ORIGINAL ARTICLE

# Clinical and microbiological features of infection with *Rhodotorula* species: Experience from Pakistan

**Sobia Muhammad Asad Khan, Ahmad Reaan Khalid, Ashja Syed, Joveria Farooqi, Faheem Naqvi, Muhammad Nadeem, Rumina Hasan, Afia Zafar, Erum Khan, Kauser Jabeen**

Aga Khan University, Karachi Pakistan

## ABSTRACT

**Background:** *Rhodotorula* species is an emerging cause of invasive fungal infection worldwide; however, data from Pakistan is limited. We analysed clinical and microbiological features of *Rhodotorula* infection identified at a tertiary care hospital laboratory in Pakistan.

**Material and Methods:** In this retrospective cross-sectional study, clinical samples yielding *Rhodotorula* species between 1st January 2010 – 30th March 2024 were retrieved using Integrated Laboratory Management System. Demographic data and relevant clinical findings were evaluated. Categorical variables are reported as frequencies (%) and continuous variables as mean ± SD or median (IQR).

**Results:** A total of 64 cases were identified, of which 81.25% (n=52) were from invasive sites; blood being the most common i.e., 54.6% (n=35). Minimum Inhibitory Concentration range of amphotericin (n=27) was 0.12–1 mcg/ml; $MIC_{50}$ and $MIC_{90}$ were 0.12 mcg/ml and 0.5mcg/ml respectively. Of the nine patients with detailed clinical findings, all isolates were invasive (5: blood, 1: CSF, 1: EVD, 1: ascitic fluid). Of these, five cases were considered significant, three were contamination/colonization and significance of one case could not be ascertained. Only three patients with fungemia received intravenous amphotericin B deoxycholate. The mean duration of treatment was 14.3± 2.8 days, all nine patients were alive at the time of discharge.

**Conclusion:** Since *Rhodotorula* species is ubiquitously present in the environment, careful assessment of clinical findings and underlying risk factors is crucial to determine its significance in clinical specimens.

**Keywords:** Amphotericin B, Beta D Glucan, Fungemia, Pakistan, *Rhodotorula*

## BACKGROUND

*Rhodotorula* species are commensal yeasts belonging to the phylum Basidiomycota, specifically to the family Sporidiobolaceae.[1,2] Previously regarded as non-pathogenic, it has emerged as a recognized human pathogen in recent years, especially in immunocompromised hosts.[3, 4] Of the 46 known species belonging to this genus; *Rhodotorula mucilaginosa* (formerly *R. rubra*), *R. glutinis* and *R. minuta* are known to cause human disease with a wide range of infections such as fungemia, meningitis, endophthalmitis, peritoneal dialysis-associated peritonitis and keratitis.[3,5,6] *Rhodotorula* species are widely distributed in the environment—including soil, ocean and lake water, shower curtains as well as various medical equipment, due to their tolerance to dryness, strong affinity for plastics and high biofilm-forming ability. They may also be present in a variety of foods and beverages e.g., peanuts, apple cider, cherries, cheese, sausages, edible molluscs, crustaceans.[1, 4, 6] Moreover, it has important infection control implications as it also constitutes normal flora of the human gastrointestinal, respiratory and genital tract and commonly found on the hands of healthcare workers and patients.[3, 4]

Owing to the above properties and its ubiquitous nature in environment; *Rhodotorula* species is the fourth most common non-candidal yeast, preceded by *Cryptococcus neoformans*, *Saccharomyces cerevisiae* and *Trichosporon* species,[7] with a total of 204 cases reported worldwide from 24 countries, including China (n=43), Brazil (n=34), Spain (n=30), India (n=16), Italy (n=12), USA (n=13), and Taiwan (n=10).[8] Although infections with *Rhodotorula* species occur worldwide, Asia-Pacific region constitutes up to 48.8% of infections as per the study by Miceli *et al*.[9] In Pakistan, non-candidal yeasts are an important cause of invasive yeast infections, especially in neonates, responsible for 13.3% of the cases, as highlighted by Rattani, S. *et al* in a 5-year survey from 2015-2019.[10] Nevertheless, little is

**Correspondence: Dr. Sobia Muhammad Asad Khan, Resident Medical Microbiology, Aga Khan University, Karachi**

**Email: khan.sobia@aku.edu**

***This article can be cited as:*** Khan SMA, Khalid AR, Syed A, Farooqi J, Naqvi F, Nadeem M, Hasan R, Zafar A, Khan E, Jabeen K. Clinical and microbiological features of infection with *Rhodotorula* species; experience from Pakistan. Infect Dis J Pak. 2026; 35(2): 76-82.

DOI: https://doi.org/10.61529/idjp.v35i2.370

Receiving date: **16 Jan 2025** Acceptance Date: **11 May 2026**
Revision date: **10 Mar 2026** Publication Date: **30 Jun 2026**

known about the epidemiological, microbiological and clinical features of *Rhodotorula* infections from Pakistan. This study aims to determine frequency of isolation of *Rhodotorula* species from patient samples, describe the clinical and microbiological characteristics and its significance in individuals with *Rhodotorula* infection at a tertiary care hospital laboratory in Karachi, Pakistan.

## MATERIAL AND METHODS

This retrospective cross-sectional study was conducted at the Aga Khan Hospital Laboratories, Karachi, Pakistan. The study was approved by the Ethics Review Committee, the Aga Khan University (ERC number 2024-10642-31931). All clinical samples yielding *Rhodotorula* species from one or more specimens between 1st January 2010 – 30th March 2024 were retrieved using Integrated Laboratory Management System and included in the study. Duplicates were removed and excluded. Demographic data and concomitant laboratory investigations (if requested) such as mycobacterial culture and/or histopathology was evaluated for all samples and detailed clinical findings were analysed for nine patients that were admitted to the affiliated hospital, by retrospective review of electronic medical record. Clinical data of the admitted patients included demographics, risk factors such as presence of central line, broad spectrum antimicrobials, gastrointestinal pathologies, malignancy, immunosuppression and others, as well as existing co-morbid conditions e.g., diabetes, hypertension, chronic diseases etc. Investigations included radiological and laboratory reports, spanning both infective markers (total leukocyte count, C-reactive protein, procalcitonin), and etiological tests such as (1,3)-β D-Glucan and cultures. Management and patient outcome were documented in terms of anti-fungal treatment duration; length of hospital stay and status at the time of discharge. On the basis of clinical information and applying the consensus definition for invasive fungal diseases according to Donnelly *et al* [11], cases were classified as: (1) Proven or probable infection: isolation of *Rhodotorula* species from one or more specimens in the presence of clinical signs of infections, underlying risk factors and supportive laboratory parameters; (2) Colonization or contamination: isolation of *Rhodotorula* species from a single specimen with no signs of infection and/or isolation of multiple environmental organisms from a single sample in the absence of clinical signs of infections, underlying risk factors and supportive laboratory parameters; and (3) Undetermined significance: isolation of *Rhodotorula* species from a single specimen in the presence of risk factors but insufficient supportive clinical and/or laboratory parameters to deem significant.

All samples were processed as per American Society of Microbiology (ASM) guidelines. Identification of yeast was done using phenotypic methods. Salmon pink mucoid or creamy textured colonies isolated on chocolate agar (CHA), sheep blood agar (SBA), and Sabouraud's Dextrose agar (SDA) inoculated from clinical specimens, which showed budding yeast on wet mount were confirmed by biochemical profile on API 20C AUX and Vitek 2 Yeast ID card (manufactured by bioMérieux, France). Susceptibilities were performed according to CLSI guidelines by colorimetric broth microdilution using YeastOne Sensititer plates (Thermo Fisher Scientific)**.** Data was analyzed using descriptive statistics, with categorical variables presented as frequencies and percentages, and continuous variables as mean ± SD or median (IQR), as appropriate. The institutional ethical review committee approved the study (2024-10642-31931) and need for informed consent was waived off.

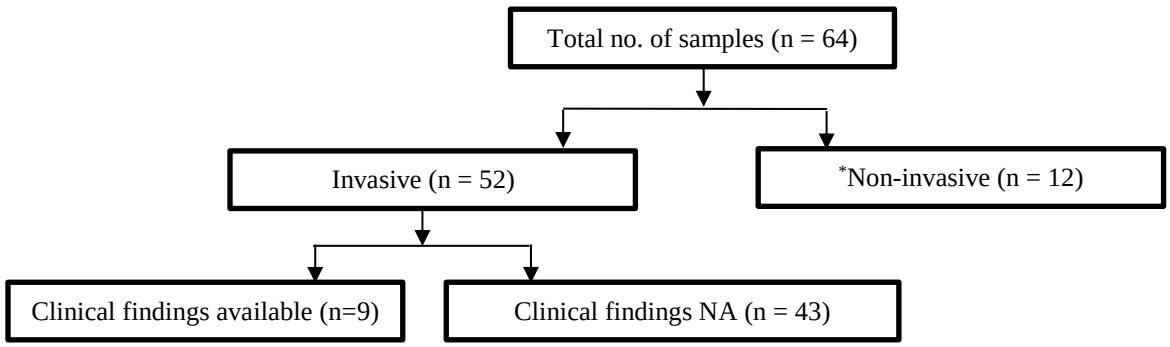


**Figure-I: Flow diagram of clinical samples with *Rhodotorula* species from January 2010- March 2024 received at a tertiary care hospital laboratory in Karachi, Pakistan.**

NA=not available; *urine and genital secretions

## RESULTS

In total, 64 clinical samples with *Rhodotorula* species were identified during the 14-year period. *Rhodotorula mucilaginosa* was the most common identified species i.e., in 39% of the samples. The median age of patients was 16.5 years (IQR 44); 35.9% (n=23) of these were less than 1 year, 14% (n=9) between 1-17 years, 32.8% (n=21) between 18-50 years and 17.1% (n=11) belonging to >50 years. Majority of the patients were males i.e., 62.5% (n=40). Of the 64 samples, 81.2% (n= 52) were from invasive sites and the remaining 18.8% (n= 12) were from non-invasive sites such as urine and genital secretions (Figure-I).

Most frequent invasive site was blood i.e., 54.6% (n=35), followed by pleural 7.8% (n=5), skin and soft tissue 7.8% (n=5), CSF and ventricular drain (CNS) 6.2% (n=4), abdominal 1.6% (n=1), whereas source could not be determined for two tissue samples. Of the patients with invasive samples, only one patient had two consecutive positive blood cultures, whereas all others had only a single positive culture. Contamination was likely in 17.1% (n=6/35) of blood culture samples and 100% (n=14/14) of non-blood culture samples owing to growth of multiple environmental organisms simultaneously. Year-wise distribution of the total identified cases revealed the highest frequency of isolation in 2017 i.e., 14% (n=9), followed by 12.5% cases (n=8) each in the year 2022 and 2023, respectively (Figure-II). Susceptibility testing against amphotericin was performed in 26 of 64 cases that were received from 2017 onwards and MIC ranged from 0.12–1 mcg/ml; $MIC_{50}$ and $MIC_{90}$ were 0.12 mcg/mL and 0.5mcg/ml, respectively (Figure-III).

Based on the chart review of clinical findings of the nine admitted patients, five cases were identified to be of proven/probable infection (Table-I). Three patients with fungemia received intravenous amphotericin B deoxycholate with the mean ± SD duration of 14.3±2.8 days. Among them, one patient also had concomitant central line associated blood stream infection (CLABSI) with *Candida glabrata* as defined by the IDSA criteria. [12] Seven out of nine patients were discharged in a stable condition, while one patient was shifted to another hospital and the other left against medical advice. Additionally, length of hospital stay was 16.4±12.8 days. Underlying risk factors were identified in six patients. Presence of a central line was identified in all of them and five of these also received empirical broad-spectrum antimicrobials. Three out of six patients received total parenteral nutrition; of whom, two patients also had intestinal perforation. Serum BDG was performed in three patients, with two patients having levels above the cut off value (>80 pg/ml); mean ± SD was 286.21±197.0 pg/ml.

**Table-I: Clinical characteristics of nine admitted patients with *Rhodotorula* infection during the 14-year study period from January 2010- March 2024.**

| Cases | Age (yrs) | Gender | Co-morbids | Source of infection | Possible risk factors | Targeted Antifungal therapy | Duration of treatment | Patient outcome | Infection [proven/ probable] (I); Colonization/ contamination(C); Undetermined significance (US) |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 1.6 | M | - | Blood | CVC (removed), TPN, intestinal perforation, Broad spectrum antibiotics | Amphotericin | 18 days | Discharged, Stable | I |
| 2. | 36 | M | Adeno-carcinoma of colon | Blood | CVC (not removed), TPN, intestinal perforation, Broad spectrum antibiotics | Amphotericin | 11 days | LAMA | I |
| 3. | <1 | M | - | Blood | CVC (removed), TPN, | Amphotericin | 14 days | Discharged, Stable | I |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4. | <1 | M | - | Blood | Broad spectrum antibiotics - | None | Cannot assess | Shifted to another hospital | US |
| 5. | 18 | M | DM Type 1 | Blood | CVC* (removed) | None | None | Discharged, Stable | **C |
| 6. | 71 | M | DM Type 2 | EVD tip | EVD (removed), PICC line (not removed), Broad spectrum antibiotics | None | None | Discharged, Stable | ‖I |
| 7. | 3 | M | - | CSF | - | None | None | Discharged, stable | ¥C |
| 8. | 70 | F | CKD, DM Type 2 | Blood | PICC line (not removed), Broad spectrum antibiotics Ω | None | None | Discharged, Stable | I |
| 9. | 58 | M | DM type 2, HCC, Alcoholic, Psoriasis | Ascitic Fluid | Ascitic drain | None | None | Discharged, Stable | €C |

*Placed 1 day after positive blood culture. ** infectious disease review taken during hospital stay. ‖ post- laminectomy surgical site infection; CSF cultures from EVD showed no growth however CSF detailed report showed evidence of infection. ¥ HSV 1 encephalitis diagnosed on CSF PCR and compatible clinical and radiological signs; Growth of *Rhodotorula* species on sub-culture of CSF. Ω admitted 1 month ago due to culture negative septic arthritis and received empirical piperacillin/tazobactam and vancomycin for 3 weeks duration via PICC line. € Growth of *Cryptococcus albidus* and *Rhodotorula* species in single ascitic fluid culture; ascitic fluid DR suggestive of transudative cause. CVC: Central venous catheter. CSF: Cerebrospinal fluid. CKD: Chronic kidney disease. DM: Diabetes mellitus. EVD: External ventricular drain. LAMA: Left against medical advice. HCC: Hepatocellular carcinoma. TPN: Total parenteral nutrition.

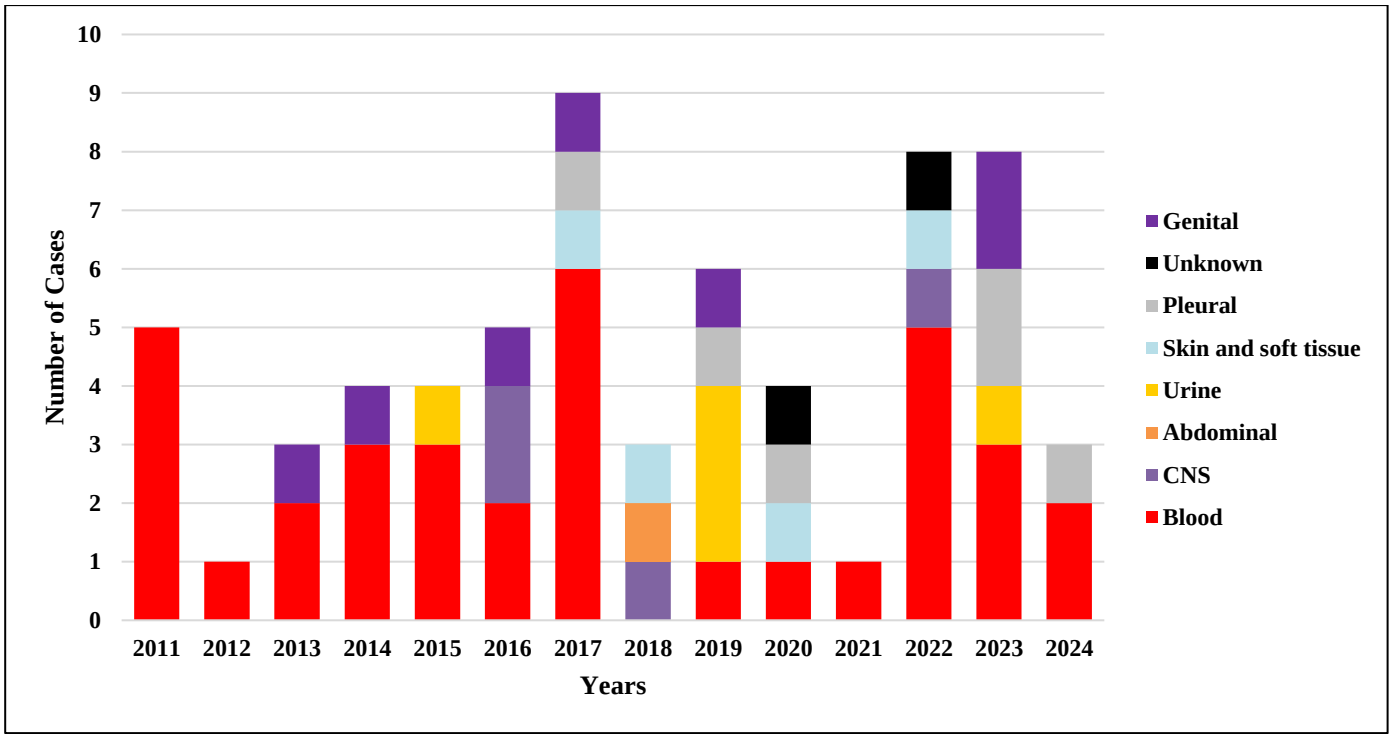


**Figure-II: Year-wise distribution of spectrum of 64 clinical specimens identified with *Rhodotorula* species from January 2010-March 2024 at a tertiary care laboratory in Karachi, Pakistan.**

Blood n=35; CNS n=4; abdominal n=1; urogenital n=12; skin and soft tissue n=5; pleural n=5; unknown tissue samples n=2

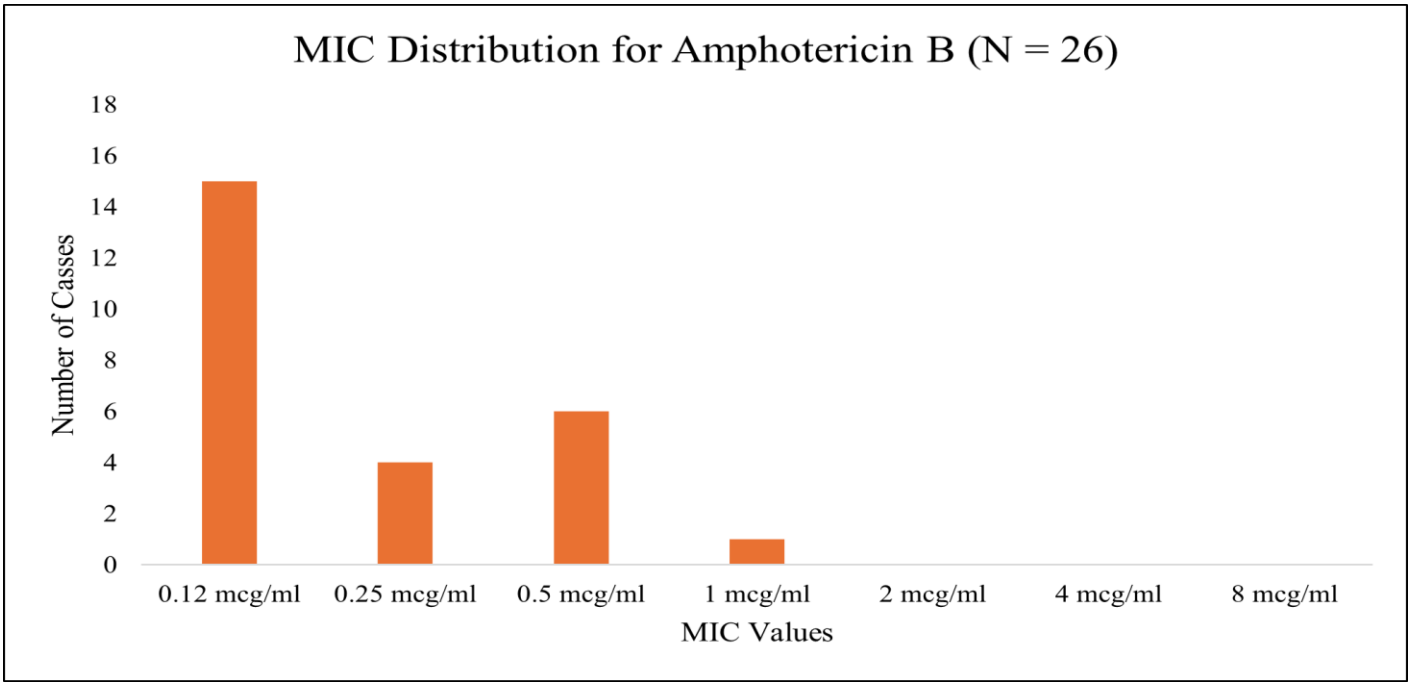


**Figure-III: MIC distribution of Amphotericin B (n=26) in clinical isolates of *Rhodotorula* species from Karachi, Pakistan.**
*MIC ranged from 0.12–1 mcg/ml; $MIC_{50}$ and $MIC_{90}$ were 0.12 mcg/mL and 0.5mcg/ml respectively.*

## DISCUSSION

Within the last decade, *Rhodotorula,* along with other non-candidal yeasts have gained importance for increasingly identified invasive infections.[10] While of lower virulence than *Candida* or *Trichosporon*, reports have shown that *Rhodotorula* can cause severe and even fatal invasive infections.[13, 14]

In this study, *Rhodotorula mucilaginosa* was the most common identified species and majority of the patients were males with more than half of invasive infections attributed to fungemia. Our findings were in concordance with systematic reviews by Tuon FF *et al* and Loannou P *et al*, where 79% of 128 cases and 61.7% of 248 of *Rhodotorula* infections were of fungemia *(Rhodotorula mucilaginosa* being the most common etiologic species).[2, 3] Isolation of *Rhodotorula* from nonsterile human sites has often been of questionable clinical significance.[4] We found a substantial number of clinical samples that likely represented contamination, especially from sites other than blood. Moreover, in the present study including nine patients with detailed clinical data evaluation, the most frequent risk factor was presence of a central venous catheter which was identified in six individuals whereas two patients had gastrointestinal (GI) malignancy and none had haematological cancer. This is also in concordance with systematic review by Tuon FF *et al*, where 83.4% and 87% of the studied cases of *Rhodotorula* fungemia cases were associated with central venous catheter and underlying immunosuppression or cancer respectively.[2] Another study also reported similar findings with the majority of patients, i.e. 88% having a central venous catheter (CVC).[15] We also found that three of nine admitted patients with fungemia in the present study received total parenteral nutrition (TPN) which was similarly reported by Gisele M *et al*., where 12% of *Rhodotorula* infected cases received TPN.[15] Interestingly, two of these TPN recipients also had intestinal perforation, which may have led to possible transient translocation of this microorganism to bloodstream. Nevertheless, this finding should be interpreted with caution due to limited number of cases and larger data will be needed to explore its true significance. The overall mortality rate ranges from 17.4%[15] to as high as 46.2% in CNS infections[16], however in the present study no mortality was observed in nine patients. This may be attributed to the fact that majority of the patients in these studies had underlying haematological malignancy or advanced immunosuppression whereas in our study only two patients had GI malignancy as described above. Similar to other studies by Zaas AK *et al* and Gomez-Lopez A *et al*, susceptibility testing showed that 59.2% of the isolates were inhibited in vitro by 0.12 mcg/ml of amphotericin.[17, 18] Lastly, role of BDG remains unclear due to insufficient available data. In our study it was

performed on Fungitell assay (Associates of Cape Cod, Inc., Falmouth, MA) in three patients with fungemia and was raised (above the cut off value set by manufacturer of >80 pg/ml) in two of them, however; one of these patients also had concomitant *Candida glabrata* CLABSI. Interestingly, of these patients two were of paediatric age i.e., 18 months and one-month, with BDG levels of > 500 pg/ml and 24.472 pg/ml respectively. Role of BDG in diagnosis of invasive fungal disease in neonates and children pose considerable challenges. In a survey conducted in 17 European countries; BDG was reported to be used more frequently as diagnostic rather than as a screening tool, and around 22% responders used a cut-off different to 80 pg/ml. Moreover, only four studies calculated an optimal cut-off for positivity in premature neonates, with values ranging from 99 pg/mL to 174 pg/ml.[19] Whereas a mean BDG cut-off of 68 pg/ml for uninfected children has been described by Smith *et al*.[20] Thus, a BDG level below cut-off, does not exclude the presence of *Rhodotorula* infection.

This study highlights the increase in isolation of *Rhodotorula* species from clinical samples, which may lead to invasive infection in susceptible hosts. This study had several limitations. Firstly, lack of clinical data for most of the cases may have led to underestimation of the clinically significant cases of *Rhodotorula* infection. Moreover, susceptibility testing was not performed in all isolates and for all antifungal agents including azoles and echinocandins due to resource limitation. Although, the tested isolates showed low MICs to amphotericin, there may be strains with higher MICs that were not tested. Lastly, owing to the retrospective nature of the study, the outcomes of the admitted patients who did not receive antifungal treatment could not be assessed beyond discharge from the hospital. There may be a possibility of clinical worsening in those patients which could not be explored.

## CONCLUSION

*Rhodotorula* species, though rare, can cause invasive infections particularly in patients with compromised immune system or risk factors such as the use of CVCs and any malignancies. The clinical findings in our study, as well as those reported in the literature, closely resemble other fungal bloodstream infections like candidemia. Interestingly, not all cases of *Rhodotorula* infection in our study received antifungal treatment; yet these patients were discharged in a stable condition. Since *Rhodotorula* is ubiquitously present in the environment, careful evaluation of the clinical findings and underlying risk factors is crucial for assessing the significance of isolation of this organism from clinical specimens. Our findings also highlight the need for standardized diagnostic criteria for this uncommon yeast infection and, more importantly, indications of antifungal therapy, alongside appropriate source control measures.

## CONFLICT OF INTEREST

None

## GRANT SUPPORT & FINANCIAL DISCLOSURE

Declared none

## AUTHOR CONTRIBUTION

**Sobia Muhammad Asad Khan:** Substantial contributions to study design, acquisition of data, manuscript writing, final approval, accountable for all aspects of publication

**Ahmad Reaan Khalid, Ashja Syed:** Manuscript writing and editing, final approval, accountable for all aspects of publication

**Joveria Farooqi:** Conceptualization, study design, administration and review, final approval, accountable for all aspects of publication

**Faheem Naqvi:** Data collection, laboratory methods validation, final approval, accountable for all aspects of publication

**Muhammad Naeem:** Data analysis, review and editing, final approval, accountable for all aspects of publication

**Rumina Hasan:** Investigation, manuscript review, resource provision, final approval, accountable for all aspects of publication

**Afia Zafar:** Investigation, manuscript review and editing, final approval, accountable for all aspects of publication

**Erum Khan:** Investigation, manuscript review and editing

**Kauser Jabeen:** Conceptualization, study design, administration and review, final approval, accountable for all aspects of publication

## REFERENCES

1. Hirano R, Mitsuhashi T, Osanai K. *Rhodotorula mucilaginosa* fungemia, a rare opportunistic infection without central venous catheter implantation, successfully

treated by liposomal amphotericin B. Case Rep Infect Dis. 2022; 2022: 7830126.
DOI: https://doi.org/10.1155/2022/7830126

2. Tuon FF, Costa SF. *Rhodotorula* infection. A systematic review of 128 cases from literature. Rev Iberoam Micol. 2008; 25(3): 135-40. DOI: https://doi.org/10.1016/s1130-1406(08)70032-9
3. Ioannou P, Vamvoukaki R, Samonis G. *Rhodotorula* species infections in humans: A systematic review. Mycoses. 2019; 62(2): 90-100.
DOI: https://doi.org/10.1111/myc.12856
4. Wirth F, Goldani LZ. Epidemiology of *Rhodotorula*: an emerging pathogen. Interdiscip Perspect Infect Dis. 2012; 2012: 465717. DOI: https://doi.org/10.1155/2012/465717
5. Duggal S, Jain H, Tyagi A, Sharma A, Chugh TD. *Rhodotorula* fungemia: two cases and a brief review. Med Mycol. 2011; 49(8): 879-82.
DOI: https://doi.org/10.3109/13693786.2011.583694
6. Arendrup MC, Boekhout T, Akova M, Meis JF, Cornely OA, Lortholary O. ESCMID and ECMM joint clinical guidelines for the diagnosis and management of rare invasive yeast infections. Clin Microbiol Infect. 2014; 20 Suppl 3: 76-98.
DOI: https://doi.org/10.1111/1469-0691.12360
7. Pfaller MA, Diekema DJ, Gibbs DL, Newell VA, Meis JF, Gould IM, *et al*. Results from the ARTEMIS DISK Global Antifungal Surveillance study, 1997 to 2005: An 8.5-year analysis of susceptibilities of Candida species and other yeast species to fluconazole and voriconazole determined by CLSI standardized disk diffusion testing. J Clin Microbiol. 2007; 45(6): 1735-45.
DOI: https://doi.org/10.1128/JCM.43.12.5848-5859.2005
8. Chen SC, Perfect J, Colombo AL, Cornely OA, Groll AH, Seidel D, *et al*. Global guideline for the diagnosis and management of rare yeast infections: an initiative of the ECMM in cooperation with ISHAM and ASM. Lancet Infect Dis. 2021; 21(12): e375-e86.
DOI: https://doi.org/10.1016/s1473-3099(21)00203-6
9. Miceli MH, Díaz JA, Lee SA. Emerging opportunistic yeast infections. Lancet Infect Dis. 2011;11(2):142-51.
DOI: https://doi.org/10.1016/s1473-3099(10)70218-8
10. Rattani S, Memon S, Jabeen K, Farooqi J. Spectrum of Invasive Yeast Infections in Neonates, Children and Adults in Pakistan Over Five Years: 2015-2019. Infect Dis J Pak. 2021; 30 (1): 14-8. Available from: https://ojs.idj.org.pk/index.php/Files/article/view/18
11. Donnelly JP, Chen SC, Kauffman CA, Steinbach WJ, Baddley JW, Verweij PE, *et al*. Revision and update of the consensus definitions of invasive fungal disease from the european organization for research and treatment of cancer and the mycoses study group education and research consortium. Clin Infect Dis. 2020; 71(6): 1367-76.
DOI: https://doi.org/10.1093/cid/ciz1008
12. Mermel LA, Allon M, Bouza E, Craven DE, Flynn P, O'Grady NP, *et al*. Clinical practice guidelines for the diagnosis and management of intravascular catheter-related infection: 2009 Update by the Infectious Diseases Society of America. Clin Infect Dis. 2009;49(1):1-45.
DOI: https://doi.org/10.1086/599376
13. Braun DK, Kauffman CA. *Rhodotorula* fungaemia: A life-hreatening complication of indwelling central venous atheters. Mycoses. 1992; 35(11-12): 305-8.
DOI: https://doi.org/10.1111/j.1439-0507.1992.tb00882.x
14. Menon S, Gupta HR, Sequeira R, Chavan S, Gholape D, Amandeep S, *et al*. *Rhodotorula* glutinis meningitis: A case report and review of literature. Mycoses. 2014; 57(7): 447-51. DOI: https://doi.org/10.1111/myc.12180
15. De Almeida GM, Costa SF, Melhem M, Motta AL, Szeszs MW, Miyashita F, *et al*. *Rhodotorula* spp. isolated from blood cultures: clinical and microbiological aspects. Med Mycol. 2008; 46(6): 547-56.
DOI: https://doi.org/10.1080/13693780801972490
16. Tsiodas S, Papageorgiou S, Meletiadis J, Tofas P, Pappa V, Panayiotides J, *et al*. *Rhodotorula* mucilaginosa associacted meningitis: A subacute entity with high mortality. Case report and review. Med Mycol Case Rep. 2014; 6: 46-50.
DOI: https://doi.org/10.1016/j.mmcr.2014.08.006
17. Zaas AK, Boyce M, Schell W, Lodge BA, Miller JL, Perfect JR. Risk of fungemia due to *Rhodotorula* and antifungal susceptibility testing of Rhodotorula isolates. J Clin Microbiol. 2003; 41(11): 5233-5.
DOI: https://doi.org/10.1128/jcm.41.11.5233-5235.2003
18. Gomez-Lopez A, Mellado E, Rodriguez-Tudela JL, Cuenca-Estrella M. Susceptibility profile of 29 clinical isolates of *Rhodotorula spp*. and literature review. J Antimicrob Chemother. 2005; 55(3): 312-6.
DOI: https://doi.org/10.1093/jac/dki020
19. Ferreras-Antolin L, Borman A, Diederichs A, Warris A, Lehrnbecher T. Serum beta-D-glucan in the diagnosis of invasive fungal disease in neonates, children and adolescents: A critical analysis of current data. J Fungi (Basel). 2022; 8(12): 1262.
DOI: https://doi.org/10.3390/jof8121262
20. Smith PB, Benjamin DK Jr, Alexander BD, Johnson MD, Finkelman MA, Steinbach WJ. Quantification of 1,3-beta-D-glucan levels in children: preliminary data for diagnostic use of the beta-glucan assay in a pediatric setting. Clin Vaccine Immunol. 2007;14(7):924-5.
DOI: https://doi.org/10.1128/cvi.00025-07.