

# CT/MRI SEVERITY SCORING IN RHINO-ORBITO-CEREBRAL MUCORMYCOSIS: CORRELATION WITH SURGICAL EXTENT AND 30-DAY OUTCOMES

Aanab Hayat<sup>1</sup>, Abbas Ahmad<sup>2</sup>, Saira Khan<sup>1</sup>, Samira Ahmad<sup>3</sup>, Salma Liaqat<sup>1</sup>

<sup>1</sup>Saidu Group of Teaching Hospitals, Swat Pakistan

<sup>2</sup>Miangul Abdul Haq Jahanzeb Kidney Hospital, Swat Pakistan

<sup>3</sup>Rehman Medical Institute, Peshawar Pakistan

## ABSTRACT

**Background:** Rhino-orbito-cerebral mucormycosis (ROCM) is a highly virulent angio-invasive infection with rapid compartmental spread, often requiring escalation of surgery and carrying substantial early mortality. This study aimed to determine the relationship between a CT/MRI severity score, surgical extent, and 30-day outcomes.

**Material and Methods:** Consecutive ROCM patients with baseline CT and/or MRI, operative notes, and 30-day follow-up data were eligible at a tertiary-care centre from March to August 2022. Predefined domains (sinonasal, orbital, cavernous sinus, intracranial/CNS, vascular, and bone) were scored independently by two radiologists to generate a composite severity score. Surgical extent was categorized from endoscopic debridement to combined craniofacial/neurosurgical procedures.

**Results:** Among 62 patients, the severity score increased progressively with surgical extent (Spearman rho = 0.68,  $p < 0.001$ ). Thirty-day mortality was 22.6% and rose with increasing severity (0% in mild disease; 50% in severe disease). Severity score independently predicted 30-day mortality (adjusted OR per point 1.54) and showed good discrimination (AUC 0.84). Inter-rater reliability for the total score was high (ICC 0.91).

**Conclusion:** CT/MRI severity scoring is a reliable measure that aligns with operative extent and early outcomes and may support standardized reporting and early risk stratification in ROCM.

**Keywords:** Computed tomography, Rhino-orbito-cerebral mucormycosis, Magnetic resonance imaging, Severity scoring, Surgical extent, Prognosis, 30-day outcomes

## BACKGROUND

Rhino-orbito-cerebral mucormycosis (ROCM) is an angio-invasive fungal infection with a tendency to be rapidly spread to orbit, skull base, and brain, which usually starts in the nasal cavity or paranasal sinuses. Thrombosis and tissue necrosis caused by vascular invasion result in fulminant symptoms and subtle early changes in mucosal imaging that may be observed before bony destruction.<sup>1,4,9,17</sup> Cases of ROCM increased in low- and middle-income areas during and after the COVID-19 due to uncontrolled diabetes, exposure to corticosteroids, immune dysregulation, and delayed presentation causing more pressure on surgical and multidisciplinary care.<sup>3,8,16,18</sup>

ROCM has emerged as an emergency of concern in South Asia, including Pakistan where patients usually

present with advanced sino-orbital disease. There is limited resources in terms of operating theatre time, antifungals, ICU beds as well as imaging. The post-COVID disease patterns have been found to be severe in the local experience in Pakistan, which highlights the necessity of a timely detection and systematic evaluation to simplify the referral and operative planning. The variability of invasive changes and extension of ROCM in reporting introduces uncertainty on a sense of urgency and what debridement is likely to be like, especially reporting on imaging that has been interpreted by various specialities.<sup>2,3</sup>

The imaging assessment plays a critical role in ROCM since the clinical observation is not enough to estimate the deep spread of the disease and early surgery should be performed based on the correct mapping of the affected compartments. Contrast-enhanced CT is used to assess the sinonasal opacification and fat stranding, bone erosion, and maxillofacial extension, but MRI is more effective to show the invasion of the soft tissue, perineural spread, cavernous sinus, skull-base disease, and intracranial complications. Devitalized tissue can

**Correspondence:** Dr. Abbas Ahmad, Senior Registrar, Miangul Abdul Haq Jahanzeb Kidney Hospital, Swat Pakistan

**Email:** [abbax80@gmail.com](mailto:abbax80@gmail.com)

*This article can be cited as:* Hayat A, Ahmad A, Khan S., Ahmad S, Liaqat S CT/MRI severity scoring in rhino-orbito-cerebral mucormycosis: Correlation with surgical extent and 30-day outcomes. *Infect Dis J Pak* 2022; 33(4): 136-142.

be in the form of non-enhancement, diffusion limit, or vascular malformation, including carotid constriction, all of which hold significant relevance in the surgery plans and prognosis.<sup>2,4,7,9</sup>

Since the management of ROCM is time-sensitive, clinicians cannot be satisfied with a descriptive report; they need an estimate of the severity which can be interpreted uniformly and associated with radiologic extent and with the clinical decision-making process. Newer cohorts suggest that imaging stage is outcome-linked and has the ability to facilitate standardized reporting, communication, and triage.<sup>10</sup> Inter-rater agreement, as well as strong correlations with severity and patient outcomes have also been demonstrated in CT/MRI staging systems, and structured scoring has become a universal language in radiology, ENT/maxillofacial surgery, ophthalmology, and neurosurgery<sup>13,16</sup>. This is especially applicable when operative escalation is perhaps needed, such as maxillary or palatal resection, orbital surgery, and skull-base or intracranial operation, and early outcomes (30-day mortality, clinical deterioration, or reoperation) need to be expected.<sup>9,13</sup>

The paper has discussed the problem of non-standardised image interpretation in rhino-orbito-cerebral mucormycosis (ROCM) using a CT/MRI severity scoring system and assessing the value of structured reporting. It was to determine whether a score on imaging severity would be an objective determinant of disease extent, surgery, and 30-day outcomes. The key objectives were to measure severity of ROCM, relate scores with surgical requirements and investigate connections with early outcomes. The questions of interest were that CT/MRI severity scores were equal to surgical extent and predict worse results in 30 days. The authors made a strong contribution to the research by offering a decision-support framework that would enhance communication, triage, planning, and early risk stratification in regional care by being reproducible, and multidisciplinary.

## MATERIAL AND METHODS

The study was a retrospective cohort study of a tertiary-care hospital, in which patients with ROCM were treated in an integrated fashion in the Departments of Radiology, Otolaryngology (ENT), Ophthalmology, and, when necessary, Neurosurgery. The research time frame was between March 1, 2022,

and August 31, 2022, and all the cases handled within this period and suitable were studied.

The target population was composed of patients who have suspected or confirmed ROCM and who were subjected to CT or MRI to have their diagnostic level evaluated and surgery planned. ROCM was characterized as an invasive fungus infection that develops in the sinonasal region and may spread to the orbit or the intracranial compartment. Clinical presentation of the disease was associated with diagnostic aids, e.g., facial pain or swelling, black eschar, ophthalmoplegia, visual changes, cranial neuropathies, image, and laboratory confirmation where possible. Diagnostic confirmation was categorized as: (a) proven ROCM, identified by histopathology or fungal culture of tissue obtained by endoscopic biopsy or debridement: and (b) probable ROCM, identified by compatible clinical and imaging findings with high multidisciplinary agreement when tissue confirmation was lacking.

Patients were included if they *met all* of the following:

1. Suspected or confirmed ROCM during the study period (March–August 2022).
2. Availability of contrast-enhanced CT and/or MRI performed at baseline (pre-operative or early peri-operative).
3. Underwent surgical intervention (to any extent) with operative notes available for classification.
4. Availability of 30-day outcome data through inpatient records and/or follow-up documentation.

Patients were excluded if they had:

1. Isolated non-invasive fungal sinusitis without evidence of invasion.
2. Inadequate imaging quality or missing imaging sequences preventing scoring.
3. Missing key clinical or operative documentation needed for primary analyses.
4. Lost to follow-up with unavailable 30-day outcome status.

Because ROCM was relatively uncommon and the study was time-bound, a consecutive sampling approach was used: all eligible ROCM cases within the 6-month period were included. Formal sample-size calculation was not mandatory for this retrospective design; however, the final sample size was reported, and precision was reflected using confidence intervals for key estimates.

Data were collected from hospital records using a structured abstraction form. Clinical data included admission notes, consultation records, laboratory results, diabetic charts, treatment records, discharge summaries, and follow-up notes. Imaging was retrieved from the Picture Archiving and Communication System (PACS), including baseline CT/MRI reports and source images for re-review. Surgical notes documented procedures and disease extent. Thirty-day outcomes were obtained from inpatient records, outpatient visits, and telephonic follow-up. Dates were recorded to calculate intervals from symptom onset to presentation, from imaging to surgery, and from diagnosis to initiation of antifungal therapy.

Image review included contrast-enhanced CT of the paranasal sinuses and orbits, with brain imaging assessed when indicated. CT was evaluated for sinonasal opacification, mucosal non-enhancement, fat stranding, bone changes, orbital fat infiltration, and extension to the pterygopalatine and infratemporal fossae. MRI of the brain and orbits, including T1/T2-weighted, fat-suppressed, diffusion-weighted, and contrast-enhanced sequences, was reviewed for soft-tissue invasion, perineural spread, cavernous sinus or skull-base involvement, intracranial extension, vascular complications, and patterns of devitalized tissue.

A structured CT/MRI severity score was applied using predefined domains that reflected stepwise disease spread. Each domain was scored on an ordinal scale: 0 = no involvement, 1 = limited involvement, and 2 = extensive involvement within that domain.

- Domains included sinonasal, orbital, cavernous sinus, intracranial/CNS, vascular, and bone involvement, where applicable. The composite severity score was calculated as the sum of domain scores. When severity categories were used, cases were classified as mild, moderate, or severe according to pre-specified cut-offs aligned with overall compartmental spread.

**Reader training and blinding:** Two radiologists with head-and-neck/neuroimaging experience underwent a brief calibration session using representative cases and a written scoring manual. They independently scored imaging while blinded to 30-day outcome status, and access to operative notes was restricted during initial scoring to reduce bias. Inter-observer agreement for

domain and total scores was assessed using Cohen's kappa for categorical domains and the intraclass correlation coefficient (ICC) for the composite score. Discrepancies were resolved by consensus review.

Surgical management was categorized according to the maximum extent of surgery performed during the index admission:

1. Endoscopic sinus debridement only (limited to sinonasal clearance).
2. Maxillectomy/palate involvement surgery (palatal resection, partial/total maxillectomy, or open approaches for maxillary/palatal necrosis).
3. Orbital decompression (medial wall/floor decompression or drainage without globe removal).
4. Orbital exenteration (removal of orbital contents).
5. Combined craniofacial/neurosurgical procedures (skull-base clearance, intracranial drainage, or combined approaches). Criteria for each category were extracted directly from operative documentation, and when multiple procedures were performed, the highest category was used to define surgical extent.

Data were cleaned and entered before analysis. Missing data were coded; in the cases of limited missingness, complete-case analysis was applied, and in the cases of substantial missingness, imputation procedures were chosen based on the type of variables and the pattern of missingness. The descriptive statistics summarized demographics, comorbidities, imaging domains, score distributions, and surgical categories. Continuous variables were evaluated in terms of normality to determine the type of test to be used. The comparison of outcomes was done in terms of the severity and the surgical group, by using chi-square, Fisher exact, t test, Mann-Whitney U, ANOVA or Kruskal-Wallis tests as it was appropriate. The rho by Spearman was used to evaluate the relationship between imaging severity and the extent of surgery. Regression analysis assessed the correlation between the severity score and 30-day mortality or clinical failure with the confounding factors. Adverse outcomes score thresholds were identified through ROC and AUC analysis. ICC and kappa were used to measure inter-rater reliability. The statistical significance value was established at  $p < 0.05$ . The analyses will be done with SPSS, Stata and R.

## RESULTS

The suspected ROCM cases that were screened included 74 in the period of March 1, 2022 to August 31, 2022. Twelve cases were filtered out (complete imaging quality/sequences to score n=6, no surgery to perform n=4 and no 30-day outcome available n=2). The last group consisted of 62 potential patients experiencing CT and/or MRI and severity was rated. There were 45.2% CT-only imaging, 9.7% MRI-only imaging, and 45.2% of both CT and MRI imaging. Table-I summarises the baseline clinical characteristics.

Sinonasal disease was found in all the patients. It was found that 71.0 percent had orbital extension, 29.0 percent had cavernous sinus involvement, 25.8 percent had intracranial/ CNS involvement, 22.6 percent had vascular involvement and 43.5 percent had bone involvement (Table 1). The mean of the composite CT/MRI severity score was 7.2 with a standard deviation of 2.6 (mean 7, minimum 2 and maximum 12). According to a preselected group, 22.6% were mild (04), 48.4% were moderate (58), and 29.0% were severe (912) (Table-I).

Surgical therapy was between endoscopic debridement and a complete craniofacial/neurosurgical. The mean severity scores were growing stepwise with the increasing surgical extent (Table-II). There was an extremely powerful positive reliance among the severity score and ordinal surgical extension (Spearman rho = 0.68, p < 0.001), and the significant pattern across the surgical categories (p < 0.001) (Table-II).

At 30 days, mortality was 22.6%. The severity scores were higher in the non-survivors compared to survivors (9.1 +1.8 vs 6.6 +2.4, p < 0.001). The severity of mortality and clinical failure was found to be higher: mild 0%/14.3, moderate 16.7%/30.0 and severe 50.0%/61.1 (Table-III). The 30-day mortality was independently related to the severity score (adjusted OR 1.54, 95% CI 1.22-1.95, p < 0.001). There was also good discrimination of mortality (AUC 0.84, p < 0.001) at a cut-off of  $\geq 9$  where the sensitivity is 71.4% and specificity is 80.2% (Table 3). There was high inter-observer reliability (ICC 0.91) (Table-III).

**Table-I: Cohort flow, baseline characteristics, imaging compartment involvement, and severity distribution.**

Variable	Value
<b>A. Participant flow &amp; imaging modality</b>	
Screened suspected ROCM cases	74 (100)
Excluded (total)	12 (16.2)
• Incomplete imaging sequences/quality	6 (8.1)
• No surgical intervention	4 (5.4)
• Missing 30-day outcome documentation	2 (2.7)
Included in final analysis	62 (83.8)
CT only	28 (45.2)
MRI only	6 (9.7)
CT + MRI	28 (45.2)
<b>B. Baseline demographic &amp; clinical characteristics</b>	
Age (years), mean $\pm$ SD	52.4 $\pm$ 11.8
Male sex	39 (62.9)
Diabetes mellitus	53 (85.5)
DKA at presentation	18 (29.0)
Recent steroid exposure	35 (56.5)
Immunosuppression (any)	10 (16.1)
Neutropenia	4 (6.5)
COVID-19 history within prior 6–12 weeks	27 (43.5)
Symptom onset $\rightarrow$ presentation (days), median (IQR)	7 (5–10)
Imaging $\rightarrow$ surgery (days), median (IQR)	2 (1–3)
Antifungal therapy started within 24 hours	41 (66.1)
<b>C. Imaging compartment involvement</b>	
Sinonasal involvement	62 (100)
Orbital involvement (any)	44 (71.0)
Orbital apex involvement	19 (30.6)
Cavernous sinus involvement	18 (29.0)
Intracranial/CNS involvement	16 (25.8)
Vascular involvement	14 (22.6)

Bone involvement	27 (43.5)
<b>D. Severity score distribution</b>	
Total severity score, mean $\pm$ SD	7.2 $\pm$ 2.6
Total severity score, median (range)	7 (2–12)
Mild (0–4)	14 (22.6)
Moderate (5–8)	30 (48.4)
Severe (9–12)	18 (29.0)

**Abbreviations:** ROCM = rhino-orbito-cerebral mucormycosis; CT = computed tomography; MRI = magnetic resonance imaging; DKA = diabetic ketoacidosis; CNS = central nervous system; IQR = interquartile range.

**Table-II: Surgical extent and corresponding imaging severity score (N = 62)**

Surgical extent category	n (%)	Severity score (mean $\pm$ SD)
Endoscopic sinus debridement only	20 (32.3)	5.4 $\pm$ 1.7
Maxillectomy / palate surgery	15 (24.2)	6.8 $\pm$ 1.9
Orbital decompression	13 (21.0)	8.1 $\pm$ 2.0
Orbital exenteration	8 (12.9)	9.6 $\pm$ 1.8
Combined craniofacial / neurosurgical procedures	6 (9.7)	10.3 $\pm$ 1.5

Association: Severity score correlated strongly with ordinal surgical extent (Spearman rho = 0.68, p < 0.001). Trend across categories: p < 0.001.

**Table-III: Thirty-day outcomes, severity association, multivariable model, ROC performance, and inter-observer agreement (N = 62)**

**Panel A. Overall 30-day outcomes**

Outcome	Value
30-day mortality	14 (22.6)
Clinical improvement at 30 days	40 (64.5)
Clinical failure at 30 days	22 (35.5)
ICU admission	19 (30.6)
Revision debridement / re-operation	12 (19.4)

**Panel B. Outcomes by severity category**

Severity category	Mortality n/N (%)	Clinical failure n/N (%)
Mild (0–4)	0/14 (0.0)	2/14 (14.3)
Moderate (5–8)	5/30 (16.7)	9/30 (30.0)
Severe (9–12)	9/18 (50.0)	11/18 (61.1)

**Panel C. Severity score by survival status**

Group	Severity score (mean $\pm$ SD)	p-value
Survivors (n=48)	6.6 $\pm$ 2.4	
Non-survivors (n=14)	9.1 $\pm$ 1.8	<0.001

**Panel D. Multivariable logistic regression (Outcome: 30-day mortality)**

Predictor	Adjusted OR (95% CI)	p-value
Severity score (per 1-point increase)	1.54 (1.22–1.95)	<0.001
DKA at presentation	3.10 (1.01–9.47)	0.048

## DISCUSSION

This study highlights the clinical value of translating CT/MRI findings in rhino-orbito-cerebral mucormycosis (ROCM) into a structured severity scale that reflects both anatomic extent and biologic aggressiveness. ROCM typically progresses from sinonasal disease to orbital, cavernous sinus, vascular, and intracranial involvement; therefore, a compartment-based score offers a concise way to summarize disease burden beyond narrative reporting.<sup>1,4,5,9,15</sup>

In the present cohort, higher CT/MRI severity scores were associated with greater surgical escalation.

Limited disease more often required endoscopic debridement alone, whereas extension into the maxillofacial soft tissues, orbital apex, cavernous sinus, skull base, or intracranial compartment was associated with more extensive procedures such as maxillectomy, orbital surgery, and combined craniofacial or neurosurgical intervention. Prior imaging studies similarly show that MRI is particularly useful for detecting early extra sinus spread, devitalized tissue, cavernous sinus involvement, and intracranial complications, whereas CT better delineates bone destruction and operative corridors, supporting a combined CT/MRI approach.<sup>2,7,9,10,11,12,14</sup>

With respect to outcomes, the score also served as an early risk marker for 30-day mortality and clinical failure. This is clinically plausible because poor outcomes in mucormycosis are influenced not only by imaging extent but also by uncontrolled diabetes or diabetic ketoacidosis, recent steroid exposure, immunosuppression, and delays in diagnosis or surgery.<sup>6,16</sup> Standardized scoring may therefore improve multidisciplinary communication, facilitate triage, and support reproducible audit. Future studies should validate mild, moderate, and severe cut-offs in larger cohorts, refine predictive thresholds for short-term outcomes, and assess whether score-guided pathways can reduce avoidable morbidity without delaying necessary aggressive surgery.

## CONCLUSION

This study showed that a systematic CT/MRI severity score for rhino-orbito-cerebral mucormycosis effectively summarized disease extent and aligned with surgical decision-making. Higher scores correlated with progressively more extensive procedures, including maxillectomy, orbital surgery, and craniofacial intervention, as compartmental spread worsened. Increasing scores were also linked to poorer 30-day outcomes, emphasizing the value of imaging in early risk stratification. The score may improve communication among radiology, ENT, ophthalmology, and neurosurgery by reducing reporting ambiguity and supporting triage and operative planning, particularly in high-burden settings. Future studies should refine score thresholds, validate the model across broader patient groups, and determine whether a score-guided pathway can improve timeliness of surgery, justify resection extent, and ultimately improve survival and functional outcomes.

## AUTHOR CONTRIBUTION

**Aanab Hayat:** Conception, the acquisition, analysis, interpretation of data and manuscript writing

**Abbas Ahmad:** Data collection and analysis

**Salma Liaqat:** Analysis and interpretation of data

**Samira Ahmad and Saira Khan:** Revised critically for important intellectual content

## REFERENCES

- Cornely OA, Alastruey-Izquierdo A, Arenz D, Chen SCA, Dannaoui E, Hochhegger B, *et al.* Global guideline for the diagnosis and management of mucormycosis: An initiative of the European confederation of medical mycology in cooperation with the mycoses study group education and research consortium. *Lancet Infect Dis.* 2019; 19(12): e405–e421. DOI: [https://doi.org/10.1016/s1473-3099\(19\)30312-3](https://doi.org/10.1016/s1473-3099(19)30312-3)
- Desai SM, Gujarathi-Saraf A, Agarwal EA. Imaging findings using a combined MRI/CT protocol to identify the “entire iceberg” in post-COVID-19 mucormycosis presenting clinically as only “the tip”. *Clin Radiol.* 2021; 76(10): 784.e27-784.e33. DOI: <https://doi.org/10.1016/j.crad.2021.07.002>
- 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. DOI: <https://doi.org/10.1007/s11046-021-00528-2>
- Pai V, Sansi R, Kharche R, Bandili SC, Pai B. Rhino-orbito-cerebral mucormycosis: Pictorial review. *Insights Imaging.* 2021; 12: 167. DOI: <https://doi.org/10.1186/s13244-021-01109-z>
- Jeong W, Keighley C, Wolfe R, Lee WL, Slavin MA, Kong DCM, *et al.* The epidemiology and clinical manifestations of mucormycosis: A systematic review and meta-analysis of case reports. *Clin Microbiol Infect.* 2019; 25(1): 26–34. DOI: <https://doi.org/10.1016/j.cmi.2018.07.011>
- Jeong W, Keighley C, Wolfe R, Lee WL, Slavin MA, Kong DCM, *et al.* Contemporary management and clinical outcomes of mucormycosis: A systematic review and meta-analysis of case reports. *Int J Antimicrob Agents.* 2019; 53(5): 589–97. DOI: <https://doi.org/10.1016/j.ijantimicag.2019.01.002>
- Kondapavuluri SK, Anchala VKR, Bandlapalli S, Gorantla R, Danaboyina AR, Kondapavuluri BK, *et al.* Spectrum of MR imaging findings of sinonasal mucormycosis in post COVID-19 patients. *Br J Radiol.* 2021; 94(1127): 20210648. DOI: <https://doi.org/10.1259/bjr.20210648>
- Mangal G, Gehlot PS, Bank A, Kausha A, Kolare R. COVID-19 associated rhino-orbito-cerebral mucormycosis: Clinical, diagnostic and radiological profile. *J Clin Diagn Res.* 2021; 15(9): TC01-TC06. DOI: <https://doi.org/10.7860/JCDR/2021/50888.15324>
- Mazzai L, Anglani M, Giraud C, Martucci M, Cester G, Causin F. Imaging features of rhinocerebral mucormycosis: From onset to vascular complications. *Acta Radiol.* 2021; 62(11): 1433–42. DOI: <https://doi.org/10.1177/0284185120988828>
- Patel DD, Adke S, Badhe PV, Lamture S, Marfatia H, Mhatre P. COVID-19 associated rhino-orbito-cerebral mucormycosis: Imaging spectrum and clinico-radiological correlation—A single centre experience. *Clin Imaging.* 2021; 82: 172-8. DOI: <https://doi.org/10.1016/j.clinimag.2021.10.014>
- Raab P, Sedlacek L, Buchholz S, Stolle S, Lanfermann H. Imaging patterns of rhino-orbital-cerebral mucormycosis in immunocompromised patients: When to suspect complicated mucormycosis. *Clin Neuroradiol.* 2017; 27(4): 469–75. DOI: <https://doi.org/10.1007/s00062-017-0629-1>
- Sanghvi D, Kale H. Imaging of COVID-19-associated craniofacial mucormycosis: A black and white review of the “black fungus”. *Clin Radiol.* 2021; 76(11): 812–9. DOI: <https://doi.org/10.1016/j.crad.2021.07.004>
- Shah K, Dave V, Bradoo R, Shinde C, Prathibha M. Orbital exenteration in rhino-orbito-cerebral mucormycosis: A prospective analytical study with

- scoring system. *Indian J Otolaryngol Head Neck Surg.* 2019; 71: 259-65. DOI: <https://doi.org/10.1007/s12070-018-1293-8>.
14. Singhal A, Jain S, Sharma S, Kottiyath VC, Khandelwal G, *et al.* Imaging of COVID-19-associated rhino-orbital-cerebral mucormycosis: A multicentric observational study. *Egypt J Radiol Nucl Med.* 2021; 52: 197. DOI: <https://doi.org/10.1186/s43055-021-00631-w>
  15. Skiada A, Pavleas I, Drogari-Apiranthitou M. Epidemiology and diagnosis of mucormycosis: An update. *J Fungi.* 2020; 6(4): 265. DOI: <https://doi.org/10.3390/jof6040265>
  16. Soni K, Das A, Sharma V, *et al.* Surgical and medical management of ROCM epidemic in COVID-19 era and its outcomes—A tertiary care center experience. *J Med Mycol.* 2022; 32(2): 101238. DOI: <https://doi.org/10.1016/j.mycmed.2021.101238>
  17. Therakathu J, Prabhu S, Irodi A, Sudhakar SV, Yadav VK, Rupa V. Imaging features of rhino cerebral mucormycosis: A study of 43 patients. *Eur J Radiol.* 2018; 107: 173-9. DOI: <https://doi.org/10.1016/j.ejrm.2018.01.001>
  18. Yasmin F, Najeeb H, Naeem A, Dapke K, Phadke R, Asghar MS, *et al.* COVID-19 associated mucormycosis: A systematic review from diagnostic challenges to management. *Diseases.* 2021; 9(4): 65. DOI: <https://doi.org/10.3390/diseases9040065>