JAPANESE DERMATOLOGICAL ASSOCIATION
THE JOURNAL OF DERMATOLOGY

doi: 10.1111/1346-8138.14653 *Journal of Dermatology* 2018; **45**: 1278–1282

REVIEW ARTICLE

Malassezia infections with systemic involvement: Figures and facts

Ana Filipa PEDROSA,[1,2,3] Carmen LISBOA,[1,2,3] Acácio Gonçalves RODRIGUES[1,3,4]

[1]*Division of Microbiology, Department of Pathology, Faculty of Medicine, University of Porto,* [2]*Department of Dermatology and Venereology, Centro Hospitalar São João EPE,* [3]*CINTESIS, Centre for Health Technology and Services Research, Faculty of Medicine of the University of Porto,* [4]*Burn Unit, Department of Plastic and Reconstructive Surgery, Centro Hospitalar São João EPE, Porto, Portugal*

ABSTRACT

***Malassezia* are lipophilic and commensal yeasts capable of inducing skin disease among susceptible hosts. However, severely immunocompromised patients and preterm infants admitted to intensive care units are particularly at risk of developing *Malassezia* systemic infections. Patients often have central venous catheters which are usually the portal of entry for colonization and infection. In addition to the clinically non-specific findings, a delay in the laboratorial diagnosis may occur as there is often the need to add lipid supplementation to culture in order to support these organisms' growth. Herein, we report three unrelated cases of *Malassezia* bloodstream infection at a university hospital during a 2-year period, followed by a discussion of the clinical results and comparison with the most recently available published data on epidemiology and risk factors, pathogenesis, diagnosis, susceptibility profile and treatment.**

Key words: antifungal therapy, fungemia, *Malassezia*, medical indwelling devices, pityriasis versicolor.

INTRODUCTION

Malassezia are lipophilic yeast inhabitants of the skin microbiome, and are most often implicated in a variety of skin diseases, namely pityriasis versicolor, *Malassezia* folliculitis, seborrheic dermatitis, atopic dermatitis and psoriasis.[1–3] Apart from *Malassezia*-related skin diseases, these organisms have been increasingly reported as fungi capable of causing severe systemic infections, especially among premature neonates and immunocompromised patients.[4]

Several topical and systemic antifungal drugs are commonly used against *Malassezia*-related skin disorders.[5–7] Because disease relapses are often found, a trend towards long-term prescription of antifungals is increasingly reported and maintenance therapy is often encouraged in clinical guidelines.[8] Hitherto, questions about the hypothetical selection of resistant clones should be raised in this setting, especially regarding azole drugs, which are most often used as the first-line empiric choice in the treatment and prophylaxis of fungemia.[9,10]

This manuscript aims to describe three cases of *Malassezia* bloodstream infections diagnosed at a Portuguese university, tertiary care hospital during a 2-year period and to review the recently published work on epidemiology and risk factors, pathogenesis, diagnosis, susceptibility profile and treatment of these infections.

METHODS

A Medline (PubMed) search of the articles published during the last 10 years in English was performed using the keywords "*Malassezia*", "bloodstream infection", "fungemia", "pityriasis versicolor", "epidemiology", "pathogenesis", "neonates", "immune suppression" and "antifungal therapy". The reference lists of key articles were then sifted for other relevant papers.

The articles were reviewed concerning in particular the epidemiology and risk factors, pathogenesis, diagnosis, antifungal susceptibility profile and treatment of *Malassezia* systemic infections in critical care and immunosuppressed patients. Specifically regarding national data about *Malassezia* systemic infections, we herein report the epidemiological data available from the University Hospital Centro Hospitalar de São João EPE, Porto, Portugal. The yeasts were first identified by matrix-assisted laser desorption ionization time-of-flight mass spectrometry (MALDI-TOF-MS) performed directly from the blood culture bottles or blood agar and speciation was confirmed by sequencing the *ITS-1*, *ITS-2* and *IGS-1* regions after amplification by polymerase chain reaction with the primers previously described by Sugita *et al*.[11] and Gaitanis *et al*.[12]

Epidemiology

Malassezia organisms may be inhabitants of the normal human skin microbiome by 3–6 months of age; *Malassezia furfur* was

Correspondence: Ana Filipa Pedrosa, M.D., Division of Microbiology, Department of Pathology, Faculty of Medicine, University of Porto, Alameda Professor Hernani Monteiro, 4200-319 Porto, Portugal. Email: anabastospedrosa@gmail.com
Received 10 August 2018; accepted 14 August 2018.

recovered from the skin in 31.8% of the neonates in a neonatal medical and surgical unit, but not immediately after birth.[13]

The non-lipid-dependent species *Malassezia pachydermatis* and the lipid-dependent *M. furfur* have both been reported to cause systemic infections.[14] Risk factors include hematological malignancies, especially if receiving chemotherapy, and other immunodeficiency states such as solid organ transplantation, prolonged glucocorticoid therapy and HIV infection. Interestingly, the majority of such cases occur in patients with central venous catheters.[15,16] In a survey of fungal bloodstream infections in critical care patients with underlying diseases or in preterm infants, *M. furfur* fungemia was more common (2.1%) than candidemia (1.4%).[17]

Outbreaks of *Malassezia* bloodstream infections have been rarely described, usually in neonatal intensive care units, most often afflicting preterm neonates receiving lipid infusions on total parenteral nutrition.[18–20] Lipid-containing infusions may thus promote *Malassezia* colonization of catheters and subsequent infection.[20,21] Additional risk factors for *Malassezia* infection may include low birthweight, severe comorbidities and more than 9 days of arterial catheterization. Notably, in one outbreak health-care workers were carriers of *M. pachydermatis*, with the yeast being isolated from their hands and pet dogs.[18] More recently, during a neonatal outbreak distinct *Malassezia* genotypes were identified by molecular biology.[22]

Malassezia furfur bloodstream infections were diagnosed in three inpatients admitted to the University Hospital, Centro Hospitalar São João EPE, Porto, Portugal, from January 2013 until December 2014. Table 1 displays these patients' clinical features. One case refers to a 2-year-old female child afflicted by fever and chronic spine osteomyelitis (no identified causal agent) and harboring a central venous catheter in which *M. furfur* was isolated too, apart from blood cultures. There were no clinical signs of pityriasis versicolor. She was treated with oral fluconazole and i.v. liposomal amphotericin B with clearance of blood cultures in 6 weeks. Despite an extensive genetic study searching for primary immunodeficiencies, there were no significant findings and an autoimmune process against the β-subunit of interleukin-12 was assumed, given the low levels of this interleukin. After 3 years of follow up, the patient developed widespread pityriasis versicolor. The patient is currently under immunomodulatory therapy with anakinra, with no recurrence of the systemic infection. The two remaining cases refer to adult immunosuppressed patients, exhibiting indolent clinical symptoms and signs of sepsis, being admitted for prolonged periods at intensive care units and prescribed i.v. fluconazole prophylaxis for prevention of fungal infection. *M. furfur* was isolated both in the blood cultures and central venous catheters. Both patients had lesions of seborrheic dermatitis but not of pityriasis versicolor. The patients were treated with liposomal amphotericin B but both had a fatal outcome.

Pathogenesis

The mechanisms of *Malassezia* pathogenicity remain a matter of debate. It is known that these commensal yeasts may transform from budding blastoconidia to a pathological mycelial phase under certain conditions, which promotes invasion of the stratum corneum and increasing skin fragility.[14]

Colonization of the skin with *Malassezia* species and subsequent extension to central venous catheters appears to be the major portal of entry for bloodstream infections in neonates; notably, *M. furfur* was cultured from the lumen of 32% of indwelling central venous catheters in a neonatal intensive care unit.[23]

Although biofilm formation at the skin surface as a virulence attribute has never been demonstrated for these yeasts, its formation at the surface of medical indwelling devices has already been demonstrated for *M. pachydermatis*[24] and *M. furfur*.[25] Additionally, when considering the yeast–host interaction, the immediate immune response seems to be crucial for the individual susceptibility to skin colonization, which may be the source for direct or indirect transmission of organisms among vulnerable patient groups.[14]

Diagnosis

The diagnosis of *Malassezia* systemic infections is quite challenging. As most clinical signs and symptoms are non-specific, an indolent course of a bloodstream infection manifested by fever of unknown origin is most often found, and the diagnosis relies mainly on laboratory isolation of the responsible agent.[15] Blood culture remains the gold standard for *Malassezia* isolation, but the lipid-dependent nature of most species implies the use of lipid supplements in culture media in order to support growth, as well as subculture in lipid-containing agar or supplementation of the blood culture with palmitic acid. Blood culture media should be incubated for a prolonged time of up to 2 weeks.[9,26,27] Culture of indwelling medical devices such as central venous catheters also represent a critical diagnostic step.[27]

Modern and reliable speciation requires the adoption of laboratory tools such as molecular biology[11,12,28] and MALDI-TOF-MS.[29,30] Although molecular tools can be performed directly on biological samples, culture is usually performed previously to enable yeast quantification, viability assessment and eventually antifungal susceptibility testing.[31] Culture media supporting *Malassezia* growth include modified Dixon, Leeming and Notman agar, CHROMagar *Malassezia*, and Sabouraud's agar with the addition of sterile olive oil.[27,30,32,33] Currently, the use of MALDI-TOF-MS has been exploited for *Malassezia* identification,[34] although the databases differ regarding the species and strains included, which may lead to misdiagnosis.[30] Furthermore, the non-uniformity in the culture media used may be another important issue when interpreting the results.[30,35]

Susceptibility profile and treatment

Therapy of *Malassezia* bloodstream infections is mainly based on previous experience and antifungal susceptibility data. Susceptibility testing has not been standardized for these yeasts and therefore is not performed by routine in many clinical laboratories. The use of broth microdilution and E-test methods has been reported, but both are still somewhat cumbersome.[36–39] More recently, an optimized colorimetric broth microdilution method has been developed for faster and more

Table 1. Clinical features of patients with *Malassezia furfur* systemic infections from January 2013 until December 2014

	Sex	Age (years)	Cause of admission	Risk factors	Antifungal prophylaxis	Treatment	Outcome
Case 1 Day 113 Pediatric ward	Female	2	Fever of unknown origin	CVC Broad-spectrum antibiotherapy Auto-immune disease (↓ IL-12) Glucocorticoid therapy	No	CVC removal Fluconazole (10 mg/kg per day) l-AMB (3 mg/kg per day) For 50 days	No-recurrence Pityriasis versicolor (3 years after)
Case 2 Day 22 Intensive care unit (infectious diseases department)	Female	68	SIRS	CVC HIV under HAART Oral epidermoid carcinoma (surgery; under RT and CHT) Miliary tuberculosis under AT treatment	Fluconazole (50 mg/day)	CVC removal l-AMB (5 mg/kg per day)	Death 15 days after the diagnosis
Case 3 Day 18 Intensive care unit	Male	60	ARDS	CVC HIV under HAART Hodgkin's disease under CHT	Fluconazole (50 mg/day)	CVC removal l-AMB (5 mg/kg per day)	Death 3 days after the diagnosis

ARDS, acute respiratory distress syndrome; AT, antituberculosis; CHT, chemotherapy; CVC, central venous catheter; HAART, highly active antiretroviral therapy; IL, interleukin; l-AMB, amphotericin B liposomal; RT, radiotherapy; SIRS, systemic inflammatory response syndrome.

efficient profiling of antifungal susceptibility of *Malassezia* isolates.[7] According to available data, *Malassezia* organisms exhibited conflicting results regarding susceptibility testing to amphotericin B: *M. pachydermatis* being inhibited by low concentrations of amphotericin B (≤1 μg/mL);[39] and *M. furfur* and *Malassezia globosa* requiring high amphotericin B minimal inhibitory concentration (MIC) values.[36] More often, reports described high MIC and wide MIC ranges depending on the strains tested.[5,7,37,38] Regarding azoles, itraconazole, posaconazole and voriconazole seem to be very active, *in vitro*, against *Malassezia*;[5,7,37,38] conversely, fluconazole and ketoconazole exhibited a more inconsistent activity against these yeasts. The highest MIC values and widest MIC ranges were often observed with fluconazole,[7,37] particularly when *M. furfur* isolates had been recovered from bloodstream infections in patients under fluconazole prophylaxis.[5] In a recent study,[7] ketoconazole exhibited low MIC values for most strains but very high MIC values for a few strains. Echinocandins and flucytosine do not seem to be effective against *Malassezia* isolates.[7,20]

Irrespective of the *in vitro* results, amphotericin B is most often used empirically for the management of *Malassezia* bloodstream infections, based solely on clinical evidence.[9,17] The lipophilic nature of this yeast may support the better *in vitro* antifungal activity of lipid-based formulations of amphotericin B compared with deoxycholate amphotericin B.[10]

Itraconazole, posaconazole or voriconazole may represent a valid alternative option based on the above-mentioned *in vitro* studies. Fluconazole is frequently used for fungal infection prophylaxis and most of the patients who develop *Malassezia* bloodstream infections were previously under fluconazole,[5] which stresses the need to use a distinct antifungal drug for treatment.

In case of central venous catheter-related *Malassezia* bloodstream infections, catheter removal, discontinuation of lipid infusion (if applied) and prompt initiation of systemic antifungal treatment is usually performed.[9,15,16] Although simple removal of central venous catheters may be enough to abort the progression of the infection, clinicians invariably prescribe systemic antifungal therapy in such instances.

DISCUSSION

Concerning the causative species, the presented data on *Malassezia* bloodstream infection isolates are in accordance with the findings of previous epidemiological surveys, unveiling *M. furfur* as the most common culprit agent.[5,17,40] The occurrence of three cases of confirmed *M. furfur* bloodstream infection in a tertiary care hospital during a 2-year period is consistent with the reported low prevalence of these invasive infections, usually confined to severely immunocompromised hosts.[9] Concerning diagnostic accuracy, there is a need to emphasize that the number of positive cases could be underestimated, because a keen clinical acumen is crucial to suspect these potential agents of fungemia in the appropriate clinical scenario, and in particular to provide optimal *Malassezia* recovery conditions from blood cultures and medical indwelling devices given the special lipid requirements (which are not provided in daily routine).[27]

The three unrelated cases herein reported all refer to patients with central venous catheters confirming the importance of this portal of entry,[40] which were removed early and afterwards replaced. No neonatal cases were found, neither cases associated with lipid infusion and/or total parenteral nutrition. An important issue involving *Malassezia* yeasts, which are common colonizers of human skin, relates to the enormous

potential of these organisms to adhere to the skin and to medical indwelling devices, presumably forming biofilms, and eventually later invade the bloodstream causing critical infections in immunocompromised patients. The inadequate and ineffective immune response to these commensal organisms is of upmost importance for the effectiveness of *Malassezia* colonization and infection. The pattern of inflammatory cytokines and antimicrobial peptides produced during early steps following contact with *Malassezia* yeasts has been under intensive exploration and should yield relevant insights regarding the most critical immune mediators involved.[41,42]

Although the reported low intrinsic pathogenicity of *Malassezia* organisms rarely causing disseminated infection,[9,43] the mortality associated with these infections is high, particularly due to the affliction of patients with underlying predisposing conditions as severe immunosuppression related to malignancy, chemotherapy, HIV infection and cases of congenital immunodeficiency.[15,16] Two of the three cases hereby described had a fatal outcome related to the fungal infection.

Currently, although speciation does not seem to be critical for the clinical management at the level of the individual patient as there are no established differences in the antifungal susceptibility profile, definitive species identification is obviously of paramount importance for both epidemiological surveillance and outbreak investigation.[9]

Amphotericin B is among the preferred therapeutic options for the first-line approach in patients who are usually under fluconazole prophylaxis.[9,17] However, the variable results regarding the susceptibility profile testing should raise concern about treatment recommendation.[5,7,36,37,39] Future comprehensive studies are warranted to elucidate which antifungal may be optimal for treatment of *Malassezia* systemic infections.

ACKNOWLEDGMENTS: We thank the European Academy of Dermatology and Venereology for the research grant to the project "*Malassezia*-related skin disorders" (PPRC-2017-7).

CONFLICT OF INTEREST: None declared.

REFERENCES

1 Gupta AK, Batra R, Bluhm R, Boekhout T, Dawson TL Jr. Skin diseases associated with *Malassezia* species. *J Am Acad Dermatol* 2004; **51**: 785–798.
2 Pedrosa AF, Lisboa C, Goncalves Rodrigues A. *Malassezia* infections: a medical conundrum. *J Am Acad Dermatol* 2014; **71**: 170–176.
3 Gaitanis G, Velegraki A, Mayser P, Bassukas ID. Skin diseases associated with *Malassezia* yeasts: facts and controversies. *Clin Dermatol* 2013; **31**: 455–463.
4 Miceli MH, Diaz JA, Lee SA. Emerging opportunistic yeast infections. *Lancet Infect Dis* 2011; **11**: 142–151.
5 Iatta R, Figueredo LA, Montagna MT, Otranto D, Cafarchia C. *In vitro* antifungal susceptibility of *Malassezia furfur* from bloodstream infections. *J Med Microbiol* 2014; **63**: 1467–1473.
6 Cafarchia C, Iatta R, Immediato D, Puttilli MR, Otranto D. Azole susceptibility of *Malassezia pachydermatis* and *Malassezia furfur* and tentative epidemiological cut-off values. *Med Mycol* 2015; **53**: 743–748.
7 Leong C, Buttafuoco A, Glatz M, Bosshard PP. Antifungal susceptibility testing of *Malassezia* spp. with an optimized colorimetric broth microdilution method. *J Clin Microbiol* 2017; **55**: 1883–1893.
8 Hald M, Arendrup MC, Svejgaard EL *et al.* Evidence-based Danish guidelines for the treatment of *Malassezia*-related skin diseases. *Acta Derm Venereol* 2015; **95**: 12–19.
9 Arendrup MC, Boekhout T, Akova M *et al.* ESCMID and ECMM joint clinical guidelines for the diagnosis and management of rare invasive yeast infections. *Clin Microbiol Infect* 2014; **20**: 76–98.
10 Iatta R, Immediato D, Montagna MT, Otranto D, Cafarchia C. *In vitro* activity of two amphotericin B formulations against *Malassezia furfur* strains recovered from patients with bloodstream infections. *Med Mycol* 2015; **53**: 269–274.
11 Sugita T, Suto H, Unno T *et al.* Molecular analysis of *Malassezia* microflora on the skin of atopic dermatitis patients and healthy subjects. *J Clin Microbiol* 2001; **39**: 3486–3490.
12 Gaitanis G, Velegraki A, Frangoulis E *et al.* Identification of *Malassezia* species from patient skin scales by PCR-RFLP. *Clin Microbiol Infect* 2002; **8**: 162–173.
13 Ashbee HR, Leck AK, Puntis JW, Parsons WJ, Evans EG. Skin colonization by *Malassezia* in neonates and infants. *Infect Control Hosp Epidemiol* 2002; **23**: 212–216.
14 Gaitanis G, Magiatis P, Hantschke M, Bassukas ID, Velegraki A. The *Malassezia* genus in skin and systemic diseases. *Clin Microbiol Rev* 2012; **25**: 106–141.
15 Morrison VA, Weisdorf DJ. The spectrum of *Malassezia* infections in the bone marrow transplant population. *Bone Marrow Transplant* 2000; **26**: 645–648.
16 Tragiannidis A, Bisping G, Koehler G, Groll AH. Minireview: *Malassezia* infections in immunocompromised patients. *Mycoses* 2010; **53**: 187–195.
17 Iatta R, Cafarchia C, Cuna T *et al.* Bloodstream infections by *Malassezia* and *Candida* species in critical care patients. *Med Mycol* 2014; **52**: 264–269.
18 Chang HJ, Miller HL, Watkins N *et al.* An epidemic of *Malassezia pachydermatis* in an intensive care nursery associated with colonization of health care workers' pet dogs. *N Eng J Med* 1998; **338**: 706–711.
19 Oliveri S, Trovato L, Betta P, Romeo MG, Nicoletti G. *Malassezia furfur* fungaemia in a neonatal patient detected by lysis-centrifugation blood culture method: first case reported in Italy. *Mycoses* 2011; **54**: e638–e640.
20 Chryssanthou E, Broberger U, Petrini B. *Malassezia pachydermatis* fungaemia in a neonatal intensive care unit. *Acta Paediatr* 2001; **90**: 323–327.
21 Gupta AK, Kohli Y, Li A, Faergemann J, Summerbell RC. *In vitro* susceptibility of the seven *Malassezia* species to ketoconazole, voriconazole, itraconazole and terbinafine. *Br J Dermatol* 2000; **142**: 758–765.
22 Ilahi A, Hadrich I, Goudjil S *et al.* Molecular epidemiology of a *Malassezia pachydermatis* neonatal unit outbreak. *Med Mycol* 2018; **56**: 69–77.
23 Aschner JL, Punsalang A Jr, Maniscalco WM, Menegus MA. Percutaneous central venous catheter colonization with *Malassezia furfur*: incidence and clinical significance. *Pediatrics* 1987; **80**: 535–539.
24 Cannizzo FT, Eraso E, Ezkurra PA *et al.* Biofilm development by clinical isolates of *Malassezia pachydermatis*. *Med Mycol* 2007; **45**: 357–361.
25 Angiolella L, Leone C, Rojas F, Mussin J, de Los Angeles Sosa M, Giusiano G. Biofilm, adherence, and hydrophobicity as virulence factors in *Malassezia furfur*. *Med Mycol* 2018; **56**: 110–116.
26 Nelson SC, Yau YC, Richardson SE, Matlow AG. Improved detection of *Malassezia* species in lipid-supplemented Peds Plus blood culture bottles. *J Clin Microbiol* 1995; **33**: 1005–1007.
27 Iatta R, Battista M, Miragliotta G, Boekhout T, Otranto D, Cafarchia C. Blood culture procedures and diagnosis of *Malassezia furfur* bloodstream infections: strength and weakness. *Med Mycol* 2017; https://doi.org/10.1093/mmy/myx122

28 Sugita T, Suzuki M, Goto S *et al.* Quantitative analysis of the cutaneous *Malassezia microbiota* in 770 healthy Japanese by age and gender using a real-time PCR assay. *Med Mycol* 2010; **48**: 229–233.
29 Kolecka A, Khayhan K, Arabatzis M *et al.* Efficient identification of *Malassezia* yeasts by matrix-assisted laser desorption ionization-time of flight mass spectrometry (MALDI-TOF MS). *Br J Dermatol* 2014; **170**: 332–341.
30 Denis J, Machouart M, Morio F *et al.* Performance of matrix-assisted laser desorption ionization-time of flight mass spectrometry for identifying clinical *Malassezia* isolates. *J Clin Microbiol* 2017; **55**: 90–96.
31 Pedrosa AF, Lisboa C, Faria-Ramos I, Silva RM, Miranda IM, Rodrigues AG. *Malassezia* species retrieved from skin with pityriasis versicolor, seborrheic dermatitis and skin free of lesions: a comparison of two sampling methods. *Br J Dermatol* 2018; **179**: 526–527.
32 Gupta AK, Kohli Y. Prevalence of *Malassezia* species on various body sites in clinically healthy subjects representing different age groups. *Med Mycol* 2004; **42**: 35–42.
33 Kaneko T, Makimura K, Abe M *et al.* Revised culture-based system for identification of *Malassezia* species. *J Clin Microbiol* 2007; **45**: 3737–3742.
34 Lecerf P, Hay R. A new approach to the diagnosis and study of *Malassezia* infections. *Br J Dermatol* 2014; **170**: 234.
35 Yamamoto M, Umeda Y, Yo A, Yamaura M, Makimura K. Utilization of matrix-assisted laser desorption and ionization time-of-flight mass spectrometry for identification of infantile seborrheic dermatitis-causing *Malassezia* and incidence of culture-based cutaneous *Malassezia microbiota* of 1-month-old infants. *J Dermatol* 2014; **41**: 117–123.
36 Velegraki A, Alexopoulos EC, Kritikou S, Gaitanis G. Use of fatty acid RPMI 1640 media for testing susceptibilities of eight *Malassezia* species to the new triazole posaconazole and to six established antifungal agents by a modified NCCLS M27-A2 microdilution method and Etest. *J Clin Microbiol* 2004; **42**: 3589–3593.
37 Rojas FD, Sosa Mde L, Fernandez MS, Cattana ME, Cordoba SB, Giusiano GE. Antifungal susceptibility of *Malassezia furfur*, *Malassezia sympodialis*, and *Malassezia globosa* to azole drugs and amphotericin B evaluated using a broth microdilution method. *Med Mycol* 2014; **52**: 641–646.
38 Rojas FD, Cordoba SB, de Los Angeles Sosa M *et al.* Antifungal susceptibility testing of *Malassezia* yeast: comparison of two different methodologies. *Mycoses* 2017; **60**: 104–111.
39 Alvarez-Perez S, Blanco JL, Pelaez T, Cutuli M, Garcia ME. *In vitro* amphotericin B susceptibility of *Malassezia pachydermatis* determined by the CLSI broth microdilution method and Etest using lipid-enriched media. *Antimicrob Agents Chemother* 2014; **58**: 4203–4206.
40 Kaneko T, Murotani M, Ohkusu K, Sugita T, Makimura K. Genetic and biological features of catheter-associated *Malassezia furfur* from hospitalized adults. *Med Mycol* 2012; **50**: 74–80.
41 Baroni A, Orlando M, Donnarumma G *et al.* Toll-like receptor 2 (TLR2) mediates intracellular signalling in human keratinocytes in response to *Malassezia furfur*. *Arch Dermatol Res* 2006; **297**: 280–288.
42 Angrisano T, Pero R, Paoletti I *et al.* Epigenetic regulation of IL-8 and beta-defensin genes in human keratinocytes in response to *Malassezia furfur*. *J Invest Dermatol* 2013; **133**: 2101–2104.
43 Blaes AH, Cavert WP, Morrison VA. Malassezia: is it a pulmonary pathogen in the stem cell transplant population? *Transpl Infect Dis* 2009; **11**: 313–317.