrotic tissues and complete treatment of Mucormycosis are criticalSurgery is an independent variable in logistic regression for a favourable treatment outcome. Patients who underwent surgical debridement for Mucormycosis had a much lower mortality rate than those who did not. The timing and extent of surgical debridement required to maximize Mucormycosis outcomes have not been fully defined.

Salvage therapy

For patients with polyene therapy-resistant or intolerant Mucormycosis, posaconazole or deferasirox are appropriate treatment options. There is a lot of clinical data on posaconazole. If the disease is being treated with Deferasirox, the treatment should be administered for 2-4 weeks. Because deferasirox toxicity increases after 4 weeks of treatment, especially in non-iron-loaded primates. on the contrary, it is quite safe to use posaconazole for years in the treatment. Patients with persistent neutropenia may

benefit from mobilizing granulocytes mobilized by granulocyte colony stimulating factor until their condition improves. In refractory non-neutropenic patients, administration of interferon-y or granulocyte macrophage colony stimulating factor may have a synergistic effect on the antifungal effect and host response.

It is treated with antifungals, may eventually require surgery. Amphotericin B (ampho-B) is an antifungal intravenous injection which must be administered every day for up to three weeks to patients diagnosed with Mucormycosis. There are two forms of the drug available: standard amphotericin B deoxycholate and liposomal amphotericin. This injection costs 3,500 rupees a dose. In order to control diabetes, it is recommended to discontinue immunomodulatory drugs and reduce steroid useTreatment comprises a normal saline (IV) infusion before to the amphotericin B infusion and antifungal medication for at least 4-6 weeks to maintain sufficient systemic hydration. Doctors emphasize the importance of monitoring hyperglycemia and blood sugar, especially in diabetics, after COVID-19 treatment. Steroids should be used at the right time, in the appropriate dose and duration. The treatment of COVID patients with Mucormycosis requires a versatile teamwork of microbiologists, dentists, ophthalmologists, surgeons, neurologists, ENT specialists, internists.

Antifungal Therapy

The existence of clinical studies with antifungal agents in the treatment of black fungus is one of the most difficult issues for clinicians to choose an antifungal agent (Table 1).

A Mumbai-based biopharmaceutical company, Bharat Serums and Vaccines Limited authorised by The Drug Controller General of India, to utilize the anti-fungal medication.

Novel Iron Chelators

The significance of iron metabolism in the development of Mucormycosis recommends the use of iron chelators as an adjuvant antifungal treatment. scientists investigated two experimental iron chelators against *R. oryzae* in-vitro conditions. Unlike deferoxamine, other iron chelators hindered organisms from absorbing iron and inhibited their in vitro development in the presence of iron. Furthermore, in guinea pigs, deferoxamine dramatically worsened common *R. oryzae* infection, although one of the other chelators had no effect on infection in vivo [53]. The potential for use of this iron chelator in combination with different antifungal agents in treatments is being investigated by scientists.

Other Adjunctive Therapies

Hyperbaric oxygen can be used in the treatment of Mucormycosis. It has been reported that hiberbaric oxygen may be beneficial in the medical antifungal and surgical treatment of Mucormycosis, especially in people with rhinocerebral disorders [54, 55]. Hyperbaric oxygen supports neutrophils ability to kill organisms by increasing their oxygen pressure. In addition, the high oxygen pressure stops fungal spores from germinating in vitro and mycelium from growing. The role of cytokinin in the treatment of Mucormycosis has not yet been clarified. Cytokines, granulocyte-macrophage colony stimulating factor, and gamma interferonall stimulate phagocytic activity. Increased activity of phagostites also increases their ability to kill Mucormycosis agents.

Excess zinc and antibiotics behind black fungus outbreak

Zinc supplements are recommended for the rapid recovery of different diseases and for the strengthening of the immune system. The zinc component also aids in strengthening the immune system and activating over 300 enzymes. Studies showed that zinc may be a growth factor for fungi, particularly Mucormycosis, and if it is removed from the diet, the survival of the fungus will be difficult. Scientists focus on investigating the role of zinc supplement intake, excessive steam use and antibiotics used in the treatment of COVID-19 in the black fungus epidemic. Antibiotics Carbapenem, Doxycycline, and Azithromycin

in combination may raise the infection risk. If excessive use of steam damages the sensitive mucus layer and causes burns from time to time, it may affect the natural defense and cause fungal growth. 10%-20% of Mucormycosis cases detected in India were caused by these burns [56].

Other fungal infections in COVID 19 patients

In comparison to western countries, Mucor inflicted the most havoc in India.. Along with COVID-19, there is an increase in different fungal infections such as candidiasis and aspergillosis. Fungi are difficult to diagnose in lung infections. Fever, shortness of breath and cough caused by COVID-19 are also seen in fungal infections, which makes diagnosis and diagnosis difficult. Clinicians should suspect fungal infections when they encounter respiratory failure during the treatment of COVID-19 patients. To include suitable therapy, bronchopulmonary lavage and fungal pathological investigation are required [57].

Prevention of Mucormycosis

Oral hygiene is very important in hospital environments and should be maintained by gargling with povidone-iodine mouthwashes. While giving oxygen to the patient, sterile humidification water should be used and care should be taken to avoid leakage from the humidifiers (**Fig. 5).**

More steroids than necessary should not be used in blood sugar control. Unnecessary use of antifungals and broad-spectrum antibiotics has a negative impact on the normal flora This situation prepares the environment for the growth of unwanted microorganisms. Excessive use of antibiotics and antifungals should be avoided. After discharge, N-95 mask should be used when going out. Necessary hygiene conditions should be provided by taking care to ensure that the environment in the house is free from dust and moisture. Regular control of blood sugar should be ensured. Construction sites and fields should be avoided as much as possible. If dealing with soil or gardening, masks, boots and rubber gloves should be used. Stay indoors as much as possible and exercise regularly. .During the recovery period after COVID, emergency medical help should be sought in complaints such as black discoloration of the nose or palate, headache, pain in the sinuses, numbness, decreased vision/double vision, toothache, bloody nasal discharge, nasal discharge.

Conclusion

The mortality rate of Black fungus or Mucormycosis fungal infection is very high and is estimated upto 50%. It is a disease that is rare but poses an important burden on immune compromised patients. This fungal infection develops in COVID-19 patients during treatment or after they are discharged.. Newly developed medications have several pathogeneses, but the cure to Mucormycosis is still a challenge. Several methods have delayed the mortality but still poses a challenge in curing mucorales. The management of Mucormycosis depends on underlying factors such as injection of antifungal agents, surgical intervention, and timely dosage of antifungal therapy. Immunology and metabolic profiling are the way to approach this black fungus i.e Mucormycosis. With early diagnosis of Mucormycosis, very serious complications can be prevented.

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Conflict of Interest

There is no conflict of interest

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Table 1. Antifungal therapies for black fungus.

Antifungal	Recommended dosage mg/kg/day	Pros	Cons
Amphotericin B	1.0-1.5	50 years' experience	High Toxicity Poor CNS penetration
Amphotericin B lipid complex	5-7.5	Less toxic than AmB	Inferior CNS penetration No comparative clinical data published
Liposomal amphotericin B	5-10	Less toxic than AmB Improved CNS penetration	Resistance seen in individual isolates; Most expensive

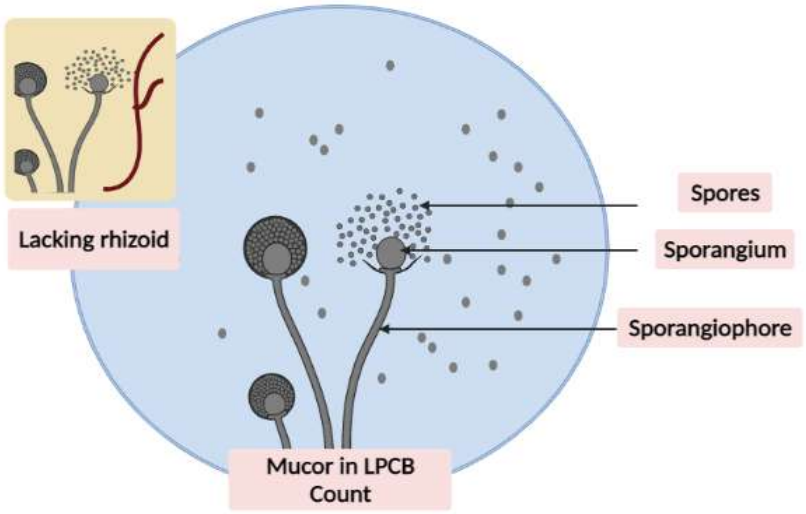

Fig. 1 Mucormycosis under LPCB mount.

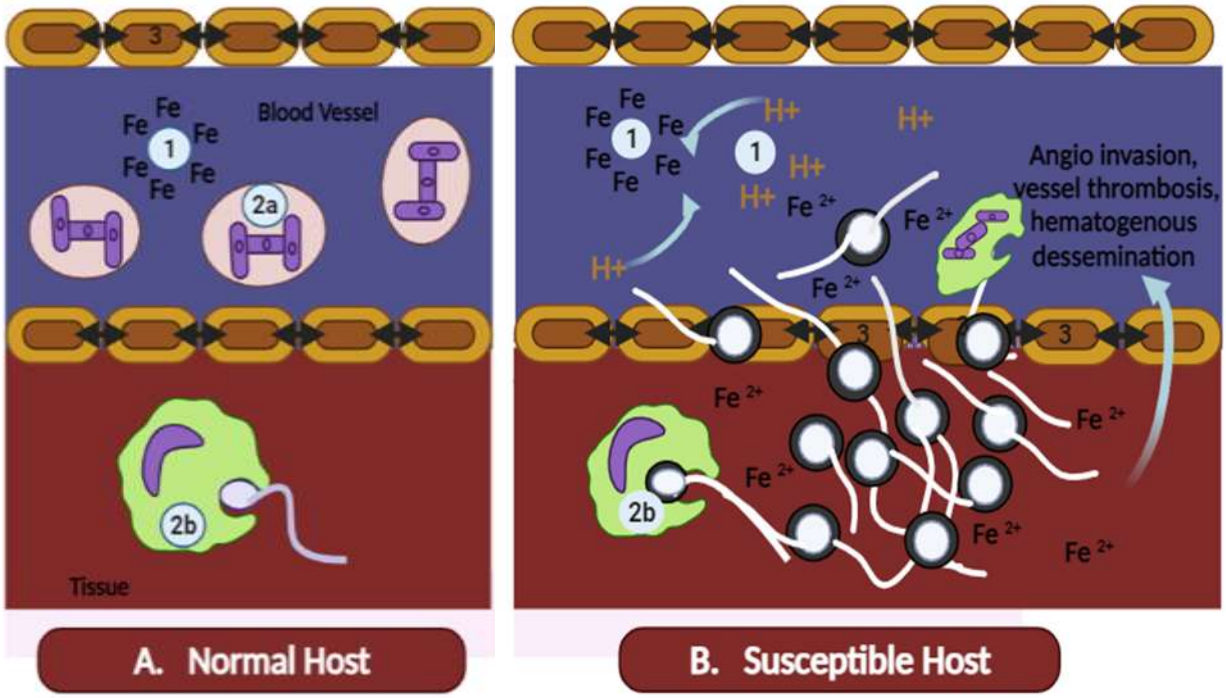

Fig. 2 Host defense mechanisms against Mucormycosis

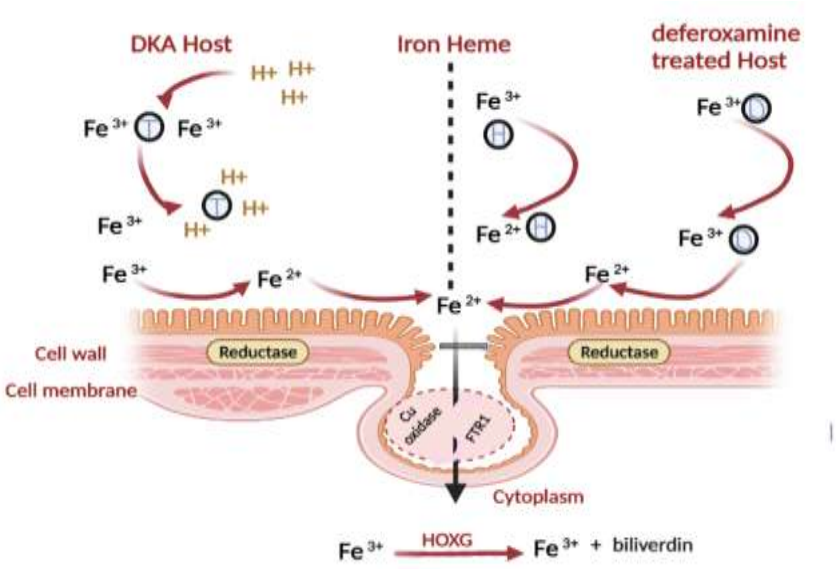

Fig. 3 Iron assimilation mechanisms against Mucormycosis

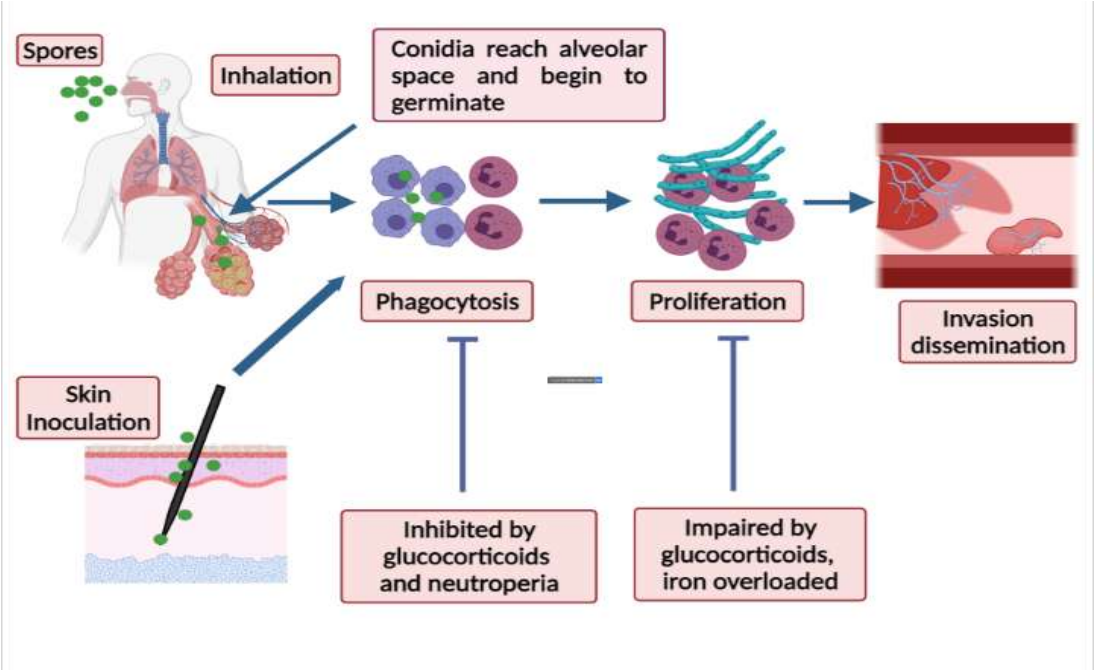

Fig. 4. Diagnosis of Mucormycosis

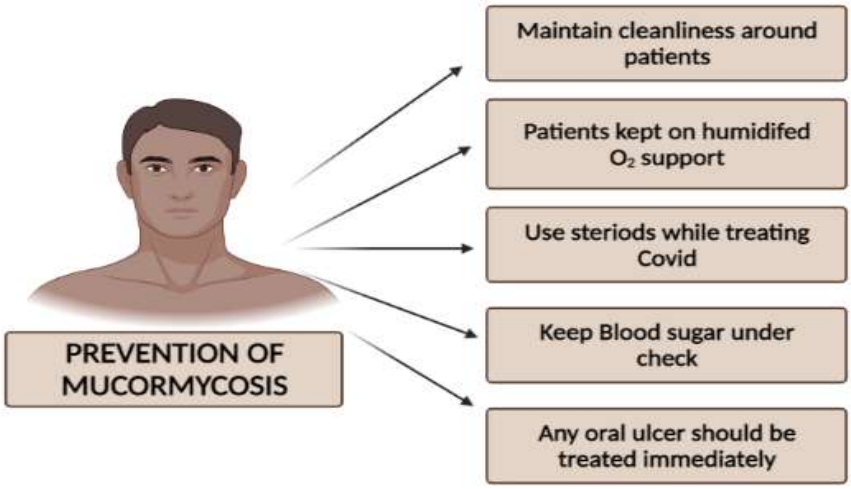

Fig. 5 Steps of prevention of Mucormycosis