



Mucormycosis in COVID-19 Pandemic: Study Involving Tertiary Hospitals in Aurangabad District, India

Pooja Muley ^{a++*}, Himanshu Gupta ^{b#} and Abha Gupta ^{at}

^a Oralcare.co.in, Maharashtra, India.

^b Seth Nandlal Dhoot Hospital, Oralcare.co.in, Maharashtra, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJRID/2023/v14i1277

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/100744>

Original Research Article

Received: 12/04/2023

Accepted: 17/06/2023

Published: 05/07/2023

ABSTRACT

Introduction: An abrupt increase in the mucormycosis patients in India during the COVID 19 pandemic was observed. A collective study was conducted in tertiary care hospitals in Aurangabad. **Materials and Methods:** A retrospective descriptive study was conducted in Aurangabad (Maharashtra), in association with the Aurangabad Municipal Corporation (AMC), oralcare.co.in and SNDH Hospital, Aurangabad. Data was collected by AMC from 3 major tertiary hospitals present in Aurangabad where treatment of Mucormycosis was done from May 2021 to July 2021. The data of total 135 patients with Mucormycosis was received by the AMC were included in the study. It included demographics of the patients, medical and clinical history, history of COVID 19, treatment of COVID 19, type of Mucormycosis, treatment and outcomes of Mucormycosis. **Results:** In the present study, 74.7% of Mucormycosis patients were males. 77.4% of Mucormycosis patients were above 50 years of age. It was seen that about 67% of patients with

⁺⁺Oral Medicine & Radiology Specialist;

[#]Chief Administrator;

^tDirector;

*Corresponding author: E-mail: poojamuley.31@gmail.com;

Mucormycosis had diabetes mellitus as the most common risk factor. About 87.4% of patients had a history of COVID-19. Majority of the patients in the study population were diagnosed with the rhino-maxillary-orbital type of Mucormycosis which is 39%, followed by the rhino-cerebral type-25%. Only 1% patients showed rhiono-nasal -orbital type of Mucormycosis. 30% patients were not categorised into any type. All the patients in the study population received amphotericin B and surgical treatment. About 84.4% patients were discharged after the Mucormycosis treatment. 15.6% patients died during or after the treatment.

Conclusion: Mucormycosis was predominantly seen in male above the age of 50 years, COVID-19 infection and diabetes mellitus was common risk factor for Mucormycosis.

Keywords: COVID-19; mucormycosis; rhino-cerebroorbital; diabetes; health care systems.

1. INTRODUCTION

“The pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS COV 2) has created mayhem all over the world” [1]. “The association of SARS COV 2 with a gamut of opportunistic of fungal and bacterial infections made it more overwhelming for the health care systems globally, especially in the developing countries” [2]. During the second wave of SARS COV2 the surge of covid 19 associated Mucormycosis in India was unanticipated and devastating due to its rapid spread, high morbidity and mortality rates and the limitation of antifungal drugs [3]. In the peak months of Mucormycosis in India (May to July 2021), more than 47,000 cases were reported and the actual figures certainly will be higher [2].

The term ‘Mucormycosis’ was coined by Dr. R. D. Baker, an American pathologist [4]. Mucormycosis is also known as zygomycosis and amongst the lay people it is popular as black fungus. Mucormycosis is an opportunistic fungal infection caused by the organisms, Mucorales, who are active in instigation and speeding the decay of organic materials [5]. It was an infection which was once very rare and affected the immunocompromised individuals. The incidence Mucormycosis varies in the range of 0.003 – 0.005–1.7 million of the population [4,6,7] “But the picture changed spontaneously during the second wave of COVID 19 in India. In India, Mucormycosis was seen in 0.14 per 1000 population, which was about 80 times higher as compared to developed countries” [8].

“Mucormycosis can be classified based on the anatomical site of involvement. It can be classified into rhino-orbito-cerebral (ROCM), pulmonary, gastrointestinal, cutaneous, renal, disseminated and other miscellaneous forms, which include infection of bones, heart, ear, parotid gland, uterus, urinary bladder and lymph”

[9,10]. It was perceived that rhino-orbital cerebral Mucormycosis was the most common disease seen in the post COVID Mucormycosis patients in India, also accounting for the highest mortality [11]. The hallmark of Mucormycosis is tissue necrosis resulting from angioinvasion and thrombosis [4]. “The common symptoms seen in the post COVID Mucormycosis patients were headache, fever, facial swelling(unilateral), orbital cellulitis, palpebral edema, ptosis, chemosis and ophthalmoplegia” [12].

It has been noted that in the developing countries, especially in India the most common predisposing factors were Diabetes mellitus which is contrasting the haematological malignancies and history of transplants in the developing countries[13,14]. Diabetes as a risk factor over 50% cases with Mucormycosis was seen in three different case series in India [15]. Even though mucormycosis was treated with aggressive surgery, still the mortality rate was high.

The present study aimed to study the association between COVID 19 and Mucormycosis, risk factors associated with Mucormycosis and the outcomes of the treatment of Mucormycosis.

2. MATERIALS AND METHODS

A retrospective descriptive study was carried out in Aurangabad (Maharashtra), in association with the Aurangabad Municipal Corporation, oralcare.co.in and SNDH Hospital, Aurangabad. Data was collected by AMC from all the tertiary hospitals present in Aurangabad where treatment of Mucormycosis was done from May 2021 to July 2021. The data of total 135 patients with Mucormycosis was received by the AMC were included in the study. All patients included in the present study were microbiology and or histopathology confirmed cases of

Mucormycosis. All Mucormycosis patients regardless of COVID-19 status were included in the study. The data provided by the hospital was sent in a predefined format provided by AMC for uniform data entry. It included demographics of the patients, medical and clinical history, history of COVID 19, use of steroids in COVID-19 treatment, use of immunosuppressant drugs, oxygen therapy, type of Mucormycosis, treatment of Mucormycosis. Diagnostic endoscopy was done in all patients and KOH testing was done and an RT-PCR for COVID 19 infection confirmation. All patients had a CT, CBCT or MRI of PNS and brain depending on the presentation of the patient. All patients were done all routine blood investigations.

The data of all the patients was not completely filled in all the areas, for such patients the missing data was directly taken from the records of the respective hospitals after the list was received.

3. RESULTS

3.1 Age and Sex Distribution in the Study Population

In the present study, 74.7% of Mucormycosis patients were males and 66% of Mucormycosis patients were females (Fig. 1). 77.4% of Mucormycosis patients were above 50 years of

age and no patient was under 25 years of age. The youngest patient was 27 years old while the oldest was 73 years of age (Fig. 2).

Table 1. Comorbidities in the study population

Comorbidity	No of patients N= 135	Percentage (%)
DM	72	53
HTN	16	12
DM AND HTN	19	14
MORE THAN 2	7	5
OTHER	8	6
NONE	13	10

3.2 Risk Factors Associated with Mucormycosis

In the present study, diabetes mellitus was the most common risk factor seen in 67% of patients with Mucormycosis. 53% were having only diabetes mellitus, 12% were having only hypertension and in 14% both diabetes and hypertension was seen. Patients with more than 2 comorbidities contributed to 5 % of total population. While 6 % patients reported other comorbidities like chronic kidney disease, hypothyroidism, CVSD. About 24% patients reported to have no any co morbidity.

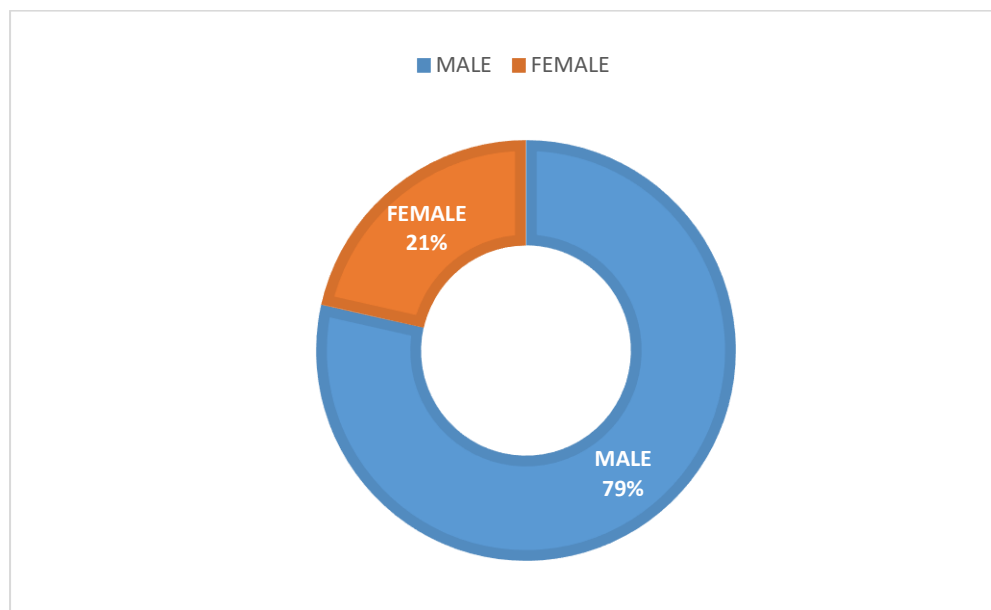


Fig. 1. Sex distribution in study population

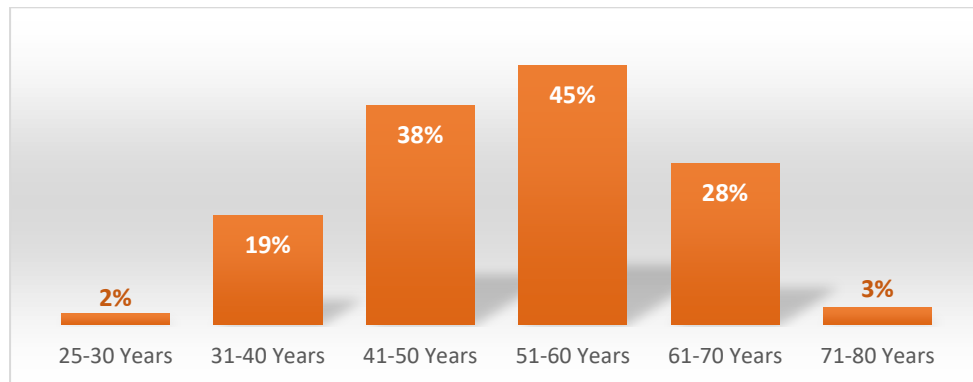


Fig. 2. Age distribution in the study population

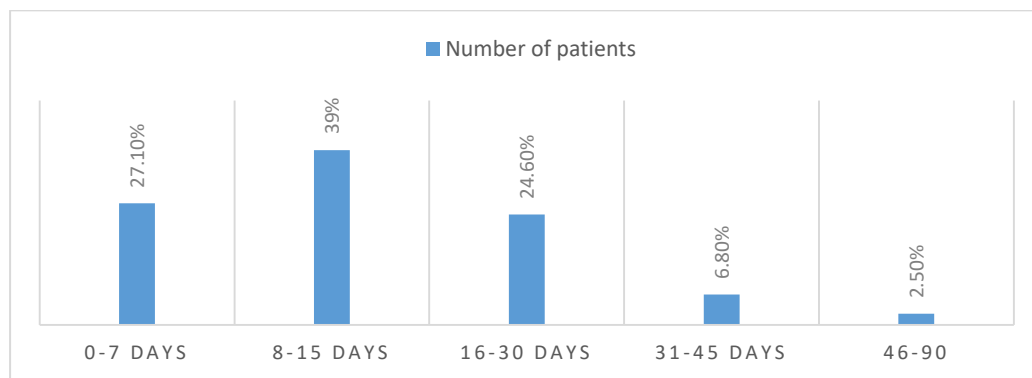


Fig. 3. Gap between COVID-19 treatment and symptoms of Mucormycosis

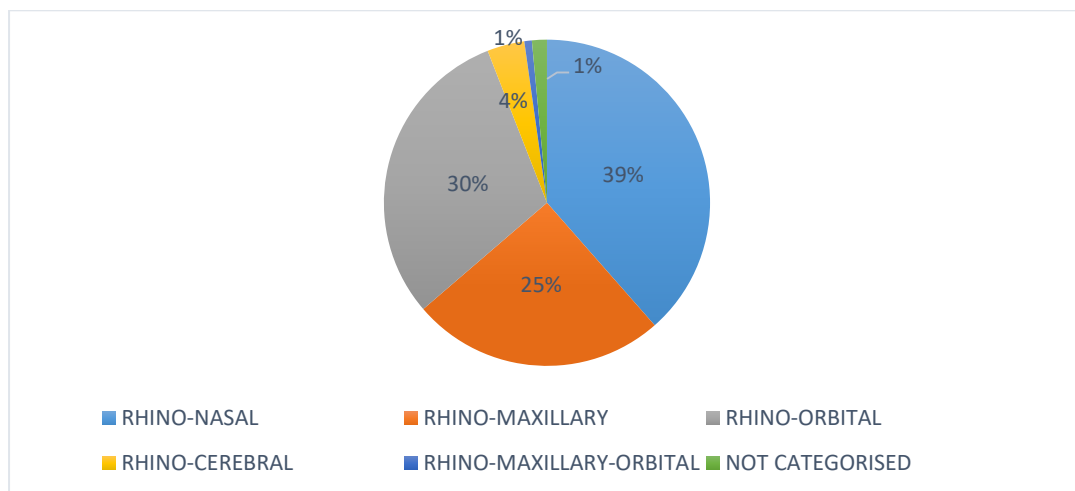


Fig. 4. Type of Mucormycosis seen in the study population

3.3 COVID 19 Infection and Mucormycosis

In the present study, 87.4% of patients with Mucormycosis had a COVID-19 infection while 12.6% patients had no any record of COVID 19 infection. Looking at the treatment of COVID 19,

64.4% patients received oxygen therapy as well as steroids. 13.6% patients had no record of the type of COVID 19 treatment.

In the present study, 80% of patients were present during COVID-19 treatment and within 15 days of COVID-19 infection. No patient with

Mucormycosis was presented after 3 months of COVID-19 infection.

Table 2. COVID-19 status in Mucormycosis patient

Mucormycosis patients	No. of patients (N= 135)	Percentage (%)
H/o COVID-19- positive	118	87.4%
No H/O COVID-19- positive	17	12.6%

3.4 Type of Mucormycosis

The majority of the patients in the study population were diagnosed with the rhino-maxillary-orbital type -39%, followed by the rhino-cerebral type-25%. Only 1% patients showed only rhino-nasal and only rhino-orbital type. 30% patients were not categorised into any type.

Table 3. COVID-19 vaccination status in Mucormycosis patient

Mucormycosis patients	No. of patients (N= 135)	Percentage (%)
Vaccinated	6	4.4%
Non vaccinated	129	85.6%

Table 4. COVID-19 treatment history

COVID treatment	No of patients N= 118	Percentage (%)
O2 and steroid	76	64.4
Only O2 and ICU	14	11.8
Only Steroid	12	10.2
Not known	16	13.6

3.5 Outcomes of Mucormycosis Treatment

All the patients in the study population received amphotericin B and surgical treatment. Multiple surgeries were done to remove all necrotic areas from nose, sinuses, palate, maxilla, pterygopalatine fossa, infratemporal fossa and mandible including orbital extirpation and in case of cerebral involvement, extensive areas were involved.

About 84.4% patients were discharged after the Mucormycosis treatment. 15.6% patients died

during or after the treatment. About 28.8% patients underwent maxillectomy, 35.3% patients underwent orbital extirpation and 6% patients were treated by cerebral surgery.

Out of 15.6% deaths all the patients were diabetics and had extensive involvement including the orbits and cerebral. One patient who was vaccinated died during the treatment. One patient was re-admitted due to complications. 5 patients were discharged against medical advice.

4. DISCUSSION

“Mucormycosis is an uncommon but fatal fungal infection caused by a group of molds collectively called mucormycetes. The mold fungi belong to Rhizopus, Mucor, Rhizomucor, Cunninghamella, and Absidia” [16].

“This fungus by toxic and mechanical modes, impairs the internal lamina of blood vessels. The spores in the after entering the sinus via nose of immuno-compromised patients, starts germinating into various hyphae in the. The pterygopalatine fossa is seen to be the prime reservoir of the fungal hyphae” [16,17]. “Later there is spread of the fungus, causing thrombosis and nerve dysfunction. The pathological manifestation involves blood vessels, cartilage, bone, neural and perineural areas, and often meninges. There is formation of palatine eschars and damages the nasal turbinates due to necrosis. The infection from the sinuses spreads causing osteolysis which consecutively invades the orbital structures. Subsequently the infection spreads to ethmoid sinuses causing involvement of the brain through the retro-orbital path or frontal lobes. As the infection spreads along the regions of the sphenoid sinuses to the neighbouring cavernous sinus, it may cause cranial nerve palsies. The extensive involvement and spread in jugular veins, the cavernous sinus, and the carotid artery may further cause worsening of the patient's state” [18,19].

There has been a sudden surge of Mucormycosis cases in India in the second wave of COVID 19. Many researchers called this as post COVID Mucormycosis [2,20,16]. In the present study a whopping number of 135 patients were operated for Mucormycosis in just one city of India, in just 3 months' duration. 84.4% had a history of COVID 19 infection.

Table 5. Outcomes of Mucormycosis patients

Outcomes of Mucormycosis treatment	N= 135	Percentage
Discharged	114	84.4
Death	21	15.6

It was observed in several reports that India was in forefront in the world for the cases of post COVID Mucormycosis [21-23]. Many studies reported that India has been accounted for by 45,435 cases of Mucormycosis till September of 2021 [24]. The black fungus cases are on the higher side in Gujarat and Maharashtra with around 7109 and 10,139 cases respectively [24].

4.1 Age and Gender

According to the study conducted by Hoenigl, majority of patients were male (78%) and the median age was 55 years (range 10–86) [25]. Priya, P the most commonly affected age-group was that between 41 and 60 year in a Tertiary Care Center in South India [26].

Rao VU in 2021 reported Mucormycosis patients with a mean age of 49.1 years while 71% were aged between 41 and 60 years and most patients were male. Wasiq, Mohammed et al reported that the mean age of the covid 19 associated Mucormycosis study group was 51.16 years with males (69%) and females (31.0) [27].

According to Chavhan et al, 74.7% of Mucormycosis patients were males and 77.4% of Mucormycosis patients were above 40 years of age and male were on the higher side [8].

Moorthy A et al, in 2021 reported that “the incidence of Mucormycosis is not age or gender dependent, and the significantly higher number of males in this study may be a reflection of higher Covid-19 prevalence of males in India” [28].

In the present study, 79% of Mucormycosis patients were males and 77.4% of Mucormycosis patients were above 50 years of age and no patient was under 25 years of age. In the present study, age and sex distribution among Mucormycosis patients was similar to previous studies done except the upper and lower limits of ages of patients, in the present study the age range was(27-73 years).

4.2 Risk Factors and Type Including COVID 19 Infection

“The most common type of risk factor in the Mucormycosis patients was uncontrolled diabetes mellitus along with hematologic disorders, steroid therapy and malnourishment” [29]. “Other risk factors include deferoxamine therapy, overload of iron, and in some cases of drug abuse, stem cell transplants or organ transplant” [16].

Patients who use corticosteroids, tocilizumab and iatrogenic immunosuppression [30] may also develop Mucormycosis. There are other conditions that may increase the risk of developing Mucormycosis, such as renal insufficiency, presenting with HIV or AIDS [31]. “Extreme malnutrition, the use of illegal drugs that involve needles, as well as hepatitis or cirrhosis have all been associated with Mucormycosis” [29].

“As discussed previously, there are multiple possible contributing factors for the development of Mucormycosis among patients with COVID-19 and these include diabetes mellitus, obesity, use of corticosteroid, and the development of cytokine storms” (16). “The triad of SARS-CoV-2, steroid and uncontrolled diabetes mellitus have contributed towards a significant increase in the incidence of angioinvasive maxillofacial Mucormycosis” [32]. “However, the presence of spores and other factors might play a role as well” [33].

Table 6. Prognosis of Mucormycosis patients

Mucormycosis patients	No of patients recovered	No of patients dead	Total
Diabetic patients	76	21	97
Vaccinated patients	5	1	6
Recurrence	1	0	1
Discharged against medical advice	5	0	5

“Pathological changes in the pancreas were observed in patients with severe COVID-19, indicating that SARS-CoV-2 can cause pancreatic injury and this could be one of the reasons why COVID-19 patients have high blood glucose levels with no history of diabetes” [34]. “The vicious cycle of hyperglycaemia and immunosuppression caused by hyperglycemia and steroids, can lead to increase in the colonisation of Mucormycosis” [35].

The relation between “endothelialitis” and COVID-19 is found in various autopsy where severe pulmonary vascular endothelial injury and new vessel growth was seen in the patients who deceased due to COVID-19 [36,37].

According to the study by John, “T.M 98% patients had diabetes mellitus as risk factors for severe COVID-19 of the 35 patients in the study with information on glycemic status, 33 (33/35, 94%) had DM, with a mean HbA1C of 10 (in patients who had an HbA1c value available)” [37].

In a systematic review by Singh et al it was found that “hyperglycemia was the single most important risk factor observed in 83.3% of the patients with Mucormycosis and COVID-19, pre-existing Diabetes mellitus in 80% and concomitant ketoacidosis in 15%” [38].

In the present study, 87.4% of patients with Mucormycosis had a COVID-19 infection while 12.6% patients had no any record of COVID 19 infection. Looking at the treatment of COVID 19, 64.4% patients received oxygen therapy as well as steroids. 13.6% patients had no record of the type of COVID 19 treatment.

In the present study, 80% of patients were present during COVID-19 treatment and within 15 days of COVID-19 infection. No patient with Mucormycosis was presented after 3 months of COVID-19 infection.

4.3 Type of Mucormycosis and Outcome

In the present study majority of the patients in the study population were diagnosed with the rhino-maxillary-orbital type -39%, followed by the rhino-cerebral type-25%. Only 1% patients showed only rhino-nasal and only rhino-orbital type. 30% patients were not categorised into any type.

“The survival rate for rhino-orbito-cerebral disease in patients without any systemic disease

is about 75%; with other diseases is about 20%; and in pulmonary disease is considered to be fatal. Data collected by Suganya et al. (2019) according to the site of infection described the survival rate in different forms of Mucormycosis: rhino-orbito-cerebral Mucormycosis – 45%, focal cerebral Mucormycosis – 33%, pulmonary Mucormycosis – 36%, sinusitis without cerebral involvement – 87%, cutaneous isolated – 90%, disseminated disease – 16%, and involvement of gastro intestinal form – 10%” [39,40].

In the present study it was found that about 84.4% patients were discharged after the Mucormycosis treatment. 15.6% patients died during or after the treatment. About 28.8% patients underwent maxillectomy, 35.3% patients underwent orbital exenteration and 6% patients were treated by cerebral surgery.

5. CONCLUSION

Similar to the reports in India and other countries, COVID 19 associated Mucormycosis cases reported in this study were diagnosed in individuals with diabetes, hyperglycaemic status and with history of previous use of corticosteroids. Identifying these individuals at risk can help the early identification of Mucormycosis. In addition, strict glycaemic control and avoidance of unnecessary corticosteroid in non-severe COVID-19 cases could help in preventing this complicated fungal infection.

CONSENT

It is not applicable.

ETHICAL APPROVAL

The study was approved by the Institutional Ethical Committee of SNDH.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Zhou F, Yu T, Du R, Fan G, Liu Y, Liu Z, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: A retrospective cohort study. *Lancet*. 2020;6736:1–9.

- Available: [https://doi.org/10.1016/S0140-6736\(20\)30566-3](https://doi.org/10.1016/S0140-6736(20)30566-3)
2. Muthu V, Rudramurthy SM, Chakrabarti A, Agarwal R. Epidemiology and pathophysiology of COVID-19-associated Mucormycosis: India versus the rest of the world. *Mycopathologia*. 2021;186(6):739-54. Available: <https://doi.org/10.1007/s11046-021-00584-8>
3. Patel A, Agarwal R, Rudramurthy S, Shevkani M, Xess I, Sharma R, et al. Multicenter epidemiologic study of coronavirus disease-associated Mucormycosis. *India Emerg Infect Dis*; 2021. Available: <https://doi.org/10.3201/Eid2709.210934>
4. Skiada A, Pavleas I, Drogari-Apiranthitou M. Epidemiology and diagnosis of Mucormycosis: An update. *J Fungi*. 2020; 6:E265. Available: <https://doi.org/10.3390/jof6040265>
5. Suganya R, Malathi N, Karthikeyan V, Janagaraj VD. Mucormycosis: a brief review. *J Pure Appl Microbiol*. 2019;13: 161–165. Available: <https://doi.org/10.22207/JPAM.13.1.16>
6. Chander J, Kaur M, Singla N, Punia RPS, Singhal SK, Attri AK, et al. Mucormycosis: battle with the deadly enemy over a five-year period in India. *J Fungi*. 2018;4:E46. Available: <https://doi.org/10.3390/jof4020046>
7. Prakash H, Chakrabarti A. Global epidemiology of Mucormycosis. *J Fungi*. 2019;5:E26. Available: <https://doi.org/10.3390/jof5010026>
8. Chavan RP, Ingole SM, Nazir HA, Desai WV, Kanchewad GS. Mucormycosis in COVID-19 pandemic: Study at tertiary hospital in India. *European Archives of Oto-Rhino-Laryngology*. 2022;5:1-0.
9. Roden MM, Zaoutis TE, Buchanan WL, Knudsen TA, Sarkisova TA, Schaufele RL, Sein M, Sein T, Chiou CC, Chu JH, et al. Epidemiology and outcome of zygomycosis: A review of 929 reported cases. *Clin. Infect. Dis*. 2005;41:634–653. DOI: 10.1086/432579. [PubMed] [CrossRef] [Google Scholar]
10. Jeong W, Keighley C, Wolfe R, Lee WL, Slavin MA, Kong DCM, Chen SCA. The epidemiology and clinical manifestations of Mucormycosis: A systematic review and meta-analysis of case reports. *Clin. Microbiol. Infect*. 2019;25:26–34. DOI: 10.1016/j.cmi.2018.07.011 [PubMed] [CrossRef] [Google Scholar]
11. Hoenigl M, Seidel D, Carvalho A, Rudramurthy SM, Arastehfar A, Gangneux JP, Nasir N, Bonifaz A, Araiza J, Klimko N, Serris A. The emergence of COVID-19 associated Mucormycosis: A review of cases from 18 countries. *The Lancet Microbe*; 2022.
12. John TM, Jacob CN, Kontoyiannis DP. When uncontrolled diabetes mellitus and severe COVID-19 converge: The perfect storm for mucormycosis. *J. Fungi*. 2021;7: 298. Available: <https://doi.org/10.3390/jof7040298>
13. Chakrabarti A, Das A, Sharma A, Panda N, Das S, Gupta KL, Sakhuja V. Ten years' experience in zygomycosis at a tertiary care centre in India. *J. Infect*. 2001; 42:261–266.
14. Chakrabarti A, Chatterjee SS, Das A, Panda N, Shivaprakash MR, Kaur A, Varma SC, Singhi S, Bhansali A, Sakhuja V. Invasive zygomycosis in India: Experience in a tertiary care hospital. *Postgrad. Med. J*. 2009;85:573–581.
15. Chakrabarti A, Das A, Mandal J, Shivaprakash MR, George VK, Tarai B, Rao P, Panda N, Verma SC, Sakhuja V. The rising trend of invasive zygomycosis in patients with uncontrolled diabetes mellitus. *Med. Mycol*. 2006;44:335–342. DOI: 10.1080/13693780500464930 [PubMed] [CrossRef] [Google Scholar]
16. Azhar Asim et al. "Mucormycosis and COVID-19 pandemic: Clinical and diagnostic approach. *Journal of Infection and Public Health*. 2022;15(4):466-479. DOI: 10.1016/j.jiph.2022.02.007
17. Hosseini SMS, Borghei P. Rhinocerebral mucormycosis: Pathways of spread. *Eur Arch Oto Rhino Laryngol J Eur Fed Oto Rhino-Laryngol Soc EUFOS Affil Ger Soc Oto Rhino Laryngol Head Neck Surg*. 2005;262:932–8. Available: <https://doi.org/10.1007/s00405-005-0919-0>
18. Therakathu J, Prabhu S, Irodi A, Sudhakar SV, Yadav VK, Rupa V. Imaging features of rhinocerebral Mucormycosis: A study of 43 patients. *Egypt J Radio Nucl Med*. 2018;49:447–52.

- Available:<https://doi.org/10.1016/j.ejrn.2018.01.001>
19. Petrikos G, Skiada A, Lortholary O, Roilides E, Walsh TJ, Kontoyiannis DP. Epidemiology and clinical manifestations of Mucormycosis. *Clin Infect Dis Publ Infect Dis Soc Am*. 2012;54(1):23–34. Available:<https://doi.org/10.1093/cid/cir866>
 20. Al-Tawfiq Jaffar A et al. COVID-19 and Mucormycosis superinfection: The perfect storm. *Infection*. 2021;49(5):833-853. DOI: 10.1007/s15010-021-01670-1
 21. Alekseyev K, Didenko L, Chaudhry B. Rhinocerebral Mucormycosis and COVID-19 pneumonia. *J Med Cases*. 2021;12(3): 85–89. Available:<https://doi.org/10.14740/jmc3637>
 22. Sahoo JP, Mishra AP, Pradhan P, Samal KC. Misfortune never comes alone - the new “black fungus” accompanying COVID-19 wave. *Biotica Res Today*. 2021;3(5): 318–320.
 23. Singh AK, Singh R, Joshi SR, Mishra A. Mucormycosis in COVID-19: A systematic review of cases reported worldwide and in India. *Diabetes, Metab Syndrome: Clin Res Rev*. Published online. 2021:1-7. DOI:10.1016/j.dsx.2021.05.019
 24. Ghosh D, Dey S, Chakraborty H, Mukherjee S, Halder A, Sarkar A, Chakraborty P, Ghosh R, Sarkar J. Mucormycosis: A new threat to Coronavirus disease 2019 with special emphasis on India. *Clinical Epidemiology and Global Health*. 2022;19:101013.
 25. Hoenigl M, Seidel D, Carvalho A, Rudramurthy SM, Arastehfar A, Gangneux JP, Nasir N, Bonifaz A, Araiza J, Klimko N, Serris A. The emergence of COVID-19 associated Mucormycosis: A review of cases from 18 countries. *The Lancet Microbe*; 2022.
 26. Priya P, Ganesan V, Rajendran T, Geni VG. Mucormycosis in a Tertiary Care Center in South India: A 4-year experience. *Indian Journal of Critical Care Medicine: Peer-Reviewed, Official Publication of Indian Society of Critical Care Medicine*. 2020;24(3):168–171. Available:<https://doi.org/10.5005/jp-journals-10071-23387>
 27. Wasiq Mohammed et al. Coronavirus disease-associated Mucormycosis (CAM): A case control study during the outbreak in India. *The Journal of the Association of Physicians of India*. 2022;70(4):11-12.
 28. Moorthy A et al. SARS-CoV-2, uncontrolled diabetes and corticosteroids – an unholy trinity in invasive fungal infections of maxillofacial region? A retrospective, multicentric analysis. *J Maxillofac Oral Surg*. 2021;6:1–8. Available:<https://doi.org/10.1007/s12663-021-01532-1>
 29. Roden MM, Zaoutis TE, Buchanan WL, Knudsen TA, Sarkisova TA, Schaufele RL, et al. Epidemiology and outcome of zygomycosis: A review of 929 reported cases. *Clin Infect Dis Publ Infect Dis Soc Am*. 2005;41:634–53. Available:<https://doi.org/10.1086/432579>
 30. Group WHOREaFC-TW, Sterne JAC, Murthy S et al. Association between administration of systemic corticosteroids and mortality among critically ill patients with COVID-19: A meta-analysis. *JAMA*. 2020;324(13):1330–1341.
 31. Badali H, Canete-Gibas C, McCarthy D et al. Epidemiology and antifungal susceptibilities of Mucoralean fungi in clinical samples from the United States. *J. Clin. Microbiol.* 2021;59(9):e01230–e01221.
 32. Garg D, Muthu V, Sehgal IS, Ramachandran R, Kaur H, Bhalla A, et al. Coronavirus disease (Covid-19) associated Mucormycosis (CAM): Case report and systematic review of literature. *Mycopathologia*. 2021;186:289–98. Available:<https://doi.org/10.1007/s11046-021-00528-2>
 33. Maini A, Tomar G, Khanna D, Kini Y, Mehta H, Bhagyasree V. Sino-orbital Mucormycosis in a COVID-19 patient: A case report. *Int J Surg Case Rep*; 2021. Available:<https://doi.org/10.1016/j.ijscr.2021.105957>
 34. Montefusco L, Ben Nasr M, D'Addio F, et al. Acute and long-term disruption of glycometabolic control after SARS-CoV-2 infection. *Nat Metab*. 2021;3:774–85.
 35. Chen J, Wu C, Wang X, et al. The impact of COVID-19 on blood glucose: A systematic review and meta-analysis. *Front Endocrinol (Lausanne)*. 2020;11:574541.
 36. Ackermann M, Verleden SE, Kuehnel M, Haverich A, Welte T, Laenger F, Vanstapel A, Werlein C, Stark H, Tzankov A et al. Pulmonary vascular endothelialitis, thrombosis, and angiogenesis in Covid-19. *N. Engl. J. Med*. 2020;383:120–128.

37. John TM, Jacob CN, Kontoyiannis DP. When uncontrolled diabetes mellitus and severe COVID-19 converge: The perfect storm for Mucormycosis. *Journal of Fungi*. 2021;7(4):298.
38. Singh AK, Singh R, Joshi SR, Misra A. Mucormycosis in COVID-19: A systematic review of cases reported worldwide and in India. *Diabetes Metab Syndr Clin Res Rev*; 2021.
DOI: 10.1016/j.dsx.2021.05.019
[CrossRef] [Google Scholar]
39. Suganya R, Malathi N, Karthikeyan V, Janagaraj VD. Mucormycosis: A brief review. *J Pure Appl Microbiol*. 2019;13:161–165.
Available: <https://doi.org/10.22207/JPAM.13.1.16>
40. Rao VU, Arakeri G, Madikeri G, Shah A, Oeppen RS, Brennan PA. COVID-19 associated Mucormycosis (CAM) in India: A formidable challenge. *British Journal of Oral and Maxillofacial Surgery*. 2021; 59(9):1095-8.

© 2023 Muley et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:
<https://www.sdiarticle5.com/review-history/100744>