Section: Pathology

Original Research Article

MYCOTIC COMPLICATIONS IN PATIENTS WITH DIABETES MELLITUS: A CLINICAL AND PATHOLOGICAL INVESTIGATION

Keerthana S[1], P. Kamalanandan[2], Vindu Srivastava[3], Navya PT[4]

[1]Postgraduate, Department of Pathology Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam – 603103, Tamil Nadu, India.
[2]Postgraduate, Department of Pathology Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam – 603103, Tamil Nadu, India.
[3]Professor and Head, Department of Pathology, Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam – 603103, Tamil Nadu, India.
[4]Associate Professor, Department of Pathology, Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam – 603103, Tamil Nadu, India, India.

Received *: 17/04/2026*
Received in revised form *: 05/06/2026*
Accepted *: 20/06/2026*

Corresponding Author:
Dr. Navya PT,
Associate Professor, Department of Pathology, Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam – 603103, Tamil Nadu, India.
Email: navyatpalavalli4@gmail.com

DOI: 10.70034/ijmedph.2026.2.609

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (2); 3699-3704

ABSTRACT

Background: Diabetes mellitus predisposes individuals to fungal infections due to impaired immune function and chronic hyperglycaemia. These infections may range from superficial cutaneous lesions to invasive systemic disease, contributing significantly to morbidity. The objective is to evaluate the clinical spectrum and immunopathological characteristics of mycotic infections in patients with diabetes mellitus.
Materials and Methods: This observational study included 20 diabetic patients with confirmed fungal infections. Demographic data, fungal species, anatomical sites of infection, glycated haemoglobin (HbA1c), eosinophil fractions, and approximate absolute eosinophil counts (AECs) were analysed using descriptive statistics.
Results: The study population comprised 12 males (60%) and 8 females (40%) with a mean age of 42.4 ± 17.9 years. The mean HbA1c was 7.8 ± 2.2%, and 45% of participants had suboptimal glycaemic control. Age showed a moderate positive correlation with HbA1c (r = 0.515). Phaeohyphomycosis was the most common fungal infection (25%), followed by unspecified fungal infections (20%), Candida species (15%), and dermatophytes (10%). Mucormycosis, aspergillosis, and onychomycosis each accounted for 5% of cases. Cutaneous involvement predominated (60%), particularly affecting the foot and toe (15%), while mucosal and systemic sites accounted for 20% and 10% of cases, respectively. Selected case profiles demonstrated heterogeneity, with HbA1c ranging from 5.6% to 12.2% and AECs from 182 to 441 cells/µL.
Conclusion: Mycotic infections in diabetic patients exhibit diverse clinical presentations and pathogen profiles, with cutaneous involvement being the most common. Poor glycaemic control appears to contribute to susceptibility to opportunistic fungal infections. Early diagnosis, optimal glycaemic management, and timely microbiological evaluation are essential for improving outcomes in affected patients.
Keywords: Diabetes mellitus, fungal infections, phaeohyphomycosis, mucormycosis, HbA1c..

INTRODUCTION

Diabetes mellitus (DM) is still one of the most widespread challenges in the 21st century, with ongoing, chronic hyperglycaemia and metabolic dysregulation. Although the benefits in terms of macrovascular and microvascular outcomes are documented, a significant clinical problem in the treatment of patients with diabetes is the susceptibility to secondary opportunistic infections.[1,2]

Mycotic (fungal) infections can be serious clinical problems, with superficial infections such as cutaneous and vulvovaginal candidiasis affecting quality of life. Invasive fungal infections like aspergillosis and mucormycosis can be associated with severe tissue necrosis, long hospital stays and even death.[2,3]

Diabetics are more susceptible to fungal colonisation and/or invasion due to biochemical and anatomical factors: high levels of systemic glucose in the blood provide a source of nutrients for opportunistic pathogens, which can enhance their virulence, growth rates and host-tissue adherence. Diabetic ketoacidosis (DKA) causes a lowering of blood pH and a rise in serum iron, creating a favourable environment for the growth of angioinvasive fungal spores, which results in rapid tissue destruction, thrombosis, and ischaemic necrosis. These alterations make it difficult to diagnose infections at an early stage.[3,4]

Diabetes-related immune dysfunction (both innate and adaptive) can lead to severe mycotic complications. High blood glucose levels cause impaired innate immune cell function, such as defective chemotaxis, reduced phagocytosis and impaired production of neutrophil extracellular traps in polymorphonuclear neutrophils and macrophages. There is a reduction in the humoral response due to defective complement structure, which affects opsonisation. Further, the ability to clear fungal pathogens is impaired due to a disruption of dendritic cell antigen presentation and a dysregulated T-helper cell population.[1,5]

Even though pathways are known, there remains a large clinical disconnect in coordinating glycaemic control, diabetes duration and comorbidities with the immunopathological defects responsible for fungal infections. This study aims to fill this void and evaluate the clinical presentation coupled with the histopathological and immunopathological profile, and how metabolic derangement affects immune-cell failure at an infection site.

MATERIALS AND METHODS

This cross-sectional study was conducted at a tertiary care teaching hospital in Chennai in the Department of Pathology between February 2026 and May 2026. Twenty patients with diabetes mellitus presenting with clinical signs of secondary fungal infections were consecutively enrolled based on inclusion criteria requiring a confirmed clinical diagnosis of diabetes and localised tissue changes highly suspicious of mycosis, excluding individuals on concurrent non-diabetic systemic immunosuppressive therapies.

Baseline clinical phenotypes were documented upon admission, and venous blood was analysed via high-performance liquid chromatography (HPLC) to determine HbA1c fractions (with >0.080 indicating suboptimal control), alongside automated haematological profiling to evaluate relative systemic eosinophil counts.

Fungal pathogens were harvested from diverse cutaneous, mucosal, and systemic anatomical sites, followed by direct microscopic screening using 10–20% potassium hydroxide (KOH) mounts; histopathological analysis of formalin-fixed paraffin-embedded tissue sections stained with haematoxylin and eosin, periodic acid–Schiff, and Grocott–Gomori methenamine silver to examine tissue architecture and cellular infiltration; and isolation on Sabouraud dextrose agar incubated at 25 °C and 37 °C for macro- and micro-morphological identification.

Statistical Analysis

Statistical processing of the resulting dataset was performed using SPSS software v21, where categorical data were summarised as frequencies and percentages, and continuous laboratory parameters were presented as mean and standard deviation.

RESULTS

Table 1: Demographic and clinical characteristics of participants

Parameter	Value	Range / Percentage
Total participants	20	—
Gender (male:female)	12:8	60% : 40%
Mean age ± SD	42.4 ± 17.9 years	14–74 years
Mean HbA1c ± SD	7.8 ± 2.2%	5.2–12.2%
Mean eosinophil ± SD	0.044 ± 0.015	0.023–0.080
Suboptimal control (HbA1c > 8%)	9 cases	45%
Age–HbA1c correlation (r)	0.515	—

As shown in [Table 1], the study included 20 participants (60% male, 40% female) with a mean age of 42.4 ± 17.9 years (range 14–74). The mean HbA1c was 7.8 ± 2.2% (range 5.2–12.2), and the mean eosinophil count was 0.044 ± 0.015 (range 0.023–0.080). Notably, 9 participants (45%) had suboptimal glycaemic control (HbA1c > 8%). Age showed a moderate positive correlation with HbA1c (r = 0.515), suggesting that increasing age was associated with poorer glycaemic control.

Table 2: Fungal species distribution and frequency

Fungal Species / Category	Number of Cases	Percentage
Phaeohyphomycosis	5	25.0%
Unspecified fungal organisms	4	20.0%
Candida species	3	15.0%
Dermatophytes	2	10.0%
Mucormycosis	1	5.0%
Aspergillus species	1	5.0%
Onychomycosis	1	5.0%
Total	20	100.0%

As shown in [Table 2], fungal infections were distributed across 20 cases, with phaeohyphomycosis being the most frequent (5 cases, 25%). Unspecified fungal organisms accounted for 4 cases (20%), followed by Candida species (3 cases, 15%) and dermatophytes (2 cases, 10%). Less common infections included mucormycosis, Aspergillus species, and onychomycosis (each 1 case, 5%). Overall, the data highlight that phaeohyphomycosis and unspecified fungi together comprised nearly half of the fungal isolates (45%).

Table 3: Anatomical sites of mycotic infection

Anatomical Site	Number of Cases	Percentage
Cutaneous sites		
Forearm	2	10.0%
Scalp	2	10.0%
Preputial skin	2	10.0%
Foot / toe	3	15.0%
Finger	1	5.0%
Gluteal region	1	5.0%
Ear	1	5.0%
Nail	1	5.0%
Mucosal sites		
Maxillary sinus	1	5.0%
Nasal polyp	1	5.0%
Nasal sinus	1	5.0%
Trachea	1	5.0%
Systemic sites		
Duodenum	1	5.0%
Renal tissue	1	5.0%
Total	20	100.0%

As shown in [Table 3], mycotic infections involved 20 anatomical sites, with cutaneous locations predominating (12 cases, 60%). The most frequent cutaneous sites were the foot/toe (3 cases, 15%), followed by the forearm, scalp, and preputial skin (each 2 cases, 10%). Single-case involvement was noted in the finger, gluteal region, ear, and nail (each 5%). Mucosal sites accounted for 4 cases (20%), including the maxillary sinus, nasal polyp, nasal sinus, and trachea (each 1 case, 5%). Systemic infections were rare, with the duodenum and renal tissue each affected in 1 case (5%). Overall, cutaneous sites represented the majority, while mucosal and systemic sites contributed smaller proportions.

Table 4: Selected case profiles demonstrating clinical heterogeneity

Case	Age/Sex	Fungal Species	HbA1c	Eosinophil	Approx. AEC (cells/µL)
Case 1	55/M	Candida	6.3	0.027	189
Case 4	69/F	Mucormycosis	7.5	0.063	441
Case 6	40/M	Aspergillus	12.2	0.026	182
Case 11	56/M	Candida	10.9	0.050	350
Case 12	74/F	Fungal	9.4	0.039	273
Case 20	28/M	Fungal	5.6	0.032	224

As shown in [Table 4], six representative cases illustrate the heterogeneity of fungal infections with respect to age, glycaemic control, and immunological response. Ages ranged from 28 to 74 years (mean ~53 years), with a male predominance (4 males, 2 females). HbA1c values spanned 5.6–12.2%, lowest in the 28-year-old male with renal fungal infection (5.6%) and highest in the 40-year-old male with Aspergillus (12.2%). Intermediate elevations were noted in systemic cases: Candida/duodenum (10.9%) and tracheal fungal infection (9.4%). Eosinophil counts varied between 0.026 and 0.063, corresponding to approximate AEC values of 182–441 cells/µL, with the highest in the 69-year-old female with mucormycosis (441 cells/µL).

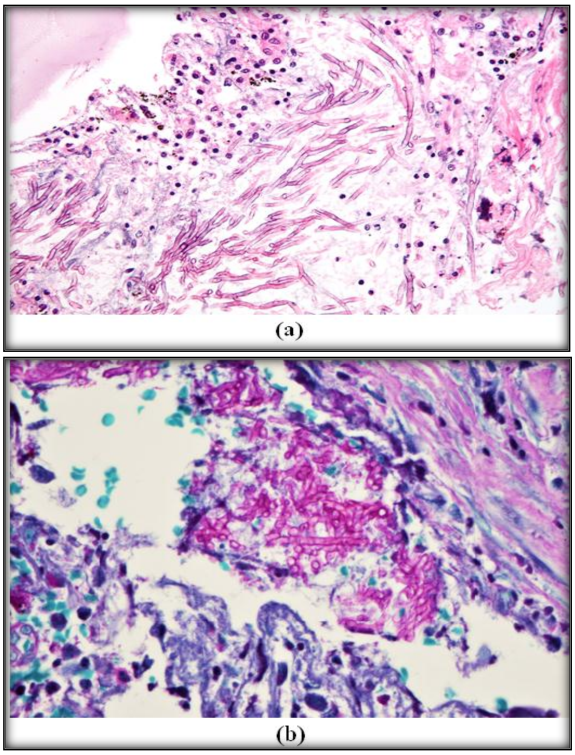

Figure 1 (a, b): Aspergillosis – acute-angle septate fungi. (a) H&E; (b) PAS.

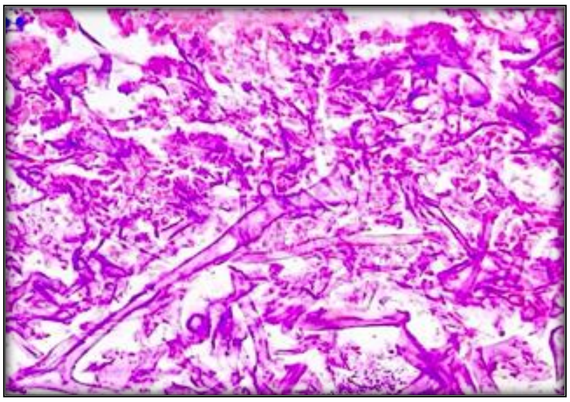

Figure 2 (c): Mucormycosis – broad, aseptate, right-angle branching fungi.

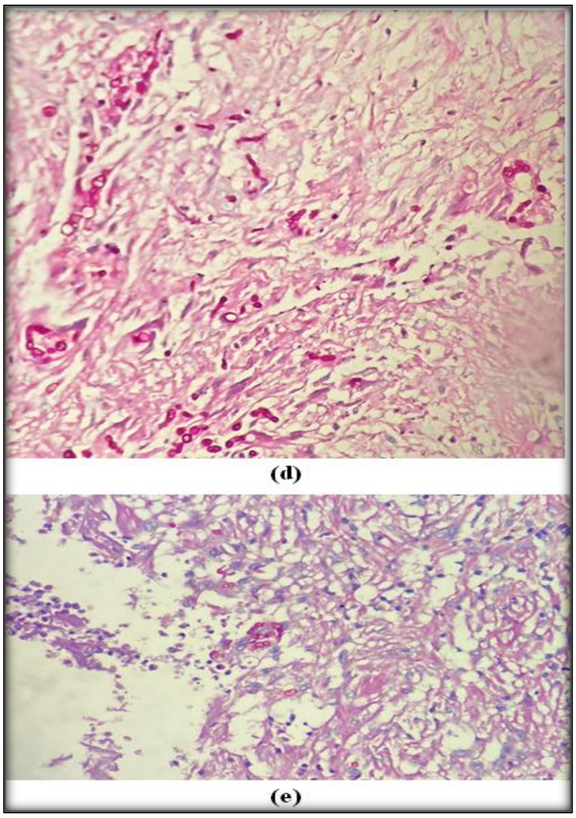

Figure 3 (d, e): Phaeohyphomycosis – pigmented fungi. (d) H&E; (e) PAS.

DISCUSSION

Fungal infections are associated with diabetes mellitus because of chronic hyperglycaemia and the adverse effect that this has on immune responses and enhances microbial growth. Diabetic patients are therefore more susceptible to superficial and invasive infections than other patients. In the present study, the mean age of the patients was 42.4 ± 17.9 years and there was a male predominance (60%). The Pearson correlation coefficient for age and HbA1c was positive, with moderate correlation ($r = 0.515$), suggesting that older age groups were less well controlled for HbA1c. The clinical significance of this finding is that there is a progressive decline in immune function with age and a higher risk of infection with prolonged hyperglycaemia.[6,7,8]

Nearly half of the participants (45%) had poor glycaemic control, a risk factor for infection in diabetes. In diabetic patients with uncontrolled hyperglycaemia there are increased incidences of fungal infection such as candidiasis and dermatophytosis due to the negative impact of elevated glucose levels on the function of leukocytes and their ability to inhibit fungal growth.[9] A fungal species distribution analysis showed that phaeohyphomycosis was the most common fungal infection (25%). Melanised fungi are more frequently associated with phaeohyphomycosis in immunocompromised patients, such as those with diabetes mellitus,[10] although Candida species have more commonly been reported in diabetic patients. The relatively high prevalence of phaeohyphomycosis in the present study could be due either to epidemiological variation or to environmental exposure.

Candida spp. are among the most common fungal pathogens and were responsible for 15% of infections. Hyperglycaemia is strongly associated with increased susceptibility to Candida infections because it increases fungal adherence, colonisation and invasion, and decreases host immune responses.[9] Candida is one of the most prevalent fungal pathogens reported in diabetic patients, and is therefore reflected in the present study. Mucormycosis and aspergillosis are significant because of their morbidity and mortality. Hyperglycaemia and ketoacidosis, which tend to be more common in poorly controlled diabetes, favour fungal growth and impair immunity, and are important risk factors for mucormycosis. The patient with aspergillosis had the highest HbA1c level at 12.2%, which indicates the relationship between poor metabolic control and opportunistic fungal infections.[11,12]

Sixty percent of infections were on the skin, with the foot and toe the most common sites. This predominance is in line with various previous reports that have shown diabetic patients to be more susceptible to fungal skin and nail infection, as a result of peripheral neuropathy, vascular insufficiency, impaired wound healing and repeated trauma.[13]

Cutaneous involvement is common, hence the need for routine foot and dermatological examinations in diabetic patients. Twenty percent of cases had mucosal involvement, involving the maxillary sinus, nasal cavity and trachea. These can be clinically significant, as fungal disease of the upper respiratory tract can become invasive in susceptible hosts, especially those with poorly controlled diabetes.[11]

Systemic fungal infections, which included infection of the duodenum and renal tissue, were rare but clinically important. These results show that fungal pathogens can penetrate the deep tissues and enter the visceral organs when host defence is inadequate. A significant number of studies have demonstrated that the incidence of invasive fungal infections is associated with significant morbidity and may necessitate aggressive therapeutic measures.[13]

The chosen case profiles also illustrated the significant clinical variability of fungal infections among diabetics. There was wide variability in glycaemic control, with HbA1c ranging from 5.6% to 12.2%. The highest HbA1c was found in the patient with aspergillosis (12.2%), and elevated HbA1c was noted in patients with candidiasis and unspecified fungal infection. These observations agree with previous findings that hyperglycaemia can play a major role in susceptibility to opportunistic fungal infections.[6,7] Eosinophil fractions and absolute eosinophil counts (AECs) varied from 182 to 441 cells/µL, with the highest count in a patient with mucormycosis. Few definitive conclusions can be drawn from the small number of patients studied, but the role of eosinophils in antifungal immunity warrants further immunological research.

Overall, the findings underscore the variety of fungal complications in diabetes mellitus, stressing the importance of good glycaemic control. These findings highlight the importance of recognising early signs and symptoms of infection and of prompt antifungal drug therapy, as well as monitoring of the diabetic patient in the context of infections with Candida, Aspergillus, and Mucor as opportunistic pathogens.[14,15]

Limitations

The results of this study may not be applicable to other centres due to the small sample size and single-centre nature of the study. It is cross-sectional and cannot establish any causal relationship between diabetes and fungal infections. In addition, the lack of a non-diabetic control group, limited species identification of fungal isolates, and the absence of detailed immunological and outcome evaluation reduce the depth of analysis.

CONCLUSION

This study revealed that different types of fungal infection can occur in patients with diabetes mellitus, the most common being fungal infection of the skin. Those affected tended to have poor glycaemic control, which appears to be a risk factor for invasive and opportunistic fungal infections. The diversity of fungal pathogens — including Aspergillus, Candida, phaeohyphomycosis and Mucor species — highlights the complexity of the mycotic implications of diabetes. To minimise morbidity and improve clinical outcomes in diabetic patients, early detection of fungal infection, careful glycaemic control, and timely microbiological and histological examination are warranted.

REFERENCES

1. Alexander M, Cho E, Gliozheni E, Salem Y, Cheung J, Ichii H. Pathology of diabetes-induced immune dysfunction. Int J Mol Sci. 2024;25(13):7105. DOI: 10.3390/ijms25137105.
2. Khanam A, Hithamani G, Naveen J, Pradeep SR, Barman S, Srinivasan K. Management of invasive infections in diabetes mellitus: a comprehensive review. Biologics. 2023;3(1):40-71. DOI: 10.3390/biologics3010004.
3. Chávez-Reyes J, Escárcega-González CE, Chavira-Suárez E, León-Buitimea A, Vázquez-León P, Morones-Ramírez JR, et al. Susceptibility for some infectious diseases in patients with diabetes: the key role of glycaemia. Front Public Health. 2021;9:559595. DOI: 10.3389/fpubh.2021.559595.
4. Mandal SM, Mahata D, Migliolo L, Parekh A, Addy PS, Mandal M, et al. Glucose directly promotes antifungal resistance in the fungal pathogen, Candida spp. J Biol Chem. 2014;289(36):25469-25473. DOI: 10.1074/jbc.c114.571778.
5. Diabetes mellitus and infection susceptibility: an immunometabolic interface. Preprints.org; 2026. DOI: 10.20944/preprints202603.2011.v1.
6. Casqueiro J, Casqueiro J, Alves C. Infections in patients with diabetes mellitus: a review of pathogenesis. Indian J Endocrinol Metab. 2012;16(Suppl 1):S27-S36.
7. Rodrigues CF, Rodrigues ME, Henriques M. Candida sp. infections in patients with diabetes mellitus. J Clin Med. 2019;8(1):76.

8. Akash MSH, Rehman K, Fiayyaz F, Sabir S, Khurshid M. Diabetes-associated infections: development of antimicrobial resistance and possible treatment strategies. Arch Microbiol. 2020;202(5):953-965.
9. Rasoulpoor S, Gholizadeh P, Dastgheib SA, et al. Candida albicans skin infection in diabetic patients: an updated review. Mycoses. 2024.
10. Revankar SG, Sutton DA. Melanized fungi in human disease. Clin Microbiol Rev. 2010;23(4):884-928.
11. John TM, Jacob CN, Kontoyiannis DP. When uncontrolled diabetes mellitus and severe COVID-19 converge: the perfect storm for mucormycosis. J Fungi (Basel). 2021;7(4):298.
12. Prakash H, Chakrabarti A. Global epidemiology of mucormycosis. J Fungi (Basel). 2019;5(1):26.
13. Gupta AK, Mays RR. The impact of diabetes on dermatophytosis and onychomycosis. Dermatol Clin. 2021;39(3):405-415.
14. Prakash H, Chakrabarti A. Global epidemiology of mucormycosis. J Fungi (Basel). 2019;5(1):26.
15. Bassetti M, Azoulay E, Kullberg BJ, et al. EORTC/MSGERC definitions of invasive fungal diseases. Clin Infect Dis. 2021;72(S2):S121-S127