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Dr. Mundhe BP
Post Graduate Student,
Department of Pathology,
S.R.T.R. Government Medical College, Ambajogai,
Maharashtra, India

Dr. Amrutwar AA
Post Graduate Student,
Department of Pathology,
S.R.T.R. Government Medical College, Ambajogai,
Maharashtra, India

Dr. Narwade SB
Assistant Professor,
Department of Pathology,
S.R.T.R. Government Medical College, Ambajogai,
Maharashtra, India

Dr. Sunil Y Swami
Associate Professor.
Department of Pathology,
S.R.T.R. Government Medical College, Ambajogai,
Maharashtra, India

Corresponding Author:
Dr. Sunil Y Swami
Associate Professor.
Department of Pathology,
S.R.T.R. Government Medical College, Ambajogai,
Maharashtra, India

Clinicopathological study of sinonasal fungal infections in 110 post-covid-19 patients

Dr. Mundhe BP, Dr. Amrutwar AA, Dr. Narwade SB and Dr. Sunil Y Swami

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Abstract
Background: In the COVID-19 pandemic, COVID 19 patients were found to have immunosuppression resulting in diverse range of bacterial and fungal infections that may be associated with preexisting comorbidities. Fungal rhinosinusitis is an emerging concern in post COVID-19 patients which needs prompt treatment for better outcome of the patients.
Design: Out of 180 sinonasal tissues received from post COVID-19 patients, fungal infection was detected in 110 cases. Tissue processing was done after overnight fixing the tissue in 10% formalin. Decalcification was done wherever required. Routine H&E slide staining was done, and histopathological findings were noted. Clinicopathological correlation was done, and results were compared to other studies.
Results and Discussion: 110 cases were diagnosed with fungal infections histopathologically of which 4 cases were having non-invasive fungal infection and rest [106] were invasive. Based on morphology of fungal hyphae on microscopy, 99 cases were suggestive of mucormycosis, followed by 8 cases of suspected aspergillosis and remaining 3 cases with combined infection. The most common involvement in our study was maxillary sinus. Orbital extension of fungal infections was found in 20 cases out of 110 cases in the present study.
Conclusion: In the post-COVID-19 patients, the symptoms like facial pain, cheek swellings, orbital pain, nasal discharge should be evaluated properly for possibility of fungal infections that may prove fatal if undiagnosed. Early diagnosis is essential for initiation of anti-fungal treatment and limit the invasive course of the disease.

Keywords: covid-19, fungus, sino-nasal, Mucormycosis, aspergillosis

Introduction
The novel severe-acute respiratory coronavirus 2 (SARS-CoV-2) is the cause of COVID-19, a condition that was declared a global pandemic by the World Health Organization on 30 January 2020 [1]. The prognosis of the disease in patients with underlying conditions is directly related with co-morbidities reported in a large number of hospitalized and severe cases [2]. The high incidence of severe infection and mortality in COVID-19 is thought to be due in part to a lack of natural immunity and to viral replication in the lower respiratory tract, as well as super-infections, secondary infections or co-infections (these terms are often used interchangeably), leading to severe lung injury and acute respiratory distress syndrome (ARDS).Co-infections with respiratory viruses (other than SARS-CoV-2), bacteria and fungi have been reported in COVID-19 patients in Wuhan, China and secondary infections were identified as one off the predictors of a fatal outcome in COVID-19 cases [3].
COVID 19 is often associated with a decrease in CD-4 T and CD-8 T cells. Critically ill patients, especially the patients who were admitted to the intensive care unit (ICU) and required mechanical ventilation, or had a longer duration of hospital stays, even if 50 days, were more likely to develop fungal co-infections. Hence, it is important to notice that COVID-19 patients can develop further fungal infections during the middle and latter stages of this disease, especially severely ill ones [4].
Mucormycosis or Zygomycosis, also called Phycomycosis, is an uncommon, aggressive, invasive, rapidly progressive, and life-threatening fungal infection. Mucormycosis can enter the body through the nose, breached skin, and tooth extraction sockets. Primary infection sites include the skin, ears, gastrointestinal tract, and there could be disseminated forms

involving multiple locations like pulmonary and rhino-orbital-cerebral [5].

The incidence rate of mucormycosis globally varies from 0.005 to 1.7 per million population [6]. Whereas, in Indian population, its prevalence is 0.14 per 1000, which is about 80 times higher than developed countries [7]. The fatality rate of mucormycosis is 46% globally [8]. However, factors like intracranial or orbital involvement, irreversible immune suppression increases fatality to as high as 50% to 80% [9]. A high suspicion for this disease must be considered in patients who are immunocompromised. Tissue necrosis, a hallmark of mucormycosis is often a late sign [8].

The most important conditions that predispose to mucormycosis, according to various studies, include Diabetes Mellitus (DM), with or without ketoacidosis, hematological malignancies (HM), other malignancies, transplantation, prolonged neutropenia, corticosteroids, trauma, iron overload, illicit intravenous drug use, neonatal prematurity, and malnourishment. Immunocompetent patients can also be affected, when the spores of the fungus are directly inoculated in the skin, because of trauma or burns [10].

Depending upon the site of infection and underlying predisposing factors, mortality rates may vary from 10% to 100%. Hence, early diagnosis and treatment is essential to prevent the potential lethal outcome of the disease. The successful treatment of mucormycosis requires four steps: (1) early diagnosis, (2) reversal of underlying predisposing risk factors like control of diabetes, (3) surgical debridement of necrotic bone and (4) prompt anti-fungal therapy. A multidisciplinary approach is required for management of such patients [11].

Materials and Methods

The present study is a prospective and retrospective observational study carried out in the department of pathology, at a rural based tertiary care centre on 180 sinonasal biopsy samples received from patients who had been affected with COVID 19 infection recently, to the histopathology laboratory of our department. The case selection was based on inclusion and exclusion criteria. Only sinonasal biopsy samples from post COVID 19 cases were included in the study while those biopsies received from cases with no prior COVID 19 infection were excluded. Pertinent data like age, sex, comorbidities, corticosteroid use and oxygen [O2] supplementation were collected from the patients. The sinonasal biopsy samples were fixed in 10% formalin, processed in automatic tissue processor and paraffin blocks were prepared. Tissue sections of 4-6µ were cut and stained with hematoxylin and eosin stain [H&E] stain.

Observations and result

A total of 180 sinonasal biopsy samples from patients affected with COVID 19 infection in recent past were studied. This 6-month study was done in the department of pathology during the period 26th April 2021 to 26th October 2021.

Out of the total 180 sinonasal biopsy samples, 110 [61%] samples showed evidence of fungal hyphae while rest 70 [39%] samples were negative for fungal hyphae.

Table 1: Age wise distribution of 110 cases of rhino-nasal fungal infection.

Age Groups	No of cases:	Percentage [%]
21-30 Years	6	5.5%
31-40 Years	15	13.6%
41-50 Years	24	21.8%
51-60 Years	22	20%
61-70 Years	37	33.6%
71-80 Years	6	5.5%
Total	110	100%

Age of the patients in our study was ranging from 23 years to 79 years. Most common age group involved was 61 to 70 years. Out of the 110 cases of post-COVID 19 sinonasal fungal infections, 80 cases were males while 30 cases were females with male to female ratio of M:F=2.7: 1.

Table 2: Clinical presentation of 110 cases of rhino-nasal fungal infection.

Clinical Presentation:	No of patients. [%]
Facial pain	90 [81%]
Facial swelling	55 [50%]
Headache	80 [72%]
Periorbiotal pain	65 [59%]
Nasal discharge	15 [13.6%]

The most common presenting symptoms in the patients with sinonasal fungal infection were facial pain seen in 90 cases [81%] followed by headache observed in 80 [72%], facial swelling in 55 [50%], cheek, peri-orbital pain in 65 [59%] and nasal discharge in 15 [13.6%] of cases.

Table 3: Case wise distribution of comorbidities in 110 cases of rhino-nasal fungal infections.

Comorbidities	No of patients	Percentage [%]
Diabetes Mellitus	28	25.6%
Hypertension	15	13.6%
DM with Hypertension	5	4.5%
Chronic Kidney Disease	2	1.8%
Ischemic Heart Disease	1	0.9%
Patients without comorbid conditions	59	53.6%
Total	110	100%

Out of 110 patients in our study, 51 cases were having underlying comorbidities. Diabetes mellitus was present in 28 [25.6%] patients followed by hypertension sin 15 [13.6%], 05 [4.5%] patients were having both diabetes and hypertension, 02 [1.8%] patients were having chronic kidney disease with hypertension and 01 [0.9%] patient was having ischemic heart disease. 59 [53.6%] patients were without any comorbidities.

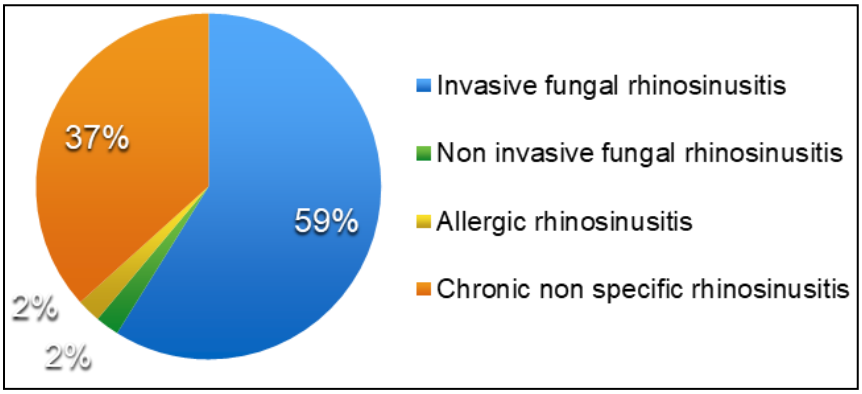

Chart 1: Histopathological diagnosis of sinonasal biopsies in 180 cases of post- Covid-19 infection:

Histopathological examination of the sinonasal tissues from 180 patients studied revealed 110 samples were having fungal hyphae, of which 106 [59%] were invasive and 04 [2%] were non-invasive. 66 [37%] patients were showing features of chronic non-specific rhino sinusitis and 04 [2%] were showing features of allergic rhino sinusitis.

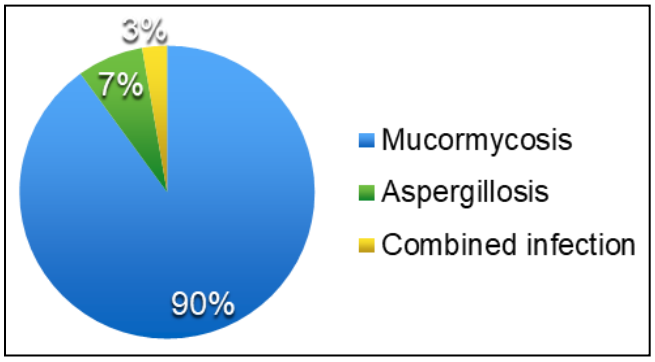

Chart 2: Distribution of types of fungal hyphae seen in 110 cases of post COVID 19 infections:

Out of the 110 cases, 99 [90%] cases showed presence of broad aseptate fungal hyphae with right angled branching suggestive of mucormycosis. 08 [7%] of cases showed presence of slender septet fungal hyphae with acute angled branching suggestive of aspergillosis. 03 [3%] showed co-existence of both mucormycosis and aspergillosis.

Table 4: Distribution of various histopathological findings seen in 180 cases:

Histopathological findings	No of cases
Fungal Balls	4
Necrosis	110
Granulomatous reaction	19
Abscess	3
Allergic Mucin	5
With Oxalate Crystals	3
Chronic Nonspecific Inflammatory lesions.	66

180 samples were studied histopathologically revealed 106 cases with presence of necrosis in 110 cases, chronic nonspecific inflammatory lesions in 66 cases, granulomatous reaction in 19 cases, Allergic mucin in 5 cases, Fungal ball in 4 cases, Abscess formation in 3 cases and evidence of oxalate crystals in 3 cases.

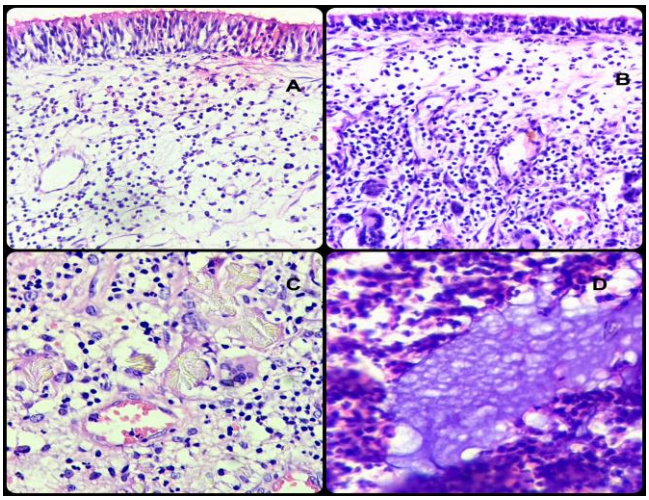

Fig 1: Photomicrograph showing: [A]: Plenty of lymphocytes, few eosinophils in the edematous stroma below the respiratory epithelium. [B]: Foreign body reaction: Lymphocytes & foreign body giant cells in the edematous stroma below the respiratory epithelium. [C]: Foreign body reaction: Lymphocytes, foreign body giant cells & calcium oxalate crystals. [D]: Allergic Mucin: Plenty of eosinophils admixed with mucin secretion. [H&E: 40X].

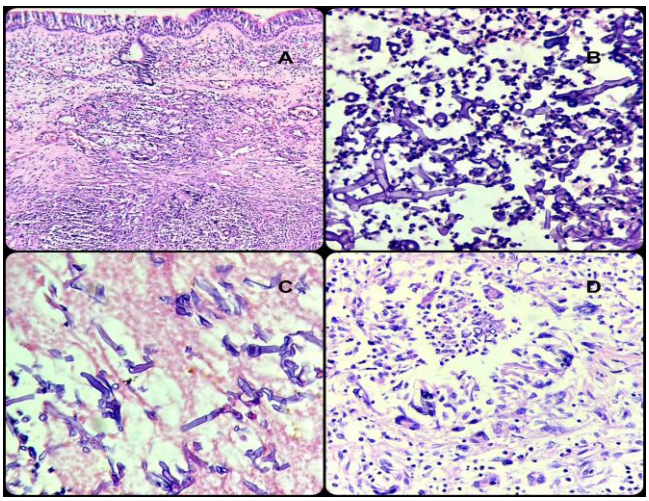

Fig 2: Photomicrograph showing: [A]: Abscess formation: Plenty of polymorphs in the edematous stroma below respiratory epithelium. [B]: Abscess: Plenty of polymorphs and fungal hyphae. [C]: Plenty of fungal hyphae in the necrotic background. [D]: Granuloma: Fungal structures surrounded by polymorphs, lymphocytes, epitheloid cells and foreign body giant cells. [H&E: 40X].

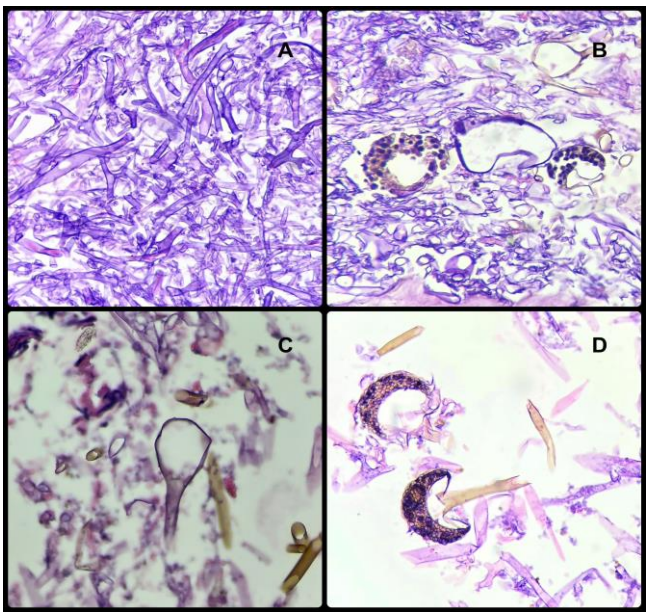

Fig 3: Photomicrograph showing: [A]: Fungal colony: Plenty of broad, aseptate right angle branching hyphae. [B, C, D]: Fungal colony: Plenty of broad, aseptate hyphae with sporangiospore formation. [H&E: 40X].

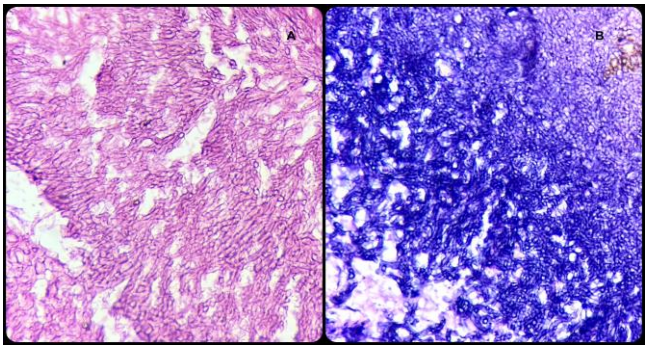

Fig 4: [A, B]: Fungal Ball/ colony: shows plenty of slender entangled fungal hyphae.[H&E: 40X]

Discussion

In the recent context of the corona virus disease 2019 (COVID-19) Pandemic, secondary fungal infections, such as invasive pulmonary aspergillosis, have been reported for about 30% of the cases admitted to the ICU, mostly in patients in whom the European organization for the research and treatment of cancer [12]. Multiple cases of invasive pulmonary aspergillosis (CAPA-COVID19 associated pulmonary aspergillosis) and invasive candidiasis (CAC-COVID19 associated candidiasis) have been reported in patients with severe COVID-19 infections.

Mucormycosis is an angio-invasive disease caused by opportunistic fungi of the order Mucorales in immunocompromised patients. Untreated mucormycosis is almost always fatal. It remains to be seen if this increasing incidence of mucormycosis in COVID-19 is related to the illness itself, the steroid and immunomodulators administered for treatment, or the worsening of underlying predisposing factors in the socioeconomic upheaval caused by the pandemic [13].

In the normal functioning immune cells, the spores and hyphae are readily taken up and destroyed by mononuclear and polymorphonuclear phagocytes. When patients have a low phagocyte count, impaired phagocyte function, neutropenia, or poorly controlled diabetes mellitus, they become increasingly susceptible to fungal infections [14].

Along with Diabetes Mellitus, hematological malignancies, corticosteroid use or any other immunosuppressive therapy, iron overload may prove as a risk factor for development of mucormycosis in post COVID 19 patients [10]. In uncontrolled diabetes like diabetic ketoacidosis, the hyperglycemia and acidic pH lead to a defect in the motility of bacteria and fungi by neutrophils. Also in acidic state, iron proven complexes dissociate that makes free iron available to the fungi. Patients with COVID-19 might present with markedly higher levels of inflammatory cytokines (such as interleukin [IL]-2R, IL-6, IL-10, and tumor necrosis factor-alpha), associated with impaired cell-mediated immune response, affecting both CD4 + T and CD8 + T cells. Hence an increased susceptibility to fungal co-infections is observed [1].

Table 5: Showing comparison of associated co-morbid conditions:

Associated comorbidities	Present study	Manouchehr *et al.*	Sharma *et al.*
Diabetes mellitus	25.5%	83.33%	91.3%
Hypertension	13.6%	58.33%	60.86%
Diabetes and hypertension	4.5%	-	-
Chronic kidney disease	1.8%	-	4.3%
Islamic heart disease	0.9%	-	-

In our study, out of the 110 cases with sinonasal fungal infections diabetes mellitus was seen in 25.6% cases followed by hypertension in13.6% cases while diabetes and hypertension both was seen in 4.5% cases followed by chronic kidney disease in 1.8% cases and ischemic heart disease in 0.9% cases. This can be compared with the study carried out by Manouchehr *et al.* in 12 patients with rhino-orbital mucormycosis in western Iran where the most common comorbidity were diabetes mellitus seen in 83.3% of the cases and hypertension seen in 58.33% of cases.[16] Sharma *et al.* studied 23 cases of post COVID 19 mucormycosis and found that 91.3% patients were having diabetes mellitus, 60.86% patients were having hypertension and 4.3% patients with chronic kidney disease as associated comorbidities [17].

Table 6: Showing comparison of clinical presentations:

Clinical presentation	Present study	Sharma *et al.*	Richa Garg *et al.*	Noah Ahmed *et al.*
Facial pain	81%	-	-	75%
Headache	72%	-	100%	-
Facial swelling and numbness	50%	34.7%	-	66.7%
Periorbital pain	59%	-	-	-
Nasal discharge	14%	18.5%	-	-
Ophthalmic involvement	18%	43.7%	30%	63.9%

Clinically, Rhino-cerebral mucormycosis can present with atypical signs and symptoms like complicated sinusitis, such as nasal blockade, nasal crusting, proptosis, facial pain and oedema, ptosis, chemosis, and even ophthalmoplegia, with headache and fever and various neurological signs and symptoms if intracranial extension is present. A black eschar is often seen in the nasal cavity or over the hard palate region but is not characteristic [17].

In our study the most common presenting symptoms in the patients with sinonasal fungal infection were facial pain seen in 81% cases followed by headache in 72% cases, peri-

orbital pain seen in 59% cases, facial swelling in 50% cases, nasal discharge in 14% cases. 20 [18%] patients were having ophthalmic involvement. Sharma *et al.* conducted a similar study and found facial swelling and numbness in 34.7% of the patients, nasal discharge in 18.5% of the patients and ophthalmic involvement in 43.7% of patients [17]. Richa Garg *et al.* found headache as the most common presenting complaint in 100% of the patients and 30% patients were having ophthalmic involvement [18]. Noha Ahmed El Kholy *et al.* conducted a similar study where the found that 75% patients presented with facial pain, 66.7% prsented with facial swelling and numbness and 63.9% patients presented with ophthalmic involvement [19].

Tissue samples from clinically suspected cases can then be taken and used for a fungal culture, which can determine the presence and type of fungal infection [20]. In clinical practice, laboratory diagnosis of mucormycosis includes histopathology, direct examination of wet mounts and culture. Histopathology is a very important diagnostic tool since it distinguishes the presence of the fungus as a pathogen in the specimen. It can furthermore reveal co-infections with other molds. Mucorales genera produce typically non-pigmented, wide (5–20 μm), thin-walled, ribbon-like hyphae with no or few septations (pauciseptate) and right-angle branching, in contrast to those of the Aspergillus species or other hyaline molds, which are typically 3–5 μm wide, septate and form acute-angle branching. Routine hematoxylin and eosin (H&E) stains may show only the cell wall with no structures inside, or occasionally, very degenerate hyphae. Stains that can help highlight the fungal wall include Grocott Methenamine Silver (GMS) and Periodic Acid-Schiff (PAS) stains, although PAS gives a better visualization of the surrounding tissue compared to GMS [10].

Table 7: Showing comparison of types of fungal infections:

Type of fungal Infections:	Present study	Noah Ahmed *et al.*	Richa Garg *et al.*
Mucormycosis	90%	77.8%	70%
Aspergillosis	7%	30.6%	20%
Mixed infection	3%	-	10%

In our present study, out of 180 post-COVID-19 infection cases studied, 110 cases were showing presence of fungal hyphae in sinonasal tissue. Depending on the morphology of fungi, 99 [90%] cases were suggestive of mucormycosis, 08 [7%] suggestive of aspergillosis and 03 [3%] were suggestive of a mixed infection. These results can be compared with the study carried out by Noha Ahmed, El Kholy *et al.* who studied 36 cases, 77.8% were showing mucormycosis and 30.6% were showing aspergillum infection [19]. Also Richa Garg *et al.* found that 70% cases were suggestive of mucormycosis, 20% were suggestive of aspergillosis while 10% are suggestive of mixed infection with both [18].

Fungal rhinosinusitis is mainly classified as non-invasive and invasive fungal infections. Non -invasive fungal infections present as saprophytic fungal infestations, fungal balls, and allergic fungal rhino sinusitis. Invasive fungal rhino sinusitis presents as acute invasive fungal rhino sinusitis, chronic invasive fungal rhino sinusitis and chronic granulomatous invasive fungal rhino sinusitis [21].

In our study, out of the 110 cases with fungal infections, 04 (3.64%) cases were having noninvasive fungal infection with evidence of fungal ball while 106 (96.36%) cases were having invasive fungal infection out of which 91[82.7%] cases were showing features suggestive of chronic invasive fungal rhino-sinusitis and 15 [13.6%] cases were showing features suggestive of chronic granulomatous invasive fungal infection. Maxillary sinus was the most common sinus involved in our study. In the study carried Sharma *et al.* most common sinus involved was Ethmoidal followed by Maxillary [17].

Conclusion

In post-COVID-19 patients, symptoms like facial pain, facial swellings, orbital pain, nasal discharge should be evaluated properly for possibility of fungal infection that may prove fatal. COVID-19 patients always have immunosuppression with a decrease in CD4 T and CD8 T cells. Critically ill patients, especially the patients who were admitted to the intensive care unit and required mechanical ventilation, or had a longer duration of hospital stays, even if 50 days, were more likely to develop fungal co-infections. An early diagnosis is essential for initiation of anti-fungal treatment and limit the invasive course of the disease. Various diagnostic modalities like radiographic examination including magnetic resonance imaging, CT scan, PET scan and direct microscopic examination like histopathological examination, microbiologic examinations like KOH mounts and culture methods are helpful in the early diagnosis of the post-COVID-19 fungal infections. Histopathological examination gives an idea about the presence of fungal infections in the given tissues and the nature of the disease i.e., invasiveness (deeper tissue and angio-invasion), severity, type of fungi involved, associated tissue damage and helps in depicting the complications. Hence histopathological examination is an important step in the management of clinically suspected post COVID19 fungal infection patients.

References

1. World Health Organization. WHO Coronavirus Disease (COVID-19) Dashboard 2020. https:// covid19.who.int/ (accessed 20 August 2020).
2. Zhou F, Ting Y, Ronghui D, Guohui F, Ying L, Zibo L, *et al.* Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: A retrospective cohort study. Lancet 2020;395:1054-62.
3. Ezeokoli T, Pohl CH. Opportunistic pathogenic fungal co-infections are prevalent in critically ill COVID19 patients: Are they risk factors for disease severity? South African Medical Journal 2020;110:1081-85.
4. Ge Song, Guanzha94o Liang, Weida Liu. Fungal Co-infections Associated with Global COVID-19 Pandemic: A Clinical and Diagnostic Perspective. Mycoathologia 2020;185:599-606.
5. Rahul Laturiya, Sheeraz Badal, Amol Doiphode, Gopal Nagargojhe, Shubhashan Bhale, Minal Sonare. Rising incidence of Mucormycosis during COVID 19: A review. Journal of Dental Research 2020;2(2):80-84.
6. Going W, Keighley C, Wolfe R, *et al*. The epidemiology and clinical manifestations manifestations of mucormycosis: A systematic review and meta-analysis of case reports. Clin Microbiol Infect 2019;25:26-34.
7. Chander J, Kaur M, Singla N, Punia R, Singhal S, Attri A *et al.* Battle with the deadly enemy over a five-year period in India. J Fungi. 1018; 6; (4): 46.

8. Werthman Ehrenreich: Mucormycosis with orbital compartment syndrome in a patient with COVID-19. Am. J Emerg Med 2021;42:264:5-8.
9. Deutsch PG, Whittaker J, Prasad S. Invasive and non-invasive fungal rhino sinusitis - A review and update of the evidence. Medicina 2019;55:1-14.
10. Anna Skiada, Ionnis Pavles, Maria Drogari Apiranthitou. Epidemiology and Diagnosis of Mucormycosis: An update. J fungi 2020;6:265.
11. Verma A, Singh V, Jindal N, Yadav S. Necrosis of maxilla, nasal and frontal bone secondary to extensive rhino-cerebral mucormycosis. National journal of Maxillofacial Surgery 2012;1:40.
12. Bellanger AP, Navellou JC, Lepiller Q, Brunel A, Mikkon L. Mixed mold infection with aspergillus fumigatus and rhizomes microsporum in a severe acute respiratory syndrome coronaries patients. Infect Dis 2021;51:630- 40.
13. Saurian Skewer Paul, Rohit Kumar, Ved Prakash Meena *et al.* Clinical characteristics and outcomes of 16 cases with COVID 19 and Mucormycosis: Experience from a tertiary care center in India and review of literature. May 2021; dos:10.21203/rs.3.rs-533347/v1.
14. Kirill Alekeryev, Lidiya Didenko,Bilal Chaudhary. Rhinicerebral mucormycosis and COVID- 19 Pneumonia. J Med Cases 2021;12:85-89.
15. Epifanio Silvino do Monte Junior, Marcos Edudaro Lera dos Santos, Igor Braga Ribeirop, Gustavo de Oliveria Luz, Elisa Ryoka Baba, Bruno Salmono Hirsch *et al.* Rare and fatal gastrointestinal Mucormycosis (Zygomycosis) in a Covid 19 patient: A case report. Clin Endosc 2020;53:746-49.
16. Manouchehr Avatef Fazeli, Leila Razaei, Etrat Javadirad, Khosro Iranfar, Abbas Khosravi, Javad Amini Saman *et al.*: Increased incidence of rhino-orbital mucormycosis in an educational therapeutic hospital during the COVID 19 pandemic in western Iran: An observational study. Wiley online Library. Mycoses 2021:1-12.
17. Sharma S, Grover M, Bhargva S, Samdani S, Kataria T. Post coronavirus disease mucormycosis: A deadly addition to the pandemic spectrum. The journal of Laryngology & Otology 2021;5:1- 6.
18. Richa Garg, Sandeep Bhavnagar, Sunil Gupta, Samiksha Bharadwaj. Post Covid 19 Infections presenting as rhino-orbital mycosis. India J Otolaryngeal Head Neck Surg 2021. https://doi.org/10.1007/s12070-021-02722-6
19. Noah Ahmed EL Kholy, Ahmed Mussad Abd El Fattah. Invasive fungal sinusitis in post Covid 19 patients: A new clinical entity. The Laryngoscope 2021;131(12):2652- 58.
20. Suwarna Patil, Dilip Sarate, Shriram Chopade, Manjiri Khade, Shweta Dhage, Swarada Kangate. Emerging challenge of mucormycosis in post COVID patients. IARC J Med Case Rep 2021;2(3):7-10.
21. Peter George Deutsch W, Joshua Hittaker, Shashi Prasad. Invasive and Noninvasive fungal rhino sinusitis: A review and update of the evidence. Medicina 2019;55(7):319.