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Case Series

Radiology Section

# The Fungal Footprint: Radiologic Spectrum in Pulmonary, Paranasal Sinus and CNS Infections

P JENIKAR[1], MG SAI SHANKAR[2], B HARSHAVARDHAN[3], SACHIN VIRMANI[4]



## ABSTRACT

Fungal infections can involve multiple organ systems, with imaging playing a pivotal role in their diagnosis and management. Fungal infections of Paranasal Sinuses (PNS) can be classified into invasive and non-invasive forms. Invasive fungal infections can be further divided into acute, chronic, or chronic granulomatous entities. It mainly affects immunocompromised patients with uncontrolled diabetes mellitus, Human Immunodeficiency Virus (HIV), and those on chemotherapy or chronic oral corticosteroids. Computed tomography remains the gold standard for sinonasal imaging while Magnetic Resonance Imaging (MRI) excels in assessing intraorbital and intracranial extensions. It is important to know and identify the characteristic imaging patterns of invasive and non-invasive fungal rhinosinusitis, and the radiologist is very important in refining the diagnosis to prevent a possible fatal outcome. This case series highlights the radiologic manifestations of fungal infections affecting the pulmonary system, Central Nervous System (CNS), and peripheral nervous system with characteristic imaging features ranging from invasive aspergillosis and mucormycosis to allergic fungal disease and rhinosporidiosis. Imaging findings includes sinus opacification, bony erosion, cavernous sinus invasion, orbital involvement, and cavitary lung lesions with Monod sign, ground-glass opacities and hyperdense mucus played a crucial role in diagnosis. By presenting a range of cases, this series aims to provide a comprehensive understanding of the imaging features associated with these infections, facilitating accurate diagnosis and treatment planning for radiologists and clinicians.

**Keywords:** Aspergillosis, Central nervous system, Pulmonary mucormycosis, Rhino-orbital-cerebral mucormycosis, Sinonasal and Histoid Hansen

## INTRODUCTION

Fungal infections are a diagnostic and therapeutic challenge. Mostly, it is concerning patients who are immunocompromised [1]. They can affect several organ systems. Imaging plays a key role in the diagnosis of these diseases [2]. Most frequently involved are the lungs, CNS, and peripheral nervous system; the immune status of the host is an important determinant of the disease presentation and progression [3,4]. The spectrum of clinical manifestations varies from innocuous colonisation to life-threatening complications such as orbital and cerebral involvement [5]. Invasive and non-invasive forms are the generally used classifications of the fungal infections of the nose and PNS [6,7]. Invasive fungal sinusitis is characterised by the presence of fungal hyphae in the mucosa, submucosa, bone, or blood vessels of the PNS. Besides, infections can be classified as acute, chronic, or chronic granulomatous entities according to the type of immunity and the course of the disease [8,9]. Poorly controlled diabetes mellitus, HIV, chemotherapy, or chronic treatment with corticosteroids can compromise immune function and be associated with invasive forms [10]. Non-invasive types, such as mycetoma and allergic fungal rhinosinusitis, do not penetrate deeper tissues but can occur in immunocompetent hosts [11]. Computed Tomography (CT) remains the gold standard in sinonasal imaging, although Magnetic Resonance Imaging (MRI) provides better details of intraorbital and intracranial extensions [12]. Recognition of characteristic imaging patterns of both invasive and non-invasive fungal rhinosinusitis must be done for proper diagnosis and timely management, which may help avoid fatal outcomes [13].

## CASES SERIES

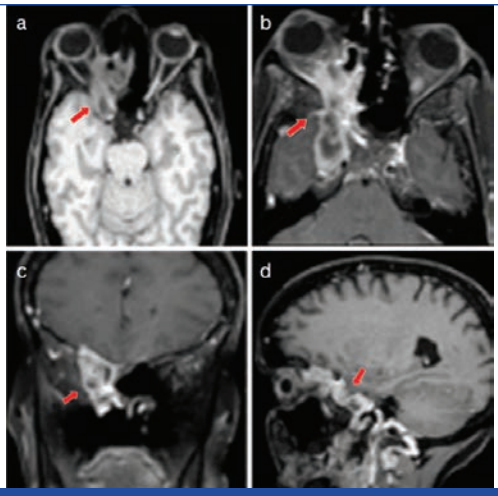
### Case 1

A 42-year-old female patient with a prior history of Histoid Hansen and type II lepra reaction since one year nine months presented with new cerebral complaints like ptosis, diplopia, insomnia, blurring of vision, and facial swelling for one week. This patient was at risk of developing infection by taking intermittent steroid therapy (prednisolone 30 mg) for approximately one year and nine months with poor compliance for lepra reaction. The patient was referred to the department of radiology for contrast MRI brain.

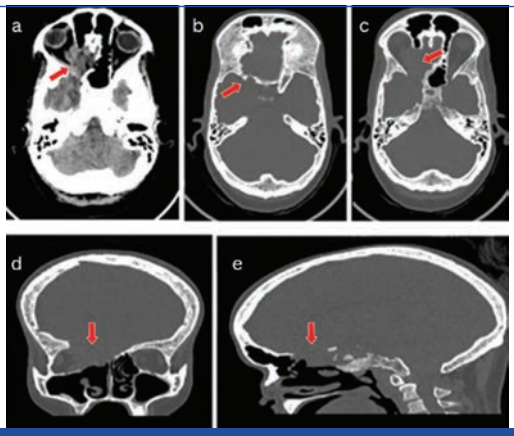
Imaging findings showed an ill-defined hetero-intense enhancing lesion arising from the posterior aspect of the right ethmoidal sinus and seen extending laterally into intra and extraconal spaces of right orbit with possible invasion of the medial rectus muscle and causing encasement of the ipsilateral thickened optic nerve. Posteriorly, the lesion was extending into right orbital apex. The heterogeneously enhancing lesion medially appeared to involve the right cavernous sinus and encase the cavernous part of the right internal carotid artery with reduced luminal calibre with adjacent meningeal enhancement [Table/Fig-1a-d].

Patient later underwent a plain CT brain study to rule out bony erosion. Destruction of right lamina papyracea, right lacrimal bone, floor of the right ethmoidal sinus, floor of the olfactory fossa with the destruction of the cribriform plate of the ethmoid bone and medial aspect of the superior orbital wall extending to the basifrontal region of the right frontal lobe was evident on CT images. The lesion also appeared to widen the right superior orbital fissure and optic canal, with the destruction of lesser, greater wing and body of sphenoid and destruction of the right anterior clinoid process with surrounding sclerosis as seen on CT [Table/Fig-2a-e]. Patient was diagnosed with rhino-cerebral aspergillosis after confirmation with biopsy, Histopathological Examination (HPE) and culture [Table/Fig-3,4].

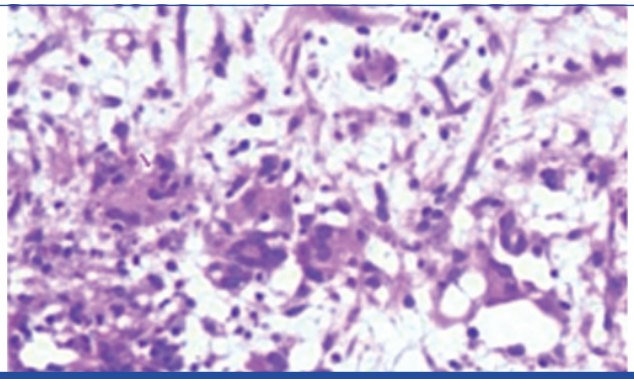
The patient was treated with voriconazole (6 mg/kg i.v. twice daily, transitioning to oral) or liposomal amphotericin B in case of intolerance, alongside thalidomide (100-200 mg daily) to manage the lepra reaction while tapering steroids. Supportive care included Intracranial Pressure (ICP) control and symptomatic relief, with regular monitoring through imaging and fungal markers. Despite




**[Table/Fig-1a,b]:** MRI brain pre-contrast T1 and post-contrast T1 fat suppressed images respectively in axial sections showing lesion involving right orbital apex; c,d) Contrast Enhanced (CE)-MRI fat suppressed T1 Weighted (T1W) coronal and sagittal images showing heterogeneously enhancing lesion involving right ethmoid sinus and orbit extending into anterior and middle cranial fossa through eroded cribriform plate and showing meningeal enhancement (red arrows).




**[Table/Fig-2]:** a) CT axial section of brain (brain window) showing lesion involving right orbital apex; b,c) CT axial sections in bone window showing erosion of sphenoid bone and medial wall of right orbit and apex of right orbit; d) CT coronal section (bone window) showing erosion of roof of right orbit and cribriform plate of ethmoid bone; e) CT sagittal section (bone window) showing erosion of right ethmoid and sphenoid bone (red arrows).



**[Table/Fig-3]:** HPE: Haematoxylin and Eosin (H&E) stained section from ethmoid sinus reveals septate hyphae with acute-angle branching invading blood vessel walls (angioinvasion) and dense inflammatory infiltrates of neutrophils, lymphocytes, and macrophages: all feature are indicative of invasive aspergillosis (fungal) infection.

**[Table/Fig-4]:** Fungal culture in sabouraud dextrose agar shows powdery growth with green surface and white periphery colonies within 3 days characteristic of aspergillus fumigates and microscopic examination of cultured isolates reveals distinctive fungal structures (conidiophores, vesicles, phialides depicted in pictorial representation).

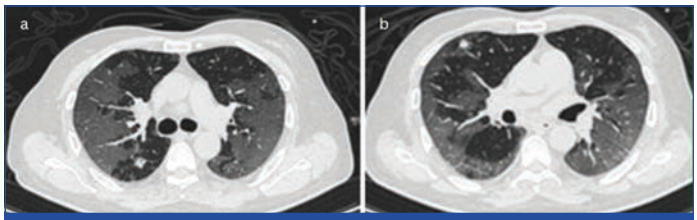
treatment, the patient was referred to a higher oncology center for further management of complicated skull base lesions because they have multidisciplinary teams that include neurosurgeons, head and neck surgeons, infectious disease specialists, and radiologists, as well as access to advanced facilities for surgical debridement, intensive antifungal therapy, and post-treatment monitoring but unfortunately succumbed to the illness.

## Case 2

A 62-year-old diabetic male presented initially with low-grade fever, headache, nasal congestion, epistaxis, and nasal hypoesthesia that had persisted for one week, suggestive of a respiratory infection. The patient had persistent symptoms that led to a positive Severe Acute Respiratory Syndrome Coronavirus 2 (SARS CoV-2) diagnosis by Reverse Transcriptase - Polymerase Chain Reaction (RT-PCR). An ENT evaluation seven days later raised suspicion for a superimposed fungal infection, necessitating further work-up.

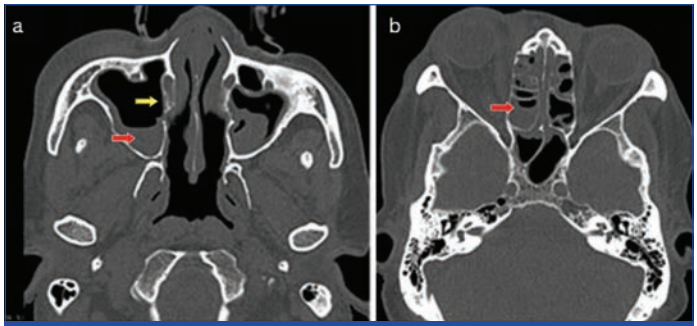
Clinical examination revealed a mucopurulent rhinorrhoea and nasal mass. Laboratory parameters revealed- elevated total counts and C-Reactive Protein (CRP).

The patient, initially suspected to have a nasal fungal infection, was evaluated with imaging. CT chest revealed confluent areas of ground-glass opacities in both lungs, predominantly involving the peripheral and subpleural regions, consistent with viral pneumonia (COVID-19), along with small, randomly arranged nodules with spiculated margins, raising suspicion for a superimposed fungal infection or malignancy [Table/Fig-5-a,b].




**[Table/Fig-5a,b] :** CT chest axial sections lung window showing confluent areas of central and peripheral ground glass opacities in both lungs- suggestive of viral pneumonia (COVID-19). Few small scattered random nodules seen in right lung upper lobe- possibly reflecting super added bacterial/fungal infections.

CT PNS revealed mucosal thickening in the bilateral maxillary and ethmoidal sinuses with subtle bony erosions in the medial wall of the right maxillary sinus [Table/Fig-6]. CT- bone window images revealed bony erosions, because of the presence of nonviable tissue in the right middle and inferior turbinates, the patient was taken to the ENT department and underwent a right endoscopic middle and inferior turbinectomy with partial ethmoidectomy and nasal debridement.

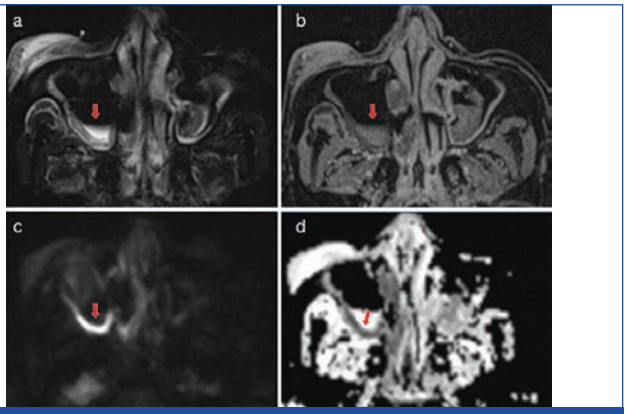



**[Table/Fig-6]:** a, b) Axial CT PNS images showing mucosal thickening involving bilateral maxillary and ethmoidal sinuses (red arrows) with mild proptosis of right orbit. Subtle bony erosions also seen involving the medial wall of right maxillary sinus (yellow arrow).

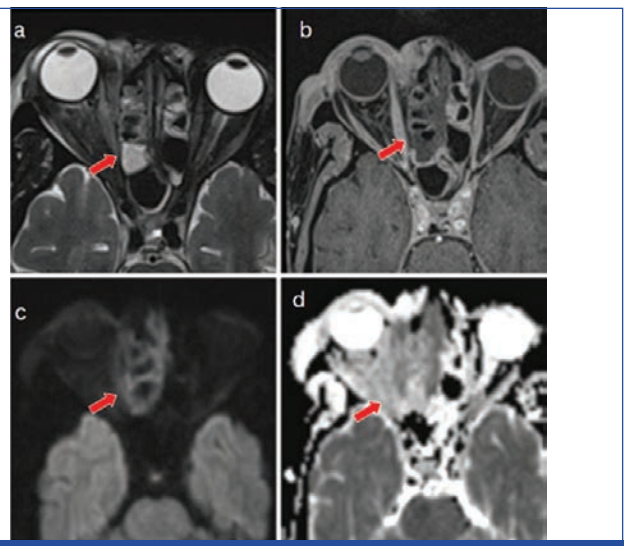
CE MRI brain study showed non-enhancing mucosal thickening on pre- and post-contrast T1W fat-saturated images, indicating necrosis. T2-weighted images demonstrated hyperintense mucosal thickening within the right ethmoidal sinus. Additional MRI findings included T2 hyperintensity in the bilateral gyrus rectus, with restricted diffusion with no evidence of enhancement characteristic of early

cerebritis [Table/Fig-7]. Diffusion Weighted Imaging (DWI) showed restricted diffusion and low Apparent Diffusion Coefficient (ADC) value that supported the suspicion of fungal involvement. (MRI did not have signs of oedema or abscess [Table/Fig-8,9].

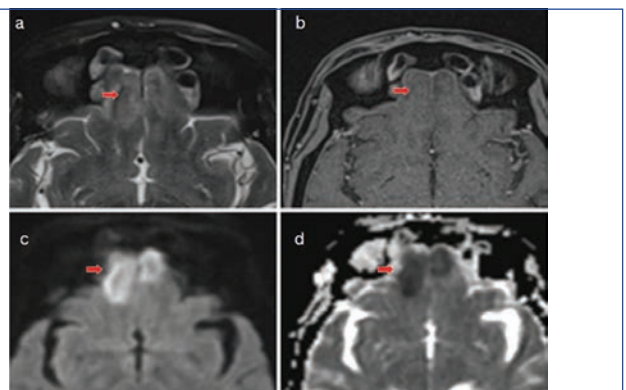
Considering the clinical suspicion of a superimposed fungal infection, a Bronchoalveolar Lavage (BAL) culture was done, which grew fungus. The patient was diagnosed with mucormycosis after biopsy and histopathological examination and fungal culture and microscopy [Table/Fig-10,11]. Additional ENT evaluation that included CT PNS and MRI brain confirmed the findings, and a turbinectomy sample was sent for histopathological examination. In both PNS and BAL samples, identical fungal findings were demonstrated, confirming the diagnosis of mucormycosis.



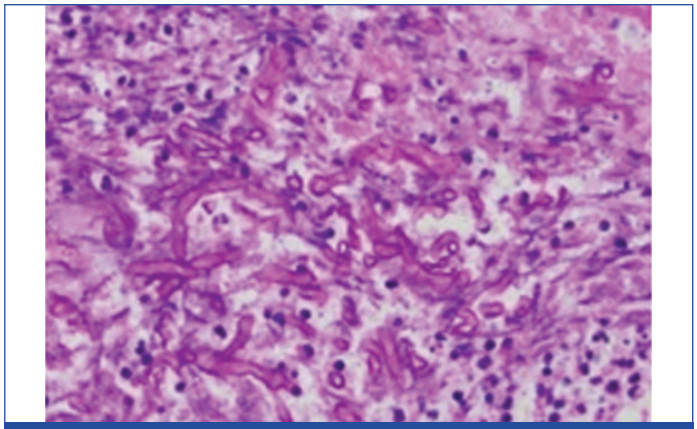

**[Table/Fig-7]:** Axial MRI Brain images (a) T2W axial image showing hyperintense mucosal thickening in both maxillary sinuses with subtle periantral fat stranding anterior to right maxillary sinus; b) T1W fat saturated post contrast image showing absence of mucosal enhancement in bilateral maxillary sinuses- suggestive of necrosis; c,d) Diffusion sequence images (DWI, ADC MAP, respectively) showing restricted diffusion in posterolateral wall of right maxillary sinus with low ADC value (red arrows).




**[Table/Fig-8]:** a) MR brain T2W axial image showing hyperintense mucosal thickening within right ethmoidal sinus; b) T1W Fat saturated post contrast images showing non-enhancing mucosal thickening- S/o necrosis; c,d) Diffusion sequence images (DWI, ADC map) showing restricted diffusivity with low ADC value (red arrows).




**[Table/Fig-9]:** a,b) Axial MRI Brain T2W and T1W post contrast images respectively showing T2 hyperintensity involving bilateral gyrus rectus (red arrows) without focal enhancing lesion-possible focal cerebritis; c,d) Diffusion sequence images (DWI, ADC map) showing restricted diffusivity with low ADC value.



**[Table/Fig-10]:** Histopathology (H&E staining) showed tissue with broad, non-septate hyphae invading surrounding tissues and blood vessels with inflammatory infiltrate neutrophils consistent with mucormycosis.

**[Table/Fig-11]:** a,b) Fungal culture in sabouraud dextrose agar shows rapid-growing gray-black colonies and microscopy confirmed broad, non-septate hyphae with irregular branching, consistent with mucormycosis (also depicted in pictorial representation [Table/Fig-11c].

The patient completed a 6-week course of intravenous liposomal amphotericin B (3-5 mg/kg daily), followed by oral posaconazole (300 mg daily) for continued antifungal therapy. Supportive care, including diabetes and respiratory management, was provided throughout the treatment.

At the end of his course, he was ready for discharge and was asked to be on follow-up with both the ophthalmology and ENT departments.

## Case 3

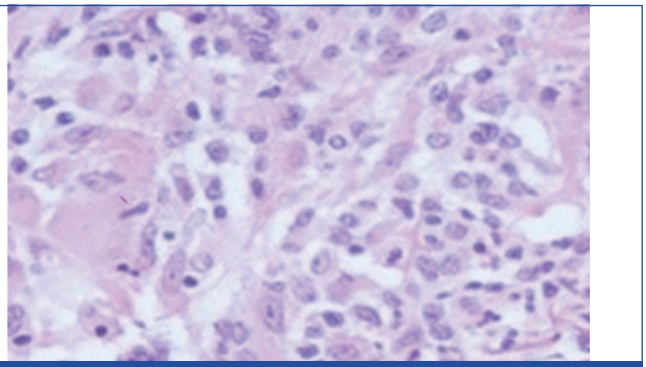
A 31-year-old female with a history of asthma for approximately eight years presented with chronic sinusitis and nasal congestion for four to five months. The patient was referred for cross-sectional imaging. CT-PNS study was done. Imaging findings showed opacification of bilateral maxillary, ethmoid, and sphenoid sinuses with hyperdense area (inspissated secretions) and sclerosis of the sinus walls [Table/Fig-12].

On sinus aspirate [Table/Fig-13], allergic fungal sinusitis was confirmed. The patient was treated with oral corticosteroids (prednisolone 40 mg daily for 2 weeks, tapering), itraconazole (200 mg daily for 6 weeks), and underwent Endoscopic Sinus Surgery (ESS) for fungal clearance. Regular follow-up was recommended to monitor for recurrence.

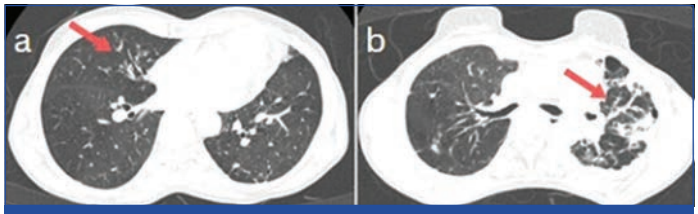
## Case 4

A 55-year-old female with a history of pulmonary Tuberculosis (TB) treated with full course of Anti-Tubercular Therapy (ATT) four years ago, presented with worsening cough, haemoptysis, and low-grade fever for three months, raising concerns for TB recurrence or reactivation. Patient was referred for cross-sectional imaging, and High Resolution Computed Tomography (HRCT) was done, which shows findings of post-tuberculous sequelae including cavitary lesions in the left upper lobe, fibrotic changes in the left upper lobe with surrounding pleural thickening and bronchiectasis [Table/Fig-14]. Cavities demonstrate a well-defined dependent mass-like structure

**[Table/Fig-12]:** CT-PNS axial section showing opacification of sphenoid and bilateral ethmoid sinuses with hyperdensity within the sphenoid sinus (red arrow).

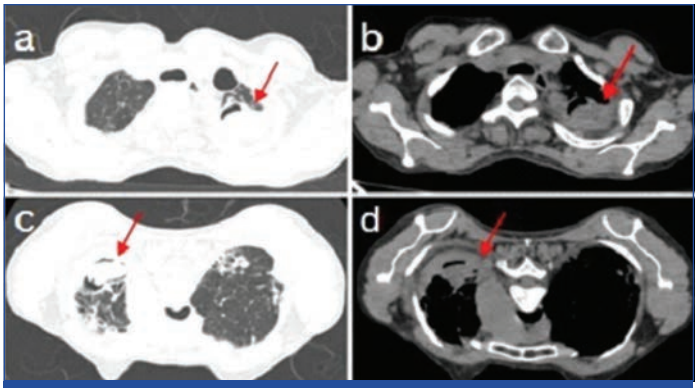


**[Table/Fig-13]:** HPE obtained from the lesion revealed sparse hyphae, eosinophilic infiltration with inflamed surrounding mucosa, suggestive of fungal sinusitis.

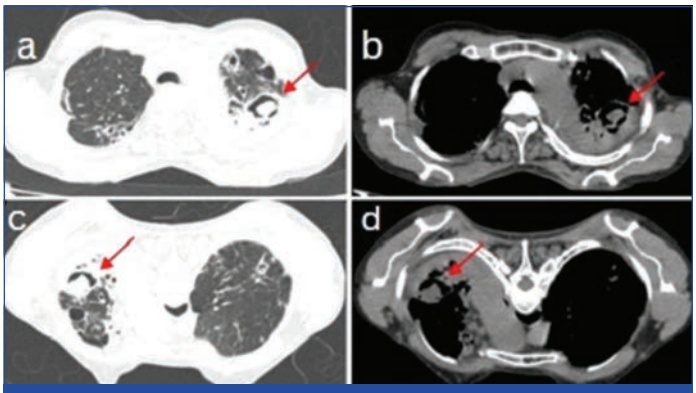



**[Table/Fig-14]:** a,b): CT-Chest axial section lung window: (a) image showing right middle lobe centrilobular nodules (red arrow; (b) left upper lobe fibrotic changes in the left upper lobe with surrounding pleural thickening and bronchiectasis (red arrow).

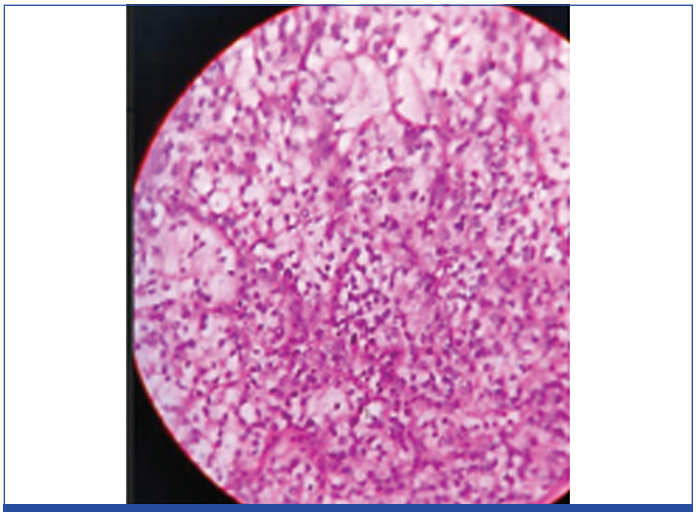
moving with relative change in patient position (supine to prone) with a distinct "Monod" sign appearance [Table/Fig-15,16] pathognomic of aspergilloma. The patient underwent bronchoscopy, HPE and fungal culture revealed fungal hyphae consistent with Aspergillus species, confirming the diagnosis of pulmonary aspergilloma secondary to TB [Table/Fig-17,18]. The patient was started on oral itraconazole (200 mg twice daily) for pulmonary aspergilloma and continued latent TB treatment with isoniazid (300 mg daily). Regular monitoring of liver and renal function was conducted during therapy. The patient reported symptomatic improvement in terms of cough and haemoptysis after approximately four weeks of therapy. She was discharged after six weeks of inpatient observation and medication stabilisation, with advice for monthly follow-up in the respiratory medicine Outpatient Department (OPD).




**[Table/Fig-15]:** a,b) CT chest axial sections in lung and mediastinal window showing thick walled cavity (red arrow)with adjacent consolidatory changes involving left upper lobe with a dependent soft-tissue density component which is seen moving with relative change in patient position (supine to prone) with a distinct "Monod" sign appearance (c,d).




**[Table/Fig-16]:** (a,b) CT chest axial sections in lung and mediastinal window showing another thick walled cavity(red arrow)with adjacent consolidatory changes involving left upper lobe with a dependent soft-tissue density component which is seen moving with relative change in patient position (supine to prone) with a distinct "Monod" sign appearance (c,d).



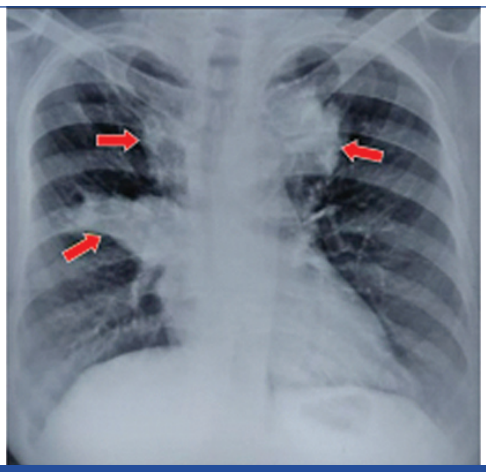
**[Table/Fig-17]:** Histopathology H&E staining shows fungal branching hyphae surrounded by lymphocytes, plasma cells, macrophages, and neutrophils consistent with Aspergillus.

**[Table/Fig-18]:** Fungal culture in sabouraud dextrose agar shows fungal growth with green surface characteristic of aspergillus and microscopic examination of cultured isolates reveals distinctive fungal structures (conidiophores, vesicles, phialides).

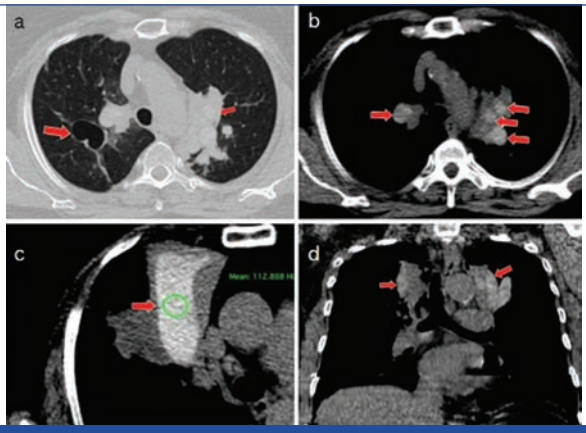
## Case 5

A 65-year-old female with a history of asthma for 10 years, type II Diabetes Mellitus (DM) for four years presented with fever, cough, and haemoptysis for the past seven days. Laboratory parameters shows elevated total serum IgE (>1000 ng/mL), or IgG level. Patient was referred for chest radiograph and cross-sectional imaging.

Radiograph shows ill-defined radio-opacity in the bilateral upper and right mid-zone with enlarged hilum [Table/Fig-19]. HRCT chest was done which revealed centrilobular nodules, dilatation of the distal aspect of central segmental bronchi (cylindrical bronchiectasis) with hyperdense mucus secretions (average Hounsfield Unit of ~112) within the dilated bronchi, consistent with mucoid impaction, giving rise to the "finger-in-glove" sign [Table/Fig-20]. Surrounding areas of resorptive/obstructive atelectasis were noted involving the bilateral upper lobes and the right middle lobe.



**[Table/Fig-19]:** Chest radiograph showing ill-defined radio-opacities (red arrows) in bilateral upper and right mid zone.

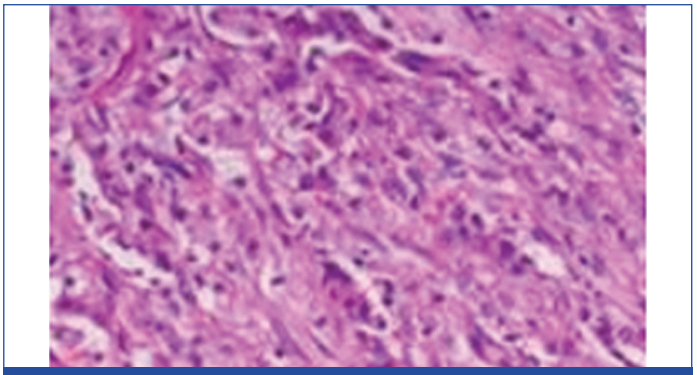



**[Table/Fig-20]:** (a) CT chest axial section in lung window; b,c) Axial sections in mediastinal window and d) Coronal section in mediastinal window showing dilatation of distal aspect of central segmental bronchi (cylindrical bronchiectasis) with uniformly hyperdense areas/collection seen within the dilated bronchi possibly representing hyperattenuating mucus of average HU ~ 120-160 (red arrow) with surrounding areas of resorptive/obstructive atelectasis involving bilateral upper lobes and right middle lobe.

The diagnosis of Pulmonary Allergic Bronchopulmonary Aspergillosis (ABPA) was confirmed through BAL culture and histopathology [Table/Fig-21]. During the hospital stay, the patient was treated with oral corticosteroids (prednisone 0.5 mg/kg/day tapered over 3 months) to manage inflammation and itraconazole (200 mg twice daily) to reduce the fungal burden. Supportive care included bronchodilators for symptom relief, and anti-IgE therapy (omalizumab) was initiated for severe hypersensitivity. However, the patient did not return for follow-up imaging, though clinical symptoms had notably improved during the hospital stay.

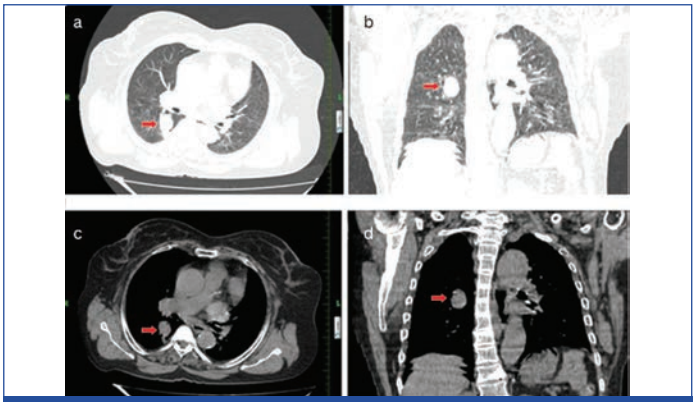
## Case 6

A 62-year-old female came to the pulmonary medicine OPD with complaints of coughing for 10 days, one episode of haemoptysis two days prior, shortness of breath, and difficulty in breathing. Patient underwent HRCT chest, which reveals a well-defined Soft tissue density lesion with surrounding ground glass opacities with adjacent areas of bronchiectatic and bronchiolectatic changes in the superior segment of the right lower lobe. Few soft tissue density nodules were seen involving the subpleural region, apical



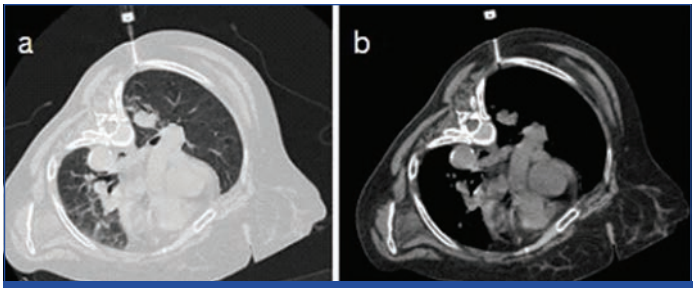
**[Table/Fig-21]:** HPE report reveals eosinophil infiltration within the bronchial walls and thick, tenacious mucous plugs with fungal hyphae in the bronchi which is suggestive of Allergic Bronchopulmonary Aspergillosis (ABPA).

and posterior segments of the right upper lobe [Table/Fig-22]. The varied radiological manifestations including ground-glass opacities, nodules, and clinical features were suggestive of infective aetiology.

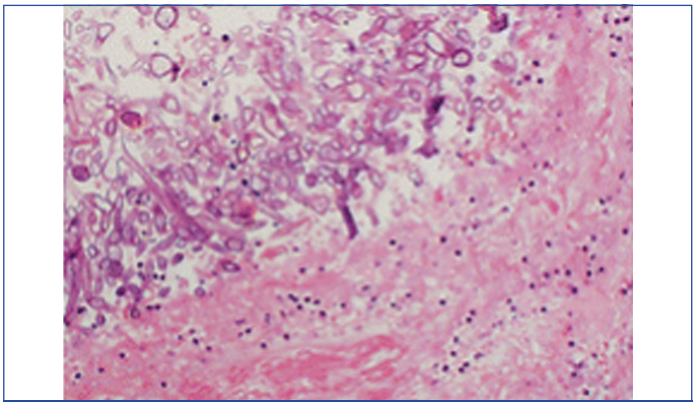



**[Table/Fig-22]:** a-d) CT chest images axial and coronal sections in lung and mediastinal windows showing round well-defined lesion (red arrows) in superior segment of right lower lobe.

Bronchoalveolar lavage sample sent for culture which is inconclusive. Further CT- guided biopsy done and specimen was sent for histopathology which revealed diagnosis of pulmonary mucormycosis [Table/Fig-23,24].

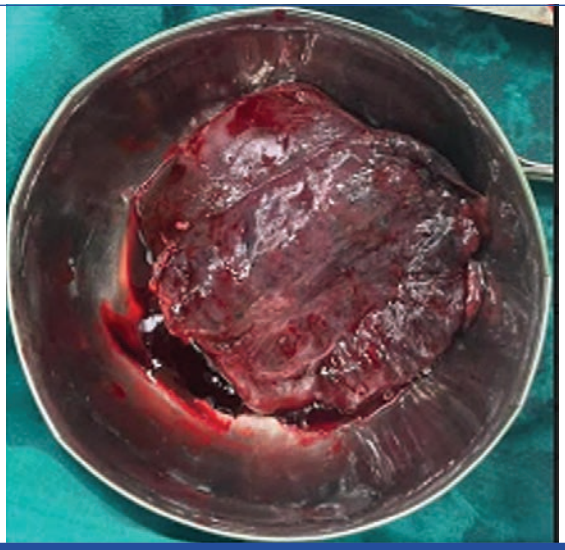



**[Table/Fig-23]:** a,b) CT axial section lung and mediastinal window showing CT guided biopsy needle with tract.

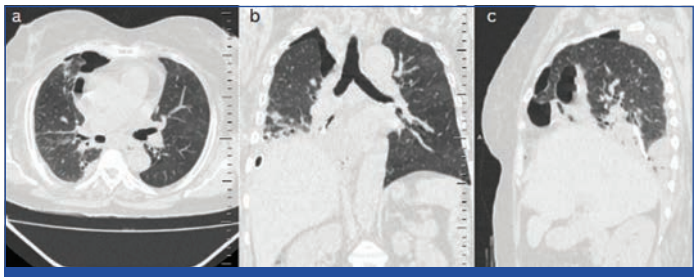


**[Table/Fig-24]:** HPE obtained from right lung lower lobe lesion, multiple clustered hyphae and sporangia- mucormycosis.

Further right lung lower lobectomy was done for the patient to prevent the spread of infection [Table/Fig-25]. After undergoing a right lung lower lobectomy, follow-up CT imaging revealed the presence of hydropneumothorax, indicating a potential postoperative complication requiring further evaluation and management [Table/Fig-26].



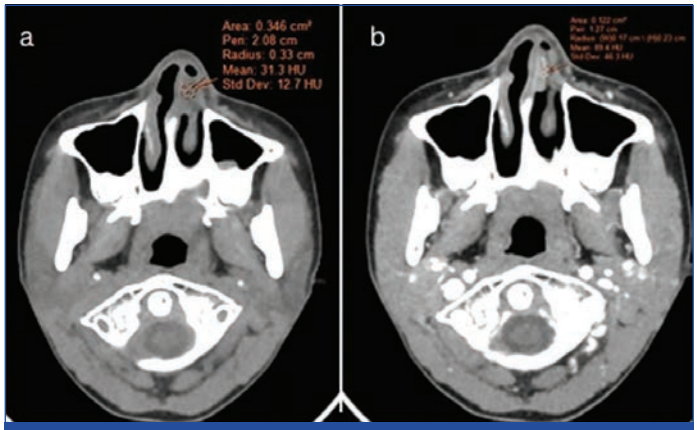
**[Table/Fig-25]:** Shows gross specimen of right lower lobe lung after lobectomy.




**[Table/Fig-26]:** a-c) Plain CT-chest lung window axial, coronal and sagittal section shows right hydro-pneumothorax.in follow-up scan after right lower lobe-lobectomy.

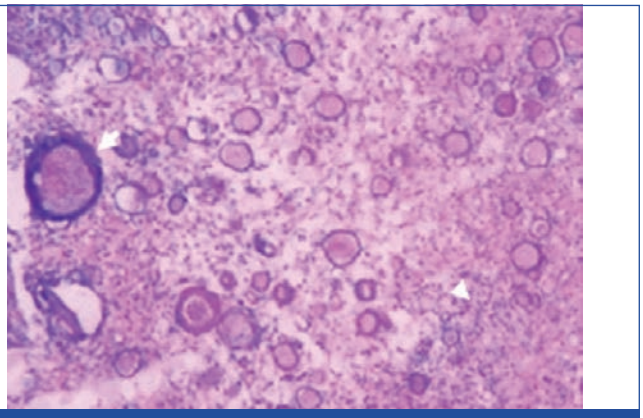
### Case 7

A 28-year-old male came to Oto-rhino-laryngology OPD with a history of chronic sinusitis for two years and complaints of left nasal congestion, presented with a soft-tissue mass structure coming out from the left-side of the nasal cavity for the past three weeks. On indirect laryngoscopy, no mass was seen in the choanae. The patient was referred to the radiology department for further investigation. Contrast-enhanced CT-PNS was done, which shows an enhancing soft-tissue density lesion in the anterior aspect of the left nasal cavity [Table/Fig-27a,b]. The radiological diagnosis based on contrast-enhanced CT-PNS findings was consistent with nasal rhinosporidiosis. Patient was treated with oral itraconazole (200 mg daily) for rhinosporidosis, nasal decongestants, corticosteroid sprays (fluticasone), and antibiotics to manage secondary infections.




**[Table/Fig-27]:** a,b) CTPNS- Plain and contrast enhanced images in soft-tissue window showing ill-defined post-contrast enhancing lesion arising from anterior aspect of left nasal cavity.

Further surgical resection was done and sample was sent for tissue biopsy and histopathology diagnosed as rhinosporidosis [Table/Fig-28]. Following the surgical resection of the rhinosporidiosis lesion, the patient did not return for follow-up; however, the patient reported being symptomatically better.



**[Table/Fig-28]:** HPE image shows sporangia with endospores (white arrow) and inflammatory cells (white arrow head ).

## DISCUSSION

Fungal infections may occur in a variety of forms, although it is very common in immunocompromised states. Imaging is the backbone of diagnosing such conditions early. The case series here depicts the diverse imaging of fungal infection involving lungs, the PNS, and CNS. Radiologic findings are important for early diagnosis that helps in timely management of this possibly debilitating disease that has a great impact on patient outcome [14].

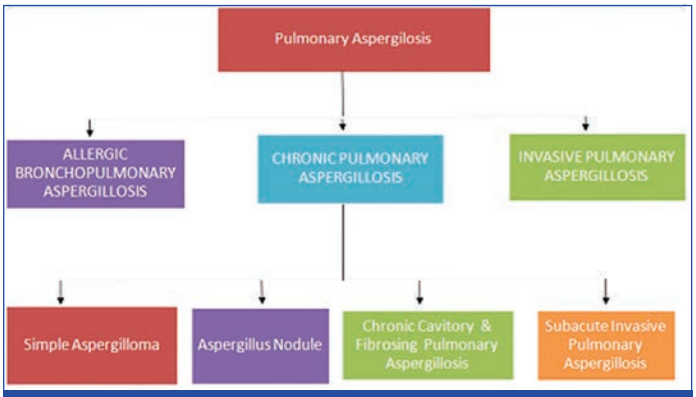
The case series highlighting key aspects including patient history, imaging findings, treatment strategies, and clinical outcomes summarised in [Table/Fig-29].

The most common pulmonary fungal infections, particularly aspergillosis classified under three broad categories clinically as described in [Table/Fig-30] [15], occur in immunocompromised populations, we demonstrated pulmonary aspergilloma in its classical presentation: cavitary lesion with a mobile fungal ball inside with relative change in patient position (supine to prone) represented the “monod sign” and distinct crescent-shaped airspace that separates a mass from the wall of a cavity depict “air crescent sign,” typical for the disease. This sign is most commonly seen in chronic pulmonary aspergillosis but can also appear in invasive aspergillosis during the healing phase when neutrophils recovery leads to cavitation and clearance of necrotic debris [6,16]. A previous history of TB pointed out that clinical background sometimes plays a crucial role in radiologic diagnosis. These appearances bring out the importance of high-image resolution techniques in defining fungal infections from other pulmonary diseases [7]. Histopathological diagnosis is still paramount in consideration of the radiological mimics of fungal infections like neoplasms [17].

Fungal infections of the PNS, especially invasive fungal sinusitis, have a tendency to spread to contiguous structures such as the orbit and CNS. Invasive fungal sinusitis with extensive involvement of the ethmoid bones, orbits, and intracranial extension is characterised by imaging findings such as bony erosion and intracranial spread, which are indicative of rhino-cerebral aspergillosis [18,19]. MRI, with its superior contrast resolution, is particularly useful for assessing soft-tissue structures, the optic nerve, and cavernous sinus involvement [9]. An illustrative instance involved a diabetic patient who developed rhino-orbital-cerebral mucormycosis following COVID-19, demonstrating the aggressive progression of mucormycosis in individuals with comorbidities. Early diagnosis is crucial to prevent the rapid spread of the infection, and imaging with CT and MRI plays a vital role in guiding timely treatment [1]. Fungal infections of the CNS, usually secondary to sinus or haematogenous spread, are life-threatening, especially in immunocompromised patients.

| Case | Patient demographics | History and symptoms | Imaging findings | Diagnosis | Type of fungal disease | Treatment | Outcome |
|---|---|---|---|---|---|---|---|
| 1 | 42-year-old female | History of histoid Hansen and type II lepra reaction, ptosis, diplopia, insomnia, facial swelling, blurring of vision | MRI: Hetero-intense enhancing lesion in right ethmoidal sinus extending into the orbit, optic nerve encasement, cavernous sinus involvement, erosion of cranial bones (CT) | Rhino-cerebral aspergillosis confirmed by biopsy | Invasive Aspergillosis | Voriconazole (6 mg/kg IV twice daily, transitioning to oral) or liposomal amphotericin B in case of intolerance, alongside thalidomide (100-200 mg daily) | "Patient succumbed to illness" |
| 2 | 62-year-old male, diabetic | History of COVID-19 infection, low-grade fever, headache, nasal congestion, epistaxis, nasal hypoesthesia | CT chest: Ground-glass opacities, nodules; MRI: Non-enhancing mucosal thickening, cerebritis, bony erosion in right maxillary sinus | COVID-19 viral pneumonia with superimposed fungal infection-Mucormycosis | Invasive Fungal Rhinosinusitis | 6 weeks of amphotericin, endoscopic turbinectomy, nasal debridement | Discharged with follow-up required. Patient did not come for follow up. |
| 3 | 30-year-old female | Chronic sinusitis, nasal congestion | CT-PNS: Opacification of bilateral maxillary, ethmoid, sphenoid sinuses with hyperdense areas | Allergic fungal sinusitis confirmed by sinus aspiration and culture | Allergic Fungal Sinusitis | Prednisolone 40 mg daily for 2 weeks, itraconazole (200 mg daily for 6 weeks | Symptomatically improved |
| 4 | 55-year-old female, | History of treated pulmonary TB 4 years ago Worsening cough, haemoptysis, low-grade fever for 3 months | HRCT: Cavitary lesions in the left upper lobe, fibrotic changes, bronchiectasis, pleural thickening, and "Monod" sign suggestive of aspergilloma | Pulmonary Aspergilloma secondary to Tuberculosis (TB) | Aspergillus species | Oral itraconazole (200 mg twice daily), Isoniazid (300 mg daily) for latent TB | Symptomatic improvement in cough and haemoptysis |
| 5 | 65-year-old female, | History of asthma, type II DM Fever, cough, haemoptysis | Chest radiograph: Ill-defined radio-opacity in bilateral upper and right mid-zone with enlarged hilum. HRCT: Centrilobular nodules, cylindrical bronchiectasis, hyperdense mucus (finger-in-glove sign), atelectasis in bilateral upper lobes and right middle lobe | Pulmonary Allergic Bronchopulmonary Aspergillosis (ABPA) | Aspergillus species | Oral corticosteroids (prednisone 0.5 mg/kg/day tapered over 3 months), itraconazole (200 mg twice daily), anti-IgE therapy (omalizumab), bronchodilators | Symptomatic improvement during hospital stay, did not return for follow-up |
| 6 | 62-year-old female | Cough, one episode of haemoptysis, shortness of breath, difficulty breathing | HRCT: Well-defined soft tissue density lesion with surrounding ground-glass opacities, bronchiectasis, bronchiolectatic changes in right lower lobe, soft tissue density nodules in subpleural regions of right upper lobe | Pulmonary Mucormycosis | Mucormycosis | Right lung lower lobectomy, antifungal therapy (specific regimen not mentioned) | Surgery (Lobectomy) completed, further CT scan done. Shows hydropneumothorax. |
| 7 | 28-year-old male | Nasal polyps, chronic sinusitis, left nasal congestion | Contrast-enhanced CT-PNS: Enhancing soft tissue density lesion in left nasal cavity | Rhinosporidiosis confirmed by tissue biopsy | Rhinosporidiosis | Surgical resection | Symptomatically improved |

**[Table/Fig-29]:** Presents a summary of the cases in this series, including patient history, imaging findings, treatment approaches providing a detailed overview of the management and outcomes.




**[Table/Fig-30]:** Pulmonary aspergillosis types [15]

Rhino-cerebral aspergillosis with orbit, cavernous sinus, and optic nerve involvement presents features that are highly characteristic of fungal infections affecting the CNS. These include no-enhancement, minimal and leptomeningeal enhancement, restricted diffusion, and ring-enhancing lesions, which are helpful in distinguishing fungal cerebritis (early and late) and abscess from other CNS infections or neoplastic lesions. This again brought out newer imaging importance in the evaluation of the CNS involvement for the sake of diagnosis, as the fungal abscess may have a non-specific appearance that may mimic other pathology [4].

A direct microscopy, histopathology, and fungal culture of surgical specimen form the cornerstones in the diagnosis of rhino-orbital-cerebral mucormycosis and radiological investigations are helpful in differentiate similar imaging feature.

Allergic Fungal Rhinosinusitis (AFRS) tends to be chronic, presenting with hyperdense sinus pacifications on CT, unlike invasive disease. The case showed extensive sinus opacification and inspissated secretions-classic findings for AFRS. As it is a non-invasive disease, although treatment may be able to achieve good symptom control, AFRS requires lifelong management due to the likelihood of recurrence, and CT imaging has a central role in diagnosis and follow-up. These imaging patterns help differentiate AFRS from the more aggressive forms of fungal sinusitis and allow less urgent interventions [20].

Rhinosporidiosis is chronic granulomatous disease caused by Rhinosporidium seeberi presently classified in class Mesomycetozoea. This disease is characterised by the presence of large, round-shaped mature stage and small endospores with resistance to culturing. Seeberi R was first reported in 1900 as a sporozoan parasite, but later classified as a lower fungus, although its morphological similarity with aquatic parasites was also noticed. The nasal cavity is a partially vascularised area, meaning that systemic medications often have limited and delayed efficacy in treating conditions like rhinosporidiosis. Due to the poor penetration of drugs in this region, conservative treatment may not always provide sufficient results, making surgical resection the preferred and more effective approach for complete removal of the lesion [21,22].

Imaging plays an important role in diagnosing fungal infection and in evaluating the extent of disease in complicated cases. CT

| Authors | Year | Fungal species | Affected system | Sample size | Study design | Key findings |
|---|---|---|---|---|---|---|
| Meena V et al., [27] | 2024 | Mucorales spp. | Rhino-Orbital-Cerebral | 40 patients | Case series | HRCT and MRI critical in diagnosing ROCM, showing orbital and cerebral invasion.<br>Radiological hallmark -Orbital invasion, cavernous sinus involvement, cerebral extension |
| Manuel RA et al., [24] | 2023 | Mucorales spp. | Paranasal sinuses (PNS) | 52 patients | Retrospective Study | Imaging highlighted mucormycosis rhinosinusitis patterns during the pandemic second wave.<br>Radiological hallmark - CT and MRI revealed characteristic sinus involvement with bony erosions; emphasized early imaging for COVID-associated mucormycosis. Sinus opacification with bony erosion |
| Patel A et al., [1] | 2020 | Mucorales spp. | Rhino-Orbital-Cerebral | 388 patients | Observational Study | Identified risk factors (diabetes, immunosuppression); highlighted high mortality and importance of early diagnosis ,management. and outcomes of mucormycosis.<br>Radiological hallmark-<br>Non-specific consolidation, sinus invasion, CNS spread |
| Gazzoni FF et al., [17] | 2014 | Various fungi (Aspergillus, Histoplasma etc.) | Pulmonary | 52 Patients | Radiologic-pathologic correlation Study | Fungal diseases can mimic primary lung cancer; emphasized imaging alone may be misleading, histopathological confirmation essential..<br>Radiological hallmark- Solitary pulmonary mass mimicking carcinoma |
| Chakrabarti A et al., [7] | 2009 | Various fungi | Paranasal sinuses | N/A | Review Article | Proposed categorization and definitional schema for fungal rhinosinusitis.<br>Radiological hallmark- Non-specific – depends on subtype; often sinus heterogeneity |
| Brumble LM et al., [4] | 2017 | Various fungi | CNS | N/A | Case series | Described clinical, radiographic, and laboratory features of CNS fungal infections highlighted challenges in diagnosis and need for multimodal approach.<br>Radiological hallmark- Ring-enhancing lesions, meningeal enhancement |
| Cho HJ et al., [14] | 2015 | Mucorales/ Aspergillus spp. | Paranasal sinuses (acute invasive) | 47 patients | Retrospective Study | Identified poor prognostic factors for survival in acute invasive fungal rhinosinusitis: intracranial extension, delayed diagnosis, and uncontrolled diabetes.<br>Radiological hallmark- Extrasinus extension, intracranial spread |
| Ferguson BJ et al., [6] | 2000 | Various fungi | Paranasal sinuses | N/A | Review ArticleStudy | Provided definitions and classification framework for fungal rhinosinusitis.<br>Radiological hallmark- Classification rather than specific signs |
| Patterson TF et al., [23] | 2016 | Aspergillus spp. | Pulmonary, CNS, Disseminated | Review Study | Practice Guideline | IDSA practice guideline for diagnosis and management of aspergillosis.<br>Radiological hallmark- Halo sign, air-crescent sign, cavitary lesions |
| Leroy J et al., [9] | 2020 | Aspergillus spp. | Rhino-Orbital-Cerebral | 1 patient | Case report | Rare case of invasive rhino-orbital-cerebral aspergillosis in an immunocompetent patient; emphasized aggressive imaging and surgical debridement; MRI/CT useful in diagnosis.<br>Radiological hallmark- Orbital cellulitis with cavernous sinus thrombosis |
| Kim MJ et al., [16] | 2001 | Aspergillus spp. | Pulmonary (IPA) | 50 patients | Retrospective Study | Described the frequency of the “crescent sign” in invasive pulmonary aspergillosis; associated with neutrophil recovery and favorable prognosis<br>Radiological hallmark- Crescent sign (air crescent around necrotic nodule) |
| Gavito-Higuera J et al., [28] | 2016 | Various i | Paranasal sinuses (PNS) | N/A | Pictorial review Article | Illustrated sinonasal fungal infections and complications; emphasized imaging hallmarks. |
| Aribandi M et al., [5] | 2007 | Various | Paranasal sinuses (PNS) | N/A | Review Article | Compared imaging features of invasive vs non-invasive fungal sinusitis; CT and MRI play complementary roles. |
| DelGaudio JM et al., [8] | 2003 | Aspergillus spp., Mucorales spp. | Paranasal Sinus (PNS) | 16 patients | Retrospective CT study | CT revealed early bone erosion and extrasinus extension, crucial for early diagnosis of invasive fungal sinusitis. |
| deShazo RD et al., [10] | 1997 | Aspergillus spp. | Paranasal Sinus (PNS) | 27 patients | Prospective clinical and radiologic study | Established diagnostic criteria for sinus mycetoma; CT demonstrated heterogeneous opacities with intralesional calcification as a hallmark feature. |
| Dagher R et al., [29 ] | 2025 | Various | Paranasal Sinus (PNS) | N/A | Narrative Review | Provides modern imaging approach and diagnostic algorithms for fungal sinusitis, emphasizing CT and MRI role in early detection. |
| Mukherji SK et al., [11] | 1998 | Allergic fungal spp. | Paranasal sinus (PNS) | N/A | Case series | CT findings characteristic for allergic fungal sinusitis, including heterogeneous opacities and sinus expansion. |

**[Table/Fig-31]:** Summarises the existing literature on the radiologic spectrum of fungal infections, highlighting key imaging features associated with pulmonary, paranasal sinus, and central nervous system involvement [1,4-11,14,16,17,23,24,27-29].

provides the optimal modality for delineation of bony involvement, whereas MRI is better for soft tissue and CNS involvement, as was demonstrated in several cases in this series. Early imaging diagnosis enables the prompt initiation of aggressive antifungal therapy, such as amphotericin B or voriconazole, significantly reducing morbidity and mortality. In advanced cases of fungal disease, surgical interventions like debridement or lobectomy may be necessary to control the spread of infection [23]. This series underlines the increasing importance of fungal infections, including recently growing cases in the setting of COVID-19 and in diabetic patients with mucormycosis. Awareness of characteristic imaging patterns is important for both radiologists and clinicians in order to ensure early detection and proper treatment, because fungal infections, particularly invasive types, can progress rapidly without being treated in time [24].

CT and MRI help provide an early diagnosis in conjunction with pathologic and microbiological correlations. Regular imaging follow-up is important to monitor for changes in the size of the aspergilloma or signs of secondary infection [25,26]. Immediate correction of immunosuppression with the initiation of amphotericin B therapy combined with extensive and diligent surgical debridement of the diseased tissue is required [27]. The existing literature on the radiologic spectrum of fungal infections is presented, emphasising the key imaging features related to pulmonary, paranasal sinus, and CNS involvement outlined in [Table/Fig-31] [1,2,4-11,14,16,17,23,24,27-29].

## CONCLUSION(S)

Recognising the imaging features of the characteristic patterns of fungal infections is crucial for timely diagnosis and management.

This case series underscores the importance of correlating clinical findings with radiologic evidence to distinguish between various fungal pathogens and tailor appropriate treatment strategies.

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**PARTICULARS OF CONTRIBUTORS:**

1. Professor, Department of Radiodiagnosis, Shri Sathya Sai Medical Colllege and Research Institute, Chengalpattu, Tamil Nadu, India.
2. Associate Professor, Department of Radiodiagnosis, Shri Sathya Sai Medical Colllege and Research Institute, Chengalpattu, Tamil Nadu, India.
3. Assistant Professor, Department of Radiodiagnosis, Shri Sathya Sai Medical Colllege and Research Institute, Chengalpattu, Tamil Nadu, India.
4. Junior Resident, Department of Radiodiagnosis, Shri Sathya Sai Medical Colllege and Research Institute, Chengalpattu, Tamil Nadu, India.

**NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:**

Dr. Sachin Virmani,
House No. 1285, Sector-19, Part-I, Huda, Kaithal-136027, Haryana, India.
E-mail: dr.virmani29@gmail.com



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