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Important Fungal Diseases, Immunity, and Therapeutics

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ABSTRACT

Fungal infections today are among the most difficult diseases to manage in humans. Some fungi cause disease in healthy people, but most fungal infections occur in individuals already experiencing serious illness, and frequently jeopardize the success of the newest medical advances in cancer care, solid organ and hematopoietic stem cell transplantation, neonatal medicine, autoimmune disease therapies, trauma and intensive care, and sophisticated surgery. Little is known about the precise mechanism involved in immunity to fungal infections. Researchers discovered that fungal prostaglandins deactivate immune cells, preventing them from destroying the infection. Fungi are known to make molecules similar to those of our own immune system. Scientists found that the fungus molecules weaken the immune system, which is essential in stopping infections. Fungal infections are more common in immunocompromised patients, including those receiving corticosteroids. Some researchers reported that using topical corticosteroids in keratitis was associated with worse visual outcomes in fungal keratitis cases. The number of fungal infections is increasing due to higher numbers of immunocompromised patients. Mammalian steroid hormones are toxic to fungi. Mucormycosis has been called one of the "most feared infections in all infectious diseases." Fungal infections escalate with the duration of corticosteroid therapy and cumulative corticosteroid dose. Aspergillosis is a disease caused by Aspergillus, a common mold that lives indoors and outdoors. "Invasive Pulmonary Aspergillosis-mimicking Tuberculosis". "Chronic fibrosing pulmonary aspergillosis: a cause of 'destroyed lung' syndrome"

Keywords: *Coccidioides immitis; Aspergillus fumigatus; Histoplasma capsulatum; Blastomyces dermatitidis; Cryptococcus neoformans, Candida albicans,* Pulmonary mycosis, Leukemia, Neutropenia, Gastrointestinal mycosis, Liposomal amphotericin B

INTRODUCTION

They are common in immunocompromised patients, as reflected in their chemotherapy, acquired immune deficiency syndrome, and/or organ transplantation (1).

Invasive fungal infections represent a global problem resulting in 1.7 million deaths every year (2).

The recent annual incidence of invasive aspergillosis, candidiasis, and mucormycosis is over 300,000, 750,000, and 10,000 cases, respectively (3).

The incidence of mucormycosis may exceed 900,000 cases per year after the inclusion of Indian data estimates (4).

Furthermore, these infections are associated with high mortality rates. The epidemiology of invasive fungal infections usually focuses on specific areas. The lack of available global data leads to a broad range of mortality rates, e.g., 30%–95% and 46%–75% in invasive aspergillosis and candidiasis, respectively (5).

The overall incidence of disseminated scedosporiosis and fusariosis is one or six cases per 1000 hematopoietic stem cell transplant recipients. (6,7)

Currently, four antifungal drug classes are used by clinicians and veterinarians for systemic treatment (8).

These classes target different parts of the fungal cell. First, the polyene class includes the heptaene amphotericin B (AMB), which interacts with ergosterol, the major part of the fungal cell membrane. AMB is highly fungicidal against *Candida* genera and *Aspergillus fumigatus* and *A. flavus* (9,10).

Second, first- and second-generation of triazoles disrupt the ergosterol biosynthesis in the lanosterol demethylation step. Generally, triazoles exhibit the fungistatic effect against yeasts but are fungicidal for *Aspergillus* spp. (11).

Echinocandins block the synthesis of β-d-glucans located in the fungal cell wall. Echinocandins are fungicidal against Candida spp. and fungistatic against *Aspergillus* spp. (12).

The overuse of antifungal agents increases the opportunistic pathogen resistance (13).

The World Health Organization has identified this type of antimicrobial resistance as one of the dominant threats of 2019 (14).

In this work, we reviewed the important approved and selected experimental antifungal drugs. Immunomodulatory therapies, covering both molecular and cell-based therapies, were not the subject of this manuscript.(15,16)

Similarly, the application of mycoviruses or therapeutic enzymes to degrade fungal biofilms or cell wall structures has not been included in the present communication and can be found elsewhere (17,18).

In humans, Aspergillus fumigatus is the most common and life-threatening airborne opportunistic fungal pathogen, which is particularly important among immunocompromised hosts [19]. Inflammatory mediators released by alveolar macrophages lead to the recruitment of neutrophils, which can eliminate the hyphae [20].

Immunity

Immunity is concerned with resistance to infection. The non-self is usually the life-threatening infectious microorganisms, but sometimes it may be tissue grafts taken from other individuals such as the kidney or a piece of skin.

Innate Immunity

Innate Immunity is a form of nonspecific host defense against invading bacteria. It is natural or “innate” to the host, depending, in part, on genetics. Adaptive Immunity. Adaptive immunity, also called acquired immunity. It is mediated by either B-cells (antibodies) or T-cells (cell-mediated immunity). As a core function, it recognizes antigenic molecules where antigens can be “foreign” or “self,” and against that, cytokines (messengers) are produced. It generally takes 7-10 days to mobilize on the first encounter. It mobilizes much faster on a second encounter (memory). They use antigen recognition molecules, antibodies on B-cells (BCRs), and T-Cell Recognition (TCR) on T-cells. Major Histocompatibility antigens (MHC on antigen-presenting cells). Adaptive immunity can be active or passive. The B or T-cell encounters the antigen for which it is specific. Reaction with the antigen causes cytokines to be produced. Cytokines affect other cells and the cell that produced the cytokine. The cell proliferates into a clone of cells all with the same specificity as the original cell. Thus, the response to the antigen is augmented. Active Immunity: The immunity that results from exposure to an antigen results in natural infection, Vaccination, and passive immunity. Immune components from an exposed individual are transferred to an individual without immunity. Usually antibodies. Occasionally, cellular Cytokines. Cytokines include chemokines, interferons, interleukins, lymphokines, and tumor necrosis factors, but generally not hormones or growth factors (despite some overlap in the terminology). Cytokines are produced by a broad range of cells, including immune cells like macrophages, B-lymphocytes, T-lymphocytes, and mast cells, as well as endothelial cells, fibroblasts, and various stromal cells; a given cytokine may be produced by more than one type of cell [21,22].

Cytokines are a variety of soluble proteins secreted by monocytes, lymphocytes, and other cells that exert profound effects on lymphocyte proliferation and terminal differentiation. These soluble proteins include monokines produced by monocytes, interleukins produced by leukocytes (lymphocytes), and lymphokines produced by T-lymphocytes. These biologically active substances are collectively known as cytokines. They are not specific to antigens. The cells of the Immune system express a vast array of surface molecules important in cellular differentiation and cell-to-cell communication. They are referred to as CD (nomenclature - Cluster of differentiation numbers, more than 250 have been identified). These surface molecules are helpful for cellular identity. The cells of the immune system express a vast array of surface molecules important in cellular differentiation and cell-to-cell communication. When T-cells pass through these areas, they are “educated” by the process of positive and negative selection. Involves MHC Class I and II expression in the cells in the thymus.

T-Lymphocytes.

Most fungi are highly immunogenic and induce strong antibody and T-cell-mediated responses, which can be detected by serology and delayed-type hypersensitivity skin reactions. Antibodies against fungi may be found in the sera of many normal people, as well as those who have overt infections. In the presence of clinical fungal infections, e.g., due to Aspergillus fumigatus, the amount of antibody may be so great as to be readily demonstrated by precipitin tests. Although there is considerable evidence to implicate such antibodies in the pathogenic effects of pulmonary fungal infections, there is no evidence that they hinder their spread once infection is established. However, the very fact that patients with immunoglobulin deficiency diseases are so unduly prone to Candida infections indicates that antibodies must play some part in protecting against initial or reinfection of 60-70% of peripheral lymphocytes. Formed in Para cortical areas of lymph nodes. T-Cells express as TSR. Paracortical areas of lymph nodes.

T-Cells Express TCR

Recognizes linear epitopes, presented by an Antigen Presenting Cell (APC) in conjunction with MHC. Non-covalently bound to the CD3 complex, a non-variable protein CD3 does not bind to antigens, but is involved in signal transduction. Each T-cell Express TCR of one structure and specificity. Demonstration of TCR gene rearrangement is a marker for T-cells. Capable of recognizing specific antigens, when expressed on the surface of Antigen Presenting Cells (APC), in conjunction with Major Histocompatibility (MHC) antigens. Two types of T-Cells: CD4+ T helper (Th) cells recognize antigen only in the context of MHC class II antigens, and CD8+ T Cytotoxic (TCT) cells recognize antigen only in the context of MHC class I.

CD4+T-Lymphocytes

Master regulator (60% of peripheral T-cells), recognizes antigen only in the context of MHC class II antigens on APCs (Class II restricted). Through cytokines, it can influence the function of all other cells of the immune system. Two subsets have been recognized: Th1 (T helper 1), Th2 (T helper 2).

Cytotoxic-T-Cell (CD8+Tct)

An effector cell recognizes antigens only in the context of MHC Class I antigens present on all nucleated cells (Class I restricted). Activated CTL kills target cells (i.e., virus infected cell, tumor cells, etc.). Cytotoxic T-cell Produces cytokines of the Th1 cell type.

B-Lymphocyte

B lymphocytes, named after their site of origin in the bursa of Fabricius in birds or in the bone marrow in humans, form the basis for humoral immunity by their production of Immunoglobulins (IgGs). B-cell disorders are divided into defects of B-cell development/immunoglobulin production (Immunodeficiencies) and excessive/uncontrolled proliferation (Lymphomas, Leukaemias).

Immunity to Fungi. Little is known about the precise mechanism involved in immunity to fungal infections. Dermatophytes are usually restricted to the non-living keratinized component of skin, hair, and nails. Immunity in Subcutaneous Mycosis Saprophytic fungi, which can cause chronic nodules or ulcers in subcutaneous tissues following trauma Eg/ Chromomycosis, Sporotrichosis, Mycetoma. S. schenckii complex is composed of closely related fungi that cause sporotrichosis. These organisms are an interesting model to study the biochemical, genetic, molecular, and physiological basis of cell differentiation and morphogenesis (23,24).

Moreover, some studies have indicated that the immune response of the host determines the degree of invasion [25].

The innate immune response plays a key role in establishing an antiSporothrix protective response [26].

Phagocytosis by macrophages and neutrophils, as well as the production of reactive oxygen species, are mechanisms by which cells of S. schenckii are eliminated [27].

Immunity to Cryptococcus neoformans

Cryptococcus neoformans is an invasive fungus that causes cryptococcosis. Cryptococcus neoformans produces polysaccharide capsules, which inhibit phagocytosis. This helps to escape from the opsonic effect of complement and antibodies.

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Immunity to Histoplasma capsulatum.

Histoplasma capsulatum is an obligate intracellular pathogen that evades macrophage killing by entering the cell via CR3 and then altering the normal pathway of phagosome maturation, in parallel to the strategies of intracellular bacteria such as Mycobacterium tuberculosis (28).

Differential recognition of H. capsulatum by macrophages and DCs may trigger unique signalling cascades. (29)

The cells recognize Pathogen-Associated Molecular Patterns (PAMPs) present in the fungal surface, like galactomannan and β-1,3-glucan among others, through Pathogen-Recognition Receptors (PRR) such as Toll-like receptors (especially TLR-1,−3,−4, and-6), the C-type lectin receptor Dectin-1 (30).

Aspergillus recognition leads to the generation of proinflammatory cytokines like IL-1α, IL1β, TNF-α, IL-8, and MIP-1α by activation of the NFkB and inflammasome pathways (31,32).

Granulomas are a sign of control of infections and are composed of macrophages and giant multinucleated cells that contain cryptococcal cells, as well as CD4+ T-cells (33).

Macrophages also infiltrate microbial infection sites in response to various inflammatory signals (34).

Proinflammatory cytokines (e.g., interferon-γ (IFN-γ)) guide the polarization of M1 macrophages, whereas Interleukin (IL)-4 mediates the development of M2 phenotypes (35).

Immunity to Candida albicans

Animals can be immunized actively and are then resistant to disseminated candidiasis. Human sera often contain IgG antibodies that can clump Candida albicans, in-vitro, and may be candidacidal. The basis of resistance to Candida is complex and incompletely understood.

Candida albicans conceals the beta-glucans of their cell wall, which would otherwise be efficiently recognized by host dectin-1 underneath an external coat of mannan, a molecule that is considerably less immune-reactive. The cutaneous fungal infections are self-limiting, and recovery is associated with certain limited resistance to reinfection. Resistance is based on cell-mediated immunity since patients develop DTH reactions, fungal antigens, and chronic infections associated with the lack of these reactions. T-cell immunity is also implicated in resistance to other fungal infections.

Immunity to Blastomyces dermatitidis.

The principal host defence mechanisms against B. dermatitidis have not been clearly defined. The fungal cells activate the complement system by both classical and alternative pathways, and antibodies directed against a glucan component of the cell wall have been identified.

Fungal Diseases

Fungal pneumonias can resemble COVID-19

Coccidioidomycosis, histoplasmosis, and blastomycosis, etc fungal diseases, produce fever, cough, and shortness of breath, similar to COVID-19 and bacterial pneumonias (36).

People are infected by inhaling fungal spores in the air. Physicians have to consider fungal pneumonias as a cause of respiratory illness, especially if the COVID-19 test is negative. It is predominant to note that these fungal diseases occur at the same time as COVID-19 (37, 38).

Pneumonia is the leading infectious cause of death in developed countries.

Respiratory diseases caused by Fungi

Diabetes mellitus, chronic alcoholism, leukaemia, treatment with corticosteroids and immunosuppressive drugs, and radiotherapy are the predisposing factors. Tissue damage, necrosis, and the elimination of a normal bacterial flora by antibiotics may also facilitate fungal infection. Allergic reactions to fungi may cause bronchial asthma (*Aspergillus fumigatus*), Allergic alveolitis, etc.

A. Pulmonary aspergillosis--(Green fungus)

A cause of "destroyed lung syndrome."

Aspergillus species constitute the second most common cause of hospital-acquired fungal infections after Candida. It is found wherever organic debris occurs, especially in soil, decomposing plant matter, household dust, building materials, some foods, and water. It is almost impossible to avoid the daily inhalation of Aspergillus spores. "It's fairly uncommon, but still life threatening," Aspergillosis is a disease caused by Aspergillus, a common mold that lives indoors and outdoors. "Invasive Pulmonary Aspergillosis-mimicking Tuberculosis". "Chronic fibrosing pulmonary aspergillosis: a cause of 'destroyed lung' syndrome".

Respiratory diseases caused by *Aspergillus fumigatus*

Allergic Bronchopulmonary Aspergillosis (ABPA) - causes shortness of breath, coughing, and wheezing.

Invasive Aspergillosis - People with weakened immune systems, like cancer patients and AIDS patients, are more likely to get invasive aspergillosis. If invasive aspergillosis goes untreated, it can lead to infectious pneumonia.

Aspergilloma - People with tuberculosis are more likely to get Aspergilloma. Exposure to the fungus can lead to the development of a fungal growth called a fungus ball.

Chronic pulmonary aspergillosis - People with lung diseases, such as tuberculosis, chronic obstructive pulmonary disease (COPD), are at risk of Chronic pulmonary aspergillosis.

B. Respiratory diseases caused by *Candida auris* (The new superbug*)*

Occasionally, in debilitated subjects, oral thrush extends into the respiratory tract to involve the bronchi or lungs. Candida infection may be a secondary invader of the lungs, where pre-existing disease is present (e.g., T.B. or cancer). Candida pneumonia is a rare infection of the lungs, with the majority of cases occurring secondary to haematological dissemination of *Candida* organisms from a distant site, usually the gastrointestinal tract or skin (39).

Candida auris enters the bloodstream and causes serious invasive infections. This yeast is often resistant to antifungal drugs and difficult to treat. Ambulatory, post-covid patients with corticosteroid therapy, central venous catheter, or other lines or tubes entering their body, or who have previously received antibiotics or antifungal medications, appear to be at the highest risk of infection with this yeast.

COVID-19-Associated Black Fungus

An Underestimated Complexity

Black fungus is Mucormycosis. It causes chest pain, unilateral pain of the face, toothache, discoloration over the nose, and breathlessness. Delay in treatment can be exceptionally alarming. Black fungus is a rare but aggressive fungal infection. Black fungus cases are more in hot tropical countries because the environment is ideal for these spores present in the air to grow. Our breath makesthe mask moist, which becomes a potentially sound place for the fungus to grow. "Black fungus is the crossing of COVID-19 and uncontrolled diabetes mellitus in the pandemic. COVID-associated aspergillosis (CAPA) and COVID-19-associated mucormycosis (CAMCR) cases are well registered. Physicians are suspicious about (COVID-19-associated mucor mucormycosis) CAMCR, especially if rhino-orbital or rhino-cerebral presentations are noted in a severely ill patient with COVID-19 and Diabetes Mellitus.DM (Diabetes Mellitus) patients with COVID-19 develop craniofacial pain without a bump. Offensive-smelling nasal extravasate with headache and foul halitosis in a diabetic and COVID-19 patient should be considered exceedingly suspicious of mucormycosis. Black fungus spreads to the eyes and causes blindness. The brain causes headaches and seizures.

Increased spread of White Fungus during the COVID-19 pandemic--

White fungus cases are fewer compared to black fungus. Symptoms are similar to those of COVID-19 –cough, headache, breathlessness, and chest pain. White fungal infection caused by a yeast called Candida. Covid-19 patients are vulnerable to white fungus as it affects the lungs and symptoms are similar that of coronavirus. *Tremela fuciformis* is commonly known as snow fungus, snow ear, silver ear fungus, and white jelly mushroom. White fungus infection can spread very easily in the lungs, kidneys, intestines, stomach, and other organs. Immune-mediated pathways contribute to the pathogenesis of COVID-19-associated candidiasis (CAC). The single-cell analyses of bronchoalveolar lavages from critically ill patients with COVID-19 showed an abundance of monocyte-derived macrophages (40).

An increased peripheral neutrophil-to-lymphocyte ratio was also observed in severe cases of COVID-19. (41)

The increased cells may contribute to tissue damage and the severity of the disease. (42)

Increased spread of Yellow Fungus during the COVID-19 pandemic-

Mucor septicus produces Yellow fungus infection. Yellow fungal infection initiates internally. It is more serious and deadly than black fungus and white fungus.

Histoplasma capsulatum

Histoplasma capsulatum is endemic to the Ohio, Missouri, and Mississippi River valleys in the United States. Internationally, the fungus is predominantly found in river valleys in North and Central America, eastern and southern Europe, and parts of Africa, eastern Asia, and Australia. *Histoplasma capsulatum* causes histoplasmosis. It is a systemic disease, mostly of the reticulo-endothelial system, manifesting itself in the bone marrow, lungs, liver, and spleen. In fact, hepatosplenomegaly is the primary sign in children, while in adults, histoplasmosis more commonly appears as pulmonary disease. This is one of the most common fungal infections. The ecological niche of H. capsulatum is in blackbird roosts, chicken houses, and bat guano. Typically, a patient will have spread chicken manure around his garden and, 3 weeks later, will develop a pulmonary infection. Histoplasmosis is a significant occupational disease in bat caves in Mexico when workers harvest the guano for fertilizer. In the endemic area, the majority of patients who develop histoplasmosis (95%) are asymptomatic. The bloodstream may be invaded, leading to metastatic lesions in the liver, spleen, and lymph nodes. Pulmonary histoplasmosis may produce pathological changes similar to those of tuberculosis. Diagnosis needs to be established through histopathology, including fungal stains of granulomas, and/or cultures from appropriate specimens. Treatment with itraconazole leads to an excellent outcome in the majority of patients. It is, therefore, indicated that clinicians/scientists be more aware of the clinical manifestations, laboratory diagnosis, and risk aspects of histoplasmosis so that patients can commence with medical therapy at the earliest, and unnecessary complications can be avoided.

Coccidioides immitis.

The dimorphic fungus Coccidioides causes coccidioidomycosis, also known as San Joaquin Valley fever, which is endemic to the arid regions of the Western Hemisphere. Coccidioides was first discovered by a medical intern in 1892 and was later named *Coccidioides immitis.* Coccidioidomycosis has a wide spectrum of clinical manifestations, from asymptomatic infection to fatal disease. Blastomycosis is a fungal infection caused by Blastomyces dermatitidis. It presents as a pulmonary infection after the inhalation of spores, and it may be either asymptomatic or have severe life-threatening complications like acute respiratory distress syndrome.

Blastomyces dermatitidis.

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Common antifungal medicines and treatment

1. **Clotrimazole---**

Facial, skin, fungal infection, Athlete's footJock itch, Ringworm, Vaginal yeast infection

Eg-Lotrimin, Canestin

2. Miconazole---

Vaginal yeast infections, Ringworm, Athlete's foot

Eg--Monistat,Micatin

3. Terbinafine-----

Toe fungal infection--Onycomycosis(Nail fungus), Tinea corporis, and Athlet's foot

Eg-Lamisil

4. Fluconazole----

Nail fungal infection--Systemic Candidiasis, Vaginal Yeast infection, Cryptococcus meningitis

Eg-Difflucan

5. Ketoconazole---

- Dandruff, Seborrheic Dermatitis, Tenia versicolar, Fungal skin infection

Eg--Niziral

6. Nystatin-

Fungal infections on the skin and moist areas. Oral Thrush, Intestinal Candidiasis, Cutaneous Yeast Infection

Eg--Mycostatin

7. Itraconazole---

Nail Fungal Infections, Blastomycosis, Histoplasmosis, Aspergillosis

Eg-Sporanox

8. Amphotericin--B---

Severe life-threatening systemic fungal infection (Highly Potent)

Eg--Fungizone, Abelcet

9. Gresiofulvin----

Tenia capitis(Scalp ring worm), Extensive skin or Nail Fungal Infections

Eg--Griffuvin

10. Econazole---

Ringworm, Athlete's foot, Jock itch, Tenia versicolar

Eg—Spectazole

The management of superficial fungal infections

The most superficial infections are treated with topical antifungal agents. One exception is onychomycosis, which usually requires treatment with systemically available antifungals; the accumulation of terbinafine and itraconazole in keratinous tissues makes them ideal agents for the treatment of onychomycosis. Oral candidiasis in immunocompromised patients also requires systemic treatment; oral fluconazole and itraconazole oral solution are highly effective in this setting. Systemic fungal infections are difficult to diagnose and are usually managed with prophylaxis or empirical therapy. Fluconazole and itraconazole are widely used in chemoprophylaxis because of their favourable oral bioavailability and safety profiles. In empirical therapy, lipid-associated formulations of amphotericin-B and intravenous itraconazole are safer than, and at least as effective as, conventional amphotericin-B (the former gold standard). The high acquisition costs of the lipid-associated formulations of amphotericin B have limited their use.(43)

Conclusion

Most fungi encountered by man are harmless saprophytes, but some species may, in certain circumstances, infect human tissue or promote damaging allergic reactions. Predisposing factors include metabolic disorders, such as diabetes mellitus, toxic states such as chronic alcoholism, diseases such as leukaemia and myelomatosis in which immunological responses are disturbed, treatment with corticosteroids and immunosuppressive drugs, and radiotherapy. Local factors such as tissue damage by suppuration or necrosis, and the elimination of the competitive influence of normal fungal infections. Fungal diseases are managed through a combination of topical, oral, or intravenous antifungals such as clotrimazole, terbinafine, and fluconazole. Superficial infections often use creams, while severe or invasive infections require systemic medication. Prevention involves keeping skin dry, avoiding bare feet in public, and managing underlying conditions.

REFERENCES

1.Pianalto K., Alspaugh J.A. New Horizons in Antifungal Therapy. J. Fungi. 2016;2:26. doi: 10.3390/jof2040026.]
2.Hidden Crisis: How 150 People Die Every Hour from Fungal Infection While the World Turns a Blind Eye. [(accessed on 3 March 2020)];
3.Bongomin F., Gago S., Oladele R.O., Denning D.W. Global and Multi-National Prevalence of Fungal Diseases—Estimate Precision. J. Fungi. 2017;3:57
4.Prakash H., Chakrabarti A. Global Epidemiology of Mucormycosis. J. Fungi. 2019;5:26.
5.Brown G.D., Denning D.W., Gow N., Levitz S.M., Netea M., White T.C. Hidden Killers: Human Fungal Infections. Sci. Transl. Med. 2012;4:165rv13.
6.Guarro J., Kantarcioglu A.S., Horré R., Rodríguez-Tudela J.L., Estrella M.C., Berenguer J., De Hoog G.S. Scedosporium apiospermum: Changing clinical spectrum of a therapy-refractory opportunist. Med. Mycol. 2006;44:295–327. doi: 10.1080/13693780600752507.
7.Nucci M., Anaissie E. Fusarium Infections in Immunocompromised Patients. Clin. Microbiol. Rev. 2007;20:695–704. doi: 10.1128/CMR.00014-07.
8.Carmona E.M., Limper A.H. Overview of Treatment Approaches for Fungal Infections. Clin. Chest Med. 2017;38:393–402
9.Kumar A., Zarychanski R., Pisipati A., Kumar A., Kethireddy S., Bow E.J. Fungicidal versus fungistatic therapy of invasiveCandidainfection in non-neutropenic adults: A meta-analysis. Mycology. 2018;9:116–128. doi: 10.1080/21501203.2017.1421592.
10.Meletiadis J., Antachopoulos C., Stergiopoulou T., Pournaras S., Roilides E., Walsh T.J. Differential Fungicidal Activities of Amphotericin B and Voriconazole against Aspergillus Species Determined by Microbroth Methodology. Antimicrob. Agents Chemother. 2007;51:3329–3337.
11.Geißel B., Loiko V., Klugherz I., Zhu Z., Wagener N., Kurzai O., Hondel C.A.M.J.J.V.D., Wagener J. Azole-induced cell wall carbohydrate patches kill Aspergillus fumigatus. Nat. Commun. 2018;9:3098.
12.Patil A., Majumdar S. Echinocandins in antifungal pharmacotherapy. J. Pharm. Pharmacol. 2017;69:1635–1660.
13.Revie N.M., Iyer K.R., Robbins N., Cowen L. Antifungal drug resistance: Evolution, mechanisms and impact. Curr. Opin. Microbiol. 2018;45:70–76
14.Ten Threats to Global Health in 2019. [(accessed on 3 June 2019
15.Ahmad S., Bhattacharya D., Kar S., Ranganathan A., Van Kaer L., Das G. Curcumin Nanoparticles Enhance Mycobacterium bovis BCG Vaccine Efficacy by Modulating Host Immune Responses. Infect. Immun. 2019;87:1–33.
16.Scriven J.E., Tenforde M.W., Levitz S.M., Jarvis J.N. Modulating host immune responses to fight invasive fungal infections. Curr. Opin. Microbiol. 2017;40:95–103
17.van de Sande W., Vonk A.G. Mycovirus therapy for invasive pulmonary aspergillosis? Med. Mycol. 2019;57:S179–S188. doi: 10.1093/mmy/myy073.
18.Nerva L., Chitarra W., Siciliano I., Gaiotti F., Ciuffo M., Forgia M., Varese G.C., Turina M. Mycoviruses mediate mycotoxin regulation in Aspergillus ochraceus. Environ. Microbiol. 2018;21:1957–1968. doi:

19. Martins N, Ferreira IC, Barros L, Silva S, Henriques M. Candidiasis: predisposing factors, prevention, diagnosis and alternative treatment. Mycopathologia. 2014;177(5):223-40.
20. Bennett RJ. The parasexual lifestyle of Candida albicans. Curr Opin Microbiol. 2015;28:10-7
21. Llewelyn M, Cohen J. Superantigens: microbial agents that corrupt immunity. The Lancet Infect Dis. 2002;2(3):156-62.
22. Kenneth Ryan J, George Ray G, Nafees Ahmed W. Medical Microbiology. 5th Ed.
23. Martínez-Álvarez JA, Pérez-García LA, Flores-Carreón A, Mora-Montes HM. The immune response against Candida spp. and Sporothrix schenckii. Rev Iberoam Micol. 2014;31(1):62-6.
24. Mora-Montes HM, Dantas AD, Trujillo-Esquivel E, de Souza Baptista AR, Lopes-Bezerra LM. Current progress in the biology of members of the Sporothrix schenckii complex following the genomic era. FEMS yeast research. 2015;15(6).
25. Lionakis MS, Netea MG, Holland SM. Mendelian genetics of human susceptibility to fungal infection. Cold Spring Harbor perspectives in medicine. 2014;4(6):a019638.
26. Mantovani A, Sica A, Sozzani S, Allavena P, Vecchi A, Locati M. The chemokine system in diverse forms of macrophage activation and polarization. Trends Immunol. 2004;25:677-86.
27. Viriyakosol S, Fierer J, Brown GD, Kirkland TN. Innate immunity to the pathogenic fungus Coccidioides posadasii is dependent on Toll-like receptor 2 and Dectin-1. Infect Immun. 2005;73(3):1553-60.
28. Abad A, Fernández-Molina JV, Bikandi J, Ramírez A, Margareto J, Sendino J, et al. What makes Aspergillus fumigatus a successful pathogen? Genes and molecules involved in invasive aspergillosis. Rev IberoamMicol.27(4) (2010) 155-82.
29. Lin J-S, Huang J-H, Hung L-Y, Wu S-Y, Wu-Hsieh BA. Distinct roles of complement receptor 3, Dectin-1, and sialic acids in murine macrophage interaction with Histoplasma yeast. J Leukoc Biol. 88(1) (2010) 95-106.
30. Morton CO, Bouzani M, Loeffler J, Rogers TR. Direct interaction studies between Aspergillus fumigatus and human immune cells; what have we learned about pathogenicity and host immunity? Front Microbiol. 3 (2012) 413.
31. Karki R, Man SM, Malireddi RKS, Gurung P, Vogel P, Lamkanfi M, et al. Concerted activation of the AIM2 and NLRP3 inflammasomes orchestrates host protection against Aspergillus infection. Cell Host Microbe. 2015;17:357-68.
32. Viriyakosol S, Jimenez Model P, Gurney MA, Ashbaugh ME, Fierer J. Dectin-1 is required for resistance to coccidioidomycosis in mice. MBio. 2013;4:e00597-12.
33. Meece JK, Anderson JL, Gruszka S, Sloss BL, Sullivan B, Reed KD. Variation in the clinical phenotype of human infection among genetic groups of Blastomyces dermatitidis. J Infect Dis. 2013;207(5):814-22.
34. Saccente M, Woods GL. Clinical and laboratory update on blastomycosis. Clin Microbiol Rev. 23 (2010) 367- 81
35. Viriyakosol S, Jimenez Model P, Gurney MA, Ashbaugh ME, Fierer J. Dectin-1 is required for resistance to coccidioidomycosis in mice. MBio. 2013;4:e00597-12.
36. Shah AS, Heidari A, Civelli VF, Sharma R, Clark CS, Munoz AD, et al. The coincidence of 2 epidemics, coccidioidomycosis and SARS-CoV-2: a case reportexternal icon. J Investig Med High Impact Case Rep. 2020 Jun 4
37. Bertolini M, Mutti MF, Barletta JA, et al. COVID-19 associated with AIDS-related disseminated histoplasmosis: a case reportexternalicon.Int J STD AIDS. 2020 Sep 9
38. Yousef Shweihat, James Perry, III,1 and Darshana Shah, Isolated *Candida* infection of the lung Respir Med Case Rep. 2015; 16: 18–19.
39. Liao, M.; Liu, Y.; Yuan, J.; Wen, Y.; Xu, G.; Zhao, J.; Cheng, L.; Li, J.; Wang, X.; Wang, F.; et al. Single-cell landscape of bronchoalveolar immune cells in patients with COVID-19. Nat. Med. 2020, 26, 842–844.
40. Zheng, M.; Gao, Y.; Wang, G.; Song, G.; Liu, S.; Sun, D.; Xu, Y.; Tian, Z. Functional exhaustion of antiviral lymphocytes in COVID-19 patients. Cell. Mol. Immunol. 2020, 17, 533–535.
41. Giamarellos-Bourboulis, E.J.; Netea, M.G.; Rovina, N.; Akinosoglou, K.; Antoniadou, A.; Antonakos, N.; Damoraki, G.; Gkavogianni, T.; Adami, M.-E.; Katsaounou, P.; et al. Complex Immune Dysregulation in COVID-19 Patients with Severe Respiratory Failure. Cell Host Microbe 2020, 27, 992–1000.
42. Lin J-S, Huang J-H, Hung L-Y, Wu S-Y, Wu-Hsieh BA. Distinct roles of complement receptor 3, Dectin-1, and sialic acids in murine macrophage interaction with Histoplasma yeast. J Leukoc Biol. 2010;88(1):95-106.
43. J F Meis 1, P E Verweij, Current management of fungal infections: Drugs.2001:61

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