ESCMID AND ECMM PUBLICATIONS 10.1111/1469-0691.12515

ESCMID and ECMM joint clinical guidelines for the diagnosis and management of systemic phaeohyphomycosis: diseases caused by black fungi

A. Chowdhary[1], J. F. Meis[2,3], J. Guarro[4], G. S. de Hoog[5], S. Kathuria[1], M. C. Arendrup[6], S. Arikan-Akdagli[7], M. Akova[8], T. Boekhout[5,9], M. Caira[10], J. Guinea[11,12,13], A. Chakrabarti[14], E. Dannaoui[15], A. van Diepeningen[5], T. Freiberger[16], A. H. Groll[17], W. W. Hope[18], E. Johnson[19], M. Lackner[20], K. Lagrou[21], F. Lanternier[22,23], C. Lass-Flörl[20], O. Lortholary[22,23], J. Meletiadis[24], P. Muñoz[11,12,13], L. Pagano[10], G. Petrikkos[25], M. D. Richardson[26], E. Roilides[27], A. Skiada[28], A. M. Tortorano[29], A. J. Ullmann[30], P. E. Verweij[3], O. A. Cornely[31] and M. Cuenca-Estrella[32]

1) *Department of Medical Mycology, Vallabhbhai Patel Chest Institute, University of Delhi, Delhi, India,* 2) *Department of Medical Microbiology and Infectious Diseases, Canisius Wilhelmina Hospital, Nijmegen,* 3) *Department of Medical Microbiology, Radboud University Medical Centre, Nijmegen, the Netherlands,* 4) *Facultat Medicina & IISPV, University Rovira i Virgili, Reus, Spain,* 5) *CBS Fungal Biodiversity Centre, Utrecht, the Netherlands,* 6) *Unit of Mycology, Department of Microbiology and Infection Control, Statens Serum Insititut, Copenhagen, Denmark,* 7) *Departments of Medical Microbiology,* 8) *Infectious Diseases, Hacettepe University Medical School, Ankara, Turkey,* 9) *Department of Internal Medicine and Infectious Diseases, University Medical Centre, Utrecht, the Netherlands,* 10) *Department of Haematology, Catholic University of Sacred Heart, Rome, Italy,* 11) *Clinical Microbiology and Infectious Diseases, Hospital General Universitario Gregorio Marañón, Madrid,* 12) *Ciber de Enfermedades Respiratorias (CIBERES), Madrid,* 13) *Department of Medicine, Universidad Complutense, Madrid, Spain,* 14) *Department of Medical Microbiology, Postgraduate Institute of Medical Education & Research, Chandigarh, India,* 15) *Unité de Parasitologie-Mycologie, Service de Microbiologie, Faculté de Médecine, APHP, Hôpital Européen Georges Pompidou, Université Paris-Descartes, Paris, France,* 16) *Centre for Cardiovascular Surgery and Transplantation, Molecular Genetics Lab, Central European Institute of Technology (CEITEC), Molecular Immunology and Microbiology RG, Masaryk University, Brno, Czech Republic,* 17) *Infectious Disease Research Programme, Centre for Bone Marrow Transplantation and Department of Paediatric Haematology/Oncology, University Hospital Münster, Münster, Germany,* 18) *Department of Molecular and Clinical Pharmacology, University of Liverpool, Liverpool,* 19) *Public Health England Mycology Reference Laboratory, PHE South West Laboratory, Bristol, UK,* 20) *Divison of Hygiene and Medical Microbiology, Innsbruck Medical University, Innsbruck, Austria,* 21) *Department of Medical Diagnostic Sciences, UZ Leuven, Leuven, Belgium,* 22) *Service des Maladies Infectieuses et Tropicales, Institut Imagine, Hôpital Necker-Enfants malades, APHP, Centre d'Infectiologie Necker-Pasteur, Université Paris-Descartes, Paris,* 23) *Unité de Mycologie Moléculaire, Institut Pasteur, Centre National de Référence Mycoses Invasives et Antifongiques, Paris, France,* 24) *Clinical Microbiology Laboratory, University General Hospital "Attikon", Athens,* 25) *Fourth Department of Internal Medicine National and Kapodistrian University of Athens Medical School, University General Hospital "Attikon", Athens, Greece,* 26) *Manchester Academic Health Science Centre, University Hospital of South Manchester, Mycology Reference Centre and University of Manchester, Manchester, UK,* 27) *Infectious Diseases Unit, Third Department of Paediatrics, Hipokration Hospital, Aristotle University School of Medicine, Thessaloniki,* 28) *Department of Infectious Diseases, Laikon General Hospital, University of Athens, Athens, Greece,* 29) *Department of Biomedical Sciences for Health, Università* degli Studi di Milano, Milan, Italy, 30) *Division of Infectious Diseases, Department of Internal Medicine II, Julius- Maximilians-University, Würzburg, ,* 31) *First Department of Internal Medicine, Clinical Trials Centre Cologne, Cologne Excellence Cluster on Cellular Stress Responses in Aging-Associated Diseases (CECAD), University of Cologne, Cologne, Germany and* 32) *Servicio de Micología, Centro Nacional de Microbiología, Instituto de Salud Carlos III, Madrid, Spain*

Abstract

The aetiological agents of many invasive fungal infections are saprobes and opportunistic pathogens. Some of these fungi are darkly pigmented due to melanin production and traditionally have been named 'dematiaceous'. The melanized fungi cause a wide array of clinical syndromes ranging from superficial to deep-seated infections. Diagnosis relies on histopathological examination of clinical specimens and on examination of cultures. Sequencing is recommended for accurate species identification, especially for unusual or newly described pathogens. In cases of mycetoma and chromoblastomycosis, pathognomonic histological findings are useful and the Fontana–Masson stain, specific for melanin, usually confirms the diagnosis. There are no standardized therapies but voriconazole, posaconazole and itraconazole demonstrate the most consistent *in vitro* activity against this group of fungi. Oral itraconazole has been considered the drug of choice, given the extensive clinical experience with this drug. However, voriconazole may presumably be superior for central nervous system infections

because of its ability to achieve good levels in the cerebrospinal fluid. Posaconazole is a well-tolerated alternative drug, backed by less clinical experience but with excellent salvage treatment results after failure of other antifungals. Amphotericin B has been useful as alternative therapy in some cases. Combination antifungal therapy is recommended for cerebral abscesses when surgery is not possible and for disseminated infections in immunocompromised patients.

Keywords: Clinical presentation, diagnosis, guideline, mycosis, phaeohyphomycosis, prophylaxis, treatment
Original Submission: 10 December 2013; **Revised Submission:** 13 December 2013; **Accepted:** 16 December 2013
M. Paul
Article published online: 31 January 2014
Clin Microbiol Infect 2014; **20** (Suppl. 3): 47–75

Corresponding author: M. Cuenca-Estrella, Spanish National Center for Microbiology Ctra. Majadahonda-Pozuelo Km2 Majadahonda, Madrid 28220, Spain
E-mail: mcuenca-estrella@isciii.es

Introduction

A panel of experts of the European Fungal Infection Study Group (EFISG) of the European Society of Clinical Microbiology and Infectious Diseases (ESCMID) undertook a data review and compiled guidelines for the diagnosis and management of infections caused by melanized (black) fungi. The deep-seated infection caused by these fungi is often referred to as phaeohyphomycosis. Many infections, however, are superficial and mild, or cause cutaneous or pulmonary colonization only. In addition, many species of black fungi have a cosmopolitan presence and are widely distributed in the environment and the possibility that a suspected clinical isolate might be a contaminant must be considered. The course of infection differs with the species, so for clinical management it is paramount to obtain an accurate species identification. Although sizeable numbers of these rare fungal pathogens have been implicated in human infections, we have reviewed only the most common ones.

Methods

The guideline development followed the AGREE II method (Appraisal of guidelines for research and evaluation II; http://www.agreetrust.org/resource-centre/agree-ii/, accessed 13 December 2013). The overall objective of the guidelines has been on the diagnosis and management of deep-seated phaeohyphomycosis, including disseminated infections. In addition, superficial and allergic manifestations caused by these fungi are also briefly discussed. The definition of the strength of recommendation and the quality of the published evidence are defined in Table 1. The health questions covered by the guidelines are specifically described in the Tables 2–4. The population to whom the recommendations are meant to apply is any patient suffering from phaeohyphomycosis. The expert panel (35 members) was set up by ESCMID/EFISG and European Confederation of Medical Mycology (ECMM) including clinical microbiologists, infectious diseases experts, paediatricians, haematologists and intensive care unit experts taking into account the target users of these guidelines. Competing interests of guideline development group members were recorded and addressed. An expert subgroup (AC, MCE, JG, SDH, SK, OAC, JFM) reviewed the available literature. The other experts of the panel acted as external reviewers. The members actively shared their views and documents by email, teleconferences and face-to face meetings during 2012–2013.

TABLE 1. System for grading strength of recommendation and quality of evidence about diagnostic procedures and therapy of infections by black fungi

Grade of recommendation	Definition
Strength of recommendation	
Grade A	ESCMID (EFISG) and ECMM strongly support a recommendation for use
Grade B	ESCMID (EFISG) and ECMM moderately support a recommendation for use
Grade C	ESCMID (EFISG) and ECMM marginally support a recommendation for use
Grade D	ESCMID (EFISG) and ECMM support a recommendation against use
Level of evidence	**Definition**
Quality of evidence accepted	
Level I	Evidence from at least one properly designed randomized, controlled trial
Level II	Evidence from at least one well-designed clinical trial, without randomization; from cohort or case–control analytical studies (preferably from more than one centre); from multiple time series; or from dramatic results of uncontrolled experiments
Level III	Evidence from opinions of respected authorities, based on clinical experience, descriptive case studies, or reports of expert committees

TABLE 2. Disease spectrum of agents of phaeohyphomycosis with their *in vitro* antifungal susceptibility profile

Aetiological agents [references]	Most common described infections	Species	*In vitro* susceptibility (MIC range, mg/L)[a]								
			AMB	ITC	VRC	POS	ISA	FC	FLU	ECHINO	TERB
Alternaria [38,55,167]	Cutaneous and subcutaneous infection, sinusitis, keratitis, ABPM, disseminated disease	*A. alternata*	0.25–1.0	0.25–1.0	1.0–4.0	0.12–0.50	–	8.0–>64.0	8.0–32.0	0.50–1.0	>16.0
		A. infectoria	0.25–1.0	0.25–1.0	1.0–4.0	0.06–0.12	–	16.0–>64.0	16.0–32.0	1.0	>8.0
		Alternaria spp.	0.03–4.0	1.0	2.0	1.0	–	16.0–>64.0	16.0–>64.0	>16.0	16.0
Acrophialophora [183–185]	Brain abscess, ocular and lung infection	*A. fusispora*	0.25–4.0	0.06–0.25	0.12–2.0	0.125–2.0		>64.0	8.0–32.0	–	–
Aureobasidium [211]	Cutaneous and subcutaneous infection, ocular infection, rare deep infection, fungaemia	*A. pullulans*	0.01–16.0	0.01–2.0	0.01–16.0	0.01–4.0	–	–	4.0–64.0	0.06–8.0	–
Bipolaris [213,242]	Cutaneous and subcutaneous infection, sinusitis, ocular infection, pneumonia, cerebral infection, disseminated disease	*B. hawaiiensis*	0.12–0.25	0.03–0.5	0.25–2.0	0.03–0.5	–	>64.0	2.0–32.0	0.50–1.0	–
		B. australiensis	0.06–0.12	0.25–0.5	0.05–1.0	0.06	–	>64.0	8.0–16.0	1.0	–
		B. spicifera	0.03–4.0	0.03–8.0	0.25–4.0	0.03–2.0	–	>64.0	4.0–>64.0	0.25–2.0	–
Chaetomium [143,257,258]	Cutaneous and subcutaneous infection, pneumonia, brain abscess	*C. globosum*	0.50–8.0	0.03–0.50	0.50	–	–	32.0–>64.0	>64.0	–	–
		C. perlucidum	0.25	0.01–0.06	0.50	0.06–0.12	–	–	–	8.0–>16.0	–
Cladophialophora [87,123]	Cutaneous and subcutaneous infection, brain abscess	*C. carrionii*	0.5–8.0	0.01–0.12	0.01–1.0	0.01–0.06	0.01–1.0	–	4.0–64.0	0.25–4.0	0.01–1.0
		C. bantiana	0.12–2.0	0.01–0.25	0.12–4.0	0.01–0.25	0.01–1.0	–	16.0–64.0	1.0–8.0	–
Curvularia [277,284]	Cutaneous and subcutaneous infection, sinusitis, keratitis, ABPM, peritonitis, cerebral infection, disseminated disease	*C. senegalensis*	0.06–0.50	0.06–1.0	0.12–4.0	0.03–0.50	–	64.0–>64.0	2.0–16.0	0.50–2.0	–
		C. lunata	0.12–>16.0	0.12–>16.0	0.25–1.0	0.03–0.50	–	>64.0	2.0–64.0	0.50–>16.0	–
		Curvularia spp.	0.06–>16.0	0.03–>16.0	0.15–>16	0.03–4.0	–	64.0–>64.0	1.0–>64.0	0.50–>16.0	–
Exophiala [334–338]	Cutaneous and subcutaneous infection, pneumonia, brain abscess, disseminated disease	*E. jeanselmei*	0.25–2.0	0.01–0.25	0.06–2.0	0.01–0.06	0.25–2.0	–	8.0–32.0	0.06–8.0	–
		E. dermatitidis	0.01–0.50	0.03–0.5	0.06–1.0	0.03–0.25	0.03–1.0	–	2.0–32.0	0.25–8.00	–
		E. spinifera	0.25–4.0	0.01–0.12	0.06–1.0	0.01–0.06	2.0	0.12–>64.0	16.0–>64.0	4.0	0.03–2.0
Exserohilum [340,375]	Cutaneous and subcutaneous infection, keratitis, meningitis and spinal infection, arthritis, disseminated disease	*E. rostratum*	0.03–0.12	0.03–0.12	0.03–1.0	0.03–0.12	–	–	–	0.03–>16.0	0.03–0.25
Fonsecaea [83,378]	Cutaneous and subcutaneous infections brain abscess	*F. monophora*	0.50–2.0	0.03–0.25	0.12–1.0	0.01–0.06	0.06–1.0	–	8.0–64.0	1.0–4.0	–
		F. pedrosoi	0.50–2.0	0.03–0.25	0.12–0.50	0.03–0.06	0.06–0.25	–	8.0–32.0	2.0–4.0	0.06–0.25
		Fonsecaea spp.	0.50–2.0	0.03–0.25	0.125–1.0	0.01–0.06	0.06–1.0	–	8.0–64.0	1.0–8.0	–
Hortae [396]	Tinea nigra, very rare deep mycosis	*H. werneckii*	0.12–2.0	0.03–0.50	0.06–0.25	0.01–0.12	0.06–0.5	–	8.0–64.0	1.0–8.0	–
Neoscytalidium [103,400,401,409]	Cutaneous infections and onychomycosis, very rare deep mycosis	*N. dimidiatum*	0.06–1.0	0.03–>16.0	0.03–4	0.06–32	–	–	0.25–32.0	0.06–>16.0	0.06–2.0
Ochroconis [434,437]	Pneumonia, brain abscess, disseminated infection	*O. gallopava*	0.12–1.0	0.01–0.50	0.12–2.0	0.01–0.12	–	16.0–>64.0	16.0–>64.0	1.0–8.0	0.03–1.0
		O. tshawytschae	4.0	0.50	0.12	–	–	–	>64.0	0.25	–
Phaeoacremonium [445,446]	Subcutaneous infection, arthritis, disseminated disease	*P. parasiticum*	2.0	0.12–8.0	0.06–0.25	0.03–0.50	–	–	8.0	>16.0	0.50–2.0
Phoma [457,459]	Cutaneous and subcutaneous infection, ocular infection, rare deep mycosis	*Phoma* spp.	0.5–1.0	0.25–8.0	0.25–8.0	–	–	–	–	–	–
Pyrenochaeta [462]	Cutaneous and subcutaneous infection, keratitis	*P. romeroi*	4.0	0.50	4.0	0.50	0.12	–	>64.0	8.0	–
Rhinocladiella [130,478,480,485]	Brain abscess	*R. mackenziei*	1.0–>16.0	0.01–0.25	0.01–2.0	0.01–0.25		4.0–16.0	16.0–64.0	1.0–8.0	–
		R. aquaspersa	1.0–2.0	0.06–0.12	2.0	0.06–0.12		–	32.0–64.0	8.0	–
Veronaea [494]	Cutaneous and subcutaneous infection, disseminated disease	*V. botryosa*	8.0–16.0	0.25–1.0	1.0–8.0	0.03–0.25	4.0–>16.0	–	>64.0	2.0–>16.0	1.0–4.0

AMB, amphotericin B; ITC, itraconazole; VRC, voriconazole; POS, posaconazole; ISA, isavuconazole; FC, flucytosine; FLU, fluconazole; ECHINO, echinocandins; TERB, terbinafine; ABPM, allergic bronchopulmonary mycosis.
[a]Depicts collective MIC ranges from all the references mentioned.

TABLE 3. Recommendations for microbiological procedures to detect infections by black fungi. Table includes grade and quality of evidences

Disease/population [references]	Intention	Diagnostic procedure	SoR	QoE	Comments
All cases with deep infections [9–13,237]	Definitive diagnosis and species identification to recommend best first-line therapy	Direct microscopy KOH, fluorescence Histopathology and Special stains H&E, Fontana–Masson stain, periodic acid Schiff (invasion) and culture	A	III	Visualization of melanized fungal structures. Fontana–Masson stain definitive detection of melanin in tissue/aspirate specimens Conventional isolation media for species identification (BHI for some strains)
Cerebral abscess and other localized infections [9–13,237]	Definitive diagnosis and species identification	As above and specimen taken at the sources of infection	A	III	*Cladophialophora bantiana* and *Rhinocladiella mackenziei* (most common species in cerebral abscess)
Disseminated infections [9–13]	Definitive diagnosis and species identification	As above and blood cultures and other specimens when possible	A	III	None
All cases [9–13]	To know local species distribution	Periodical epidemiological surveys	A	III	None
Cases by isolates difficult to identify and sibling/cryptic species [14]	Definitive species identification	Molecular identification (DNA target sequencing)	B	III	May be essential investigation for some rare species
All cases with deep infections [15–17]	To detect high MIC values *in vitro* and recommend the best therapy	MIC determination	A	III	Use reference procedure
All cases [18,19]	To detect local resistance *in vitro*	Periodical epidemiological MIC determination surveys	A	III	Use reference procedures
All cases with deep infection [20–22]	Detect infection	β-D-glucan quantification	C	III	Panfungal detection. Insufficient data
All cases with deep infection [9]	Detect infection	*Aspergillus* galactomannan quantification	D	III	Cross-reactivity in some cases
Infections by *F. pedrosoi* and *C. carrionii* [12]	Detect infection	In-house ELISA techniques	C	III	Not validated
All cases [23,24]	Detect infection in tissues	PCR-based methods	C	III	Insufficient data
All cases [12,25]	Detect infection in blood, serum or other sterile fluids	PCR-based methods	C	III	No data

BHI, brain–heart infusion; H&E, haematoxylin and eosin; QoE, quality of evidence; SoR, strength of evidence.

Once the first consensus was reached, the preliminary recommendations were discussed, developed further and finalized as a group consensus. The methods to evaluate the quality of evidence and to reach consensus recommendations were described previously in detail when the first official ESCMID guidelines on the diagnosis and treatment of *Candida* infections were published [1–6].

The characteristic feature of phaeohyphomycosis is the presence of melanin in the fungal cell walls, which gives a dark colour to the hyphae, and is considered a major virulence factor. The criteria for selecting the evidence were searching the literature using the string 'melanized', 'dark', 'phaeoid' and 'dematiaceous' and search results were systematically reviewed. As the clinical syndromes associated with these fungi are common across the different pathogens (Table 2), the first part of this guideline presents recommendations for each clinical entity (localized cutaneous and subcutaneous infection, chromoblastomycosis, mycetoma, keratitis, pulmonary infections, cerebral infection, disseminated disease and allergic manifestations). Subsequently, specific issues for each of the fungal pathogens are presented in alphabetical order. Most recommendations in this guideline are based on dramatic results of uncontrolled experiments, opinions of respected authorities, clinical experience, descriptive case studies, or reports of expert committees. In some cases, *in vitro* data and animal studies are also included. Unfortunately, much of the older literature could not be included because of the unreliability of the non-molecular strain identification methods used. These guidelines highlight the fact that there is no standard approach for treatment of phaeohyphomycosis. Also, the reference microdilution methodologies for *in vitro* antifungal susceptibility testing have not been standardized nor are the validated MIC breakpoints that are used for interpretation of the results for antifungal drugs against the phaeoid fungi available. Unlike the other guidelines for fungal infections caused by rare yeasts and the mucorales, which recommend clear-cut therapeutic approaches [7,8], the huge diversity of dematiaceous fungi and their host range make it impossible to advise a uniform approach for phaeohyphomycosis. Length of therapy and choice of intervention (surgery, antifungals or both) for each clinical entity is primarily based on the clinical presentation, the underlying condition of the host and the initial response. The prolonged duration of therapy in the diseases caused by phaeoid fungi generally ranges from several weeks to months or longer. The clinical entities and their therapeutic recommendations are given below and summarized in Tables 1–4. Table 3 includes recommendations for diagnostic procedures and susceptibility testing of these diseases [9–25]. These guidelines will be periodically updated.

TABLE 4. Recommendations for targeted treatment of infection by black fungi. Table includes grade and quality of evidence

Disease[a]	Intention	Intervention [references]	SoR	QoE	Comments
Localized cutaneous infection or subcutaneous nodule(s)	Cure	Surgery [12,26–32]	A	II	Dramatic results of uncontrolled cases and multiple time series
Subcutaneous nodule	Cure	Cryotherapy, laser therapy, heat therapy or potassium iodide [33–37]	B	III	Reports from areas where antifungal agents are unavailable or failure/contraindication of antifungals
	To prevent dissemination	Add itraconazole (400 mg) or voriconazole (400 mg) [12]	B	III	Expert opinion (particularly in immunocompromised patients)
Multiple subcutaneous nodules	Cure	Itraconazole (400 mg) or voriconazole (400 mg) [38–44]	A	III	Descriptive case studies; treatment duration 3–12 months
	Cure	Itraconazole (200 mg), posaconazole (800 mg), amphotericin B (1 mg/kg), liposomal amphotericin B (3 mg/kg), caspofungin (70/50 mg), terbinafine (250–500 mg) or combination therapy[b] with itraconazole PLUS terbinafine or itraconazole PLUS amphotericin B [12,41,45–58]	C	III	Few descriptive case studies and insufficient data. Some cases including surgery when possible
Mycetoma	Cure or reduce infections in advanced cases	Itraconazole (400 mg) for at least 3 months (years in some cases) PLUS surgery [59–64]	A	II	Dramatic results of uncontrolled cases and some time series
	As above	Voriconazole (400 mg), posaconazole (800 mg) or terbinafine (250 mg) PLUS surgery [66–69]	A	III	Dramatic results of uncontrolled few cases
	As above	Ketoconazole (400 mg) [59,63,64]	D	III	Side effects
	As above	Amphotericin B (1 mg/kg) [12]	D	III	Impractical given the therapy duration
Refractory mycetoma	Reduce lesions	Combination antifungal therapy (azoles PLUS terbinafine or flucytosine) [65,67]	B	III	Descriptive case studies Surgery when possible
Chromoblastomycosis	Cure or reduced infections in advanced cases	Itraconazole (400 mg) for months to years PLUS surgery [72–74,76]	A	II	Dramatic results of uncontrolled cases and multiple time series
	As above	Terbinafine (250 mg) or posaconazole (800 mg) PLUS surgery [72,75,77,78,88]	B	III	Descriptive case studies
	As above	Cryotherapy, laser therapy, heat therapy or potassium iodide [75,79–81]	B	III	Descriptive case studies
Refractory chromoblastomycosis	Reduce lesions	Combination antifungal therapy (itraconazole plus terbinafine) [72,74,75,82–84]	B	III	Descriptive case studies Surgery when possible
Keratitis	Cure	Natamycin alone or PLUS other topical agents [89,90,92–94]	A	II	Multiple time series
	Cure	Topical azoles alone [95–97]	B	III	Descriptive case studies
Refractory keratitis	Cure	Oral triazoles (conventional doses) PLUS surgery if needed [89,91–93]	B	III	Descriptive case studies
	Cure	Intrastromal voriconazole injection [96,98]	C	III	Insufficient data
Pulmonary infection	Cure or control of infection	Systemic liposomal amphotericin B (3 mg/kg), itraconazole (400 mg), voriconazole (400 mg) or posaconazole (800 mg) [12,102–107]	B	III	Descriptive case studies in immunocompromised or with underlying pulmonary disease (few cases for posaconazole)
Solitary pulmonary nodule in immunocompetent	Cure	Surgery [12,99,108]	B	III	Descriptive case studies
Cerebral abscess	Cure	Complete excision (when possible) [109,112,117–120]	A	II	Dramatic results of uncontrolled cases
	Cure when surgery is not possible	Voriconazole (400 mg) or posaconazole (800 mg) [121–128]	C	II	Multiple time series and animal model and *in vitro* data
	As above	Amphotericin B (several doses) [122–124,129]	D	III	Descriptive case studies, failures and results from animal models and *in vitro* data
	As above	New combination therapy (voriconazole or posaconazole plus echinocandin plus flucytosine) [12,116,130]	B	III	Expert opinion and descriptive case studies (very few)
Bone and joint infections	Cure	Surgery PLUS itraconazole (400 mg), voriconazole (400 mg), posaconazole (800 mg) or liposomal amphotericin B (3 mg/kg) [12,131,132]	B	III	Descriptive case studies
Peritonitis	Cure (associated with peritoneal dialysis)	Catheter removal PLUS systemic antifungal therapy [133–137]	A	II	Dramatic results of uncontrolled cases removing the catheter
Disseminated infection	Cure or infection control	Liposomal amphotericin B (3 mg/kg), itraconazole (400 mg), voriconazole (400 mg), or posaconazole (800 mg) [138,141–147]	C	III	Descriptive case studies
	As above	Voriconazole (400 mg) or posaconazole (800 mg) PLUS terbinafine (250 mg) PLUS colony-stimulating factors/leucocyte infusion [148–150]	B	III	Expert opinion and descriptive case studies (very few and based on experience with *Scedosporium* infections)
Allergic sinusitis	Remove the mucin and reduce symptoms	Surgery PLUS systemic steroids [151–154]	A	II	Prospective, randomized, placebo-controlled trial (24 patients only) and reviews
	Reduce requirements of steroids	Add itraconazole (several doses) [152,153,155]	C	III	Descriptive case studies
Refractory allergic sinusitis	Reduce symptoms	Add itraconazole (several doses) or voriconazole (400 mg) [156–158]	B	III	Descriptive case studies
Sinus fungus ball	Cure	Surgery [159]	A	II	Dramatic results of uncontrolled cases
Invasive sinusitis	Cure	Liposomal amphotericin B (3 mg/kg) 2 weeks followed by voriconazole (400 mg) 3 months [159]	C	III	Insufficient evidence
Allergic bronchopulmonary mycosis	Reduce symptoms	Steroids [12,151,161,162]	B	III	Descriptive case studies
	Reduce symptoms	Add itraconazole (several doses) [160,163]	D	III	Expert opinion

QoE, quality of evidence; SoR, strength of recommendation.
[a]The population to whom the recommendations are meant to apply is any patient suffering from phaeohyphomycosis.
[b]Dosage recommendation for combination antifungal therapy is the conventional dosing.

Recommendations by Clinical Entities

Localized cutaneous infection and subcutaneous nodules

One of the common manifestations of dematiaceous fungi is superficial localized cutaneous and subcutaneous disease. Most superficial infections are secondary to trauma. Lesions typically appear as isolated cystic or papular lesions on exposed areas of the body, such as limbs and hands. *Alternaria* spp. are the most common aetiological agent and others include species of *Exophiala* spp. and *Phialophora*. Clinical presentation is usually indolent, with a gradually enlarging mass. Generally immunocompromised patients are at increased risk of subsequent dissemination. On histopathological examination the phaeohyphomycotic cyst presents as a single dermal lesion with minimal changes in the epidermis and granulomatous inflammation with abundant giant cells. Fungal elements such as yeast-like structures and septate hyphae can be found in the specimen. For subcutaneous nodules in particular, surgery alone has been effective (recommendation AII) [12,26–32]. Cryotherapy, laser, heat and photodynamic therapy have also been used successfully in many cases (recommendation BIII) [33–37]. Oral antifungals, mainly azoles, have been widely used as co-adjunctive therapies particularly in immunocompromised patients and to prevent dissemination (recommendation BIII) [12]. Multiple subcutaneous nodules have to be treated with systemic antifungal agents. Itraconazole or voriconazole at 400 mg are recommended (recommendation AIII) [38–44]. Other antifungal agents have been used in some cases (recommendation CIII, Table 4) [12,41,45–58].

Eumycotic mycetoma

Mycetomas are localized infections that involve cutaneous and subcutaneous tissue, fascia and bone. Lesions consist of abscesses, granulomata and draining sinuses from which granules may be recovered. They may be caused by different fungi, which produce granules of different colours, such as *Acremonium* spp. (white), *Aspergillus nidulans* (white), *Exophiala jeanselmei* (black), *Leptosphaeria senegalensis* (black), *Madurella grisea* (black), *Madurella mycetomatis* (black), *Neotestudina rosatii* (white) and *Pyrenochaeta romeroi* (black). Mycetoma is difficult to cure and therapy includes amputation of the affected limb or large surgical excision of the affected tissue to reduce the disease burden. However, excision alone is rarely sufficient for a complete cure. This condition always requires surgery and prolonged systemic antifungal therapy (recommendation AII) [59–64]. Historically, the majority of cases reported used ketoconazole or itraconazole. Itraconazole appears to have consistent clinical activity (recommendation AII), and ketoconazole should be avoided because of side effects (recommendation DIII). Also, the newer triazoles (voriconazole and posaconazole; recommendation AIII) and combination therapy with terbinafine or flucytosine have been used successfully (recommendation BIII) [65–69].

Chromoblastomycosis

This is a chronic subcutaneous infection by dematiaceous fungi characterized by the presence of muriform cells or sclerotic bodies (medlar bodies) in tissue sections or wet preparations of pus or scrapings. Muriform cells are thick-walled, spherical, dark brown cells, which swell and often develop intersecting septa in various planes. The most commonly involved fungi are *Cladophialophora carrionii*, *Fonsecaea compacta*, *Fonsecaea pedrosoi* and *Phialophora verrucosa*. These causative agents of chromoblastomycosis are rarely recovered from nature but are selectively enriched by the human host [70]. The infection is difficult to cure, and relapses are common, possibly due to resistance development during therapy [71–76]. Overall, several studies suggest that standard of therapy should include itraconazole plus surgery (recommendation AII) [72–74,76]. In a few cases of chromoblastomycosis terbinafine monotherapy and surgery have been applied successfully (recommendation BIII) [72,75,77,78]. In addition, laser, heat and potassium iodide therapies have also been used in the past with successful outcome (recommendation BIII) [75,79–81]. Recommendations for refractory cases are combination antifungal therapy including cryotherapy or surgery when possible (recommendation BIII) [72,74,75,82–84]. Based on experimental and *in vitro* studies the new triazole drug posaconazole is promising and could be useful when other therapy has failed (recommendation BIII) [85–88].

Keratitis

Keratitis due to dematiaceous fungi is mainly reported from India where trauma accounts for up to 20% of cases [89–91]. The majority of patients can be treated with topical agents, the most commonly used are 5% natamycin and topical amphotericin B (0.15–0.3%) with or without topical azoles (1%) for at least 4 weeks to several months (recommendation AII) [89,90,92–94]. Topical azoles alone especially itraconazole and voriconazole (1%) can also be used (recommendation BIII) [95–97]. Severe and refractory cases require administration of oral azoles and usually surgery including penetrating and lamellar keratoplasty (recommendation BIII) [89,91–93]. An intracorneal injection of voriconazole (1%) as salvage therapy has been efficient in patients not responding to topical and systemic therapy in some cases (recommendation CIII) [96,98].

Pulmonary infections

These are potentially life threatening and are mainly seen in immunocompromised patients or those with underlying lung disease although cases in immunocompetent patients have been reported [99–101]. A wide variety of species can be involved and clinical manifestations include pneumonia, pulmonary nodules and endobronchial lesions. Therapy consists of intravenous liposomal amphotericin B or mould-active azoles except ketoconazole for a prolonged period (recommendation BIII). However, mortality rates are high in immunocompromised patients if underlying host defence defects are not resolved [12,102–107]. Solitary pulmonary nodule in immunocompetent patients can be treated with surgery (recommendation BIII) [12,99,108].

Cerebral infection

Cerebral abscess due to dematiaceous fungi is rare but frequently fatal and a surprisingly high proportion of these infections occurs in apparently immunocompetent individuals [109–116]. These infections are spread haematogenously, probably from an initial, presumably subclinical pulmonary focus, although spread from the sinus or following surgery may also occur. The neurotropic fungi are often geographically restricted, such as *Rhinocladiella mackenziei* occurring in the Middle East and *Cladophialophora bantiana* mainly in India. Although most infections with *Exophiala dermatitidis* are reported from East Asia the fungus is encountered worldwide. Overall, the therapeutic studies suggest that complete excision of brain abscesses has better outcome than only aspiration or partial excision (recommendation AII) [109,112,117–120]. Even with antifungal therapy outcome is poor; however, single cases suggest that voriconazole and posaconazole may provide clinical improvement and voriconazole penetrates into brain tissue most effectively (recommendation CII) [121–128]. Amphotericin B therapy generally has a poor outcome (recommendation DIII) [122–124,129]. Combination therapy including a triazole plus an echinocandin plus flucytosine, which also has *in vitro* activity against many of the black moulds and achieves good brain penetration, could be the first-line therapy when surgery is not possible (recommendation BIII) [12,116,130].

Other localized deep infections

These comprise mainly bone and joint infections and peritonitis. Recommendations can be found in Table 4 [12,131–137].

Disseminated infection

This is uncommon and reported mainly in the immunocompromised population [138]. Occasionally *Exophiala asiatica* causes dissemination in patients without known immunodeficiency or risk factors and it was recently reported from China [139,140]. There are at present no antifungal regimens associated with improved survival in disseminated infection, including multiple combination therapies (recommendation CIII) [138,141–147]. Combination antifungal therapy with adjunctive treatments has been effective in some cases of infections with hyaline fungi and multi-resistant *Scedosporium* spp. (recommendation BIII) [148–150].

Allergic fungal sinusitis

This entity is a hypersensitivity reaction, especially in immunocompetent, often atopic patients, and is caused by many species of dematiaceous fungi. The main black fungi involved are *Bipolaris*, *Curvularia*, *Exserohilum* and *Alternaria* species. Diagnosis depends on a histopathological demonstration of allergic mucin with visible fungal elements. Therapy consists of systemic steroids combined with surgical removal of the mucin (recommendation AII) [151–154]. The role of antifungal therapy, mostly azoles, is still under debate but may have a steroid-sparing effect (recommendation CIII) [152,153,155]. Recent reports indicate that oral triazole therapy can reduce symptoms of refractory sinusitis (recommendation BIII) [156–158]. In many instances the dematiaceous fungi can be the aetiological agents of sinus fungus balls. Surgical resection of fungus balls is generally sufficient (recommendation AII) unless local tissue invasion of the surrounding mucosa is demonstrated. Additional systemic antifungal drugs are indicated when this occurs (recommendation CIII) [159].

Allergic bronchopulmonary mycosis

This mycosis caused by fungi other than *Aspergillus* is a rare disease with <200 reported cases worldwide [160]. The two most commonly implicated dematiaceous fungi are *Bipolaris* and *Curvularia*. Analogous to allergic bronchopulmonary mycosis due to *Aspergillus*, the treatment of allergic bronchopulmonary mycosis consists of systemic steroids (recommendation BIII) [12,151,161,162]. Treatment with azoles is not yet clearly established and therefore, not recommended (recommendation DIII) [160,163].

Black Fungal Species with Clinical Relevance

During the last few decades the list of dematiaceous fungi implicated in human infections has continued to evolve and will further expand in line with the increase in the numbers of susceptible patients and the employment of better diagnostic tools. The important black fungi, their clinical manifestations, risk factors for infection, diagnosis and treatment are discussed along with their current taxonomical nomenclature.

Alternaria

The genus *Alternaria* is a plant pathogen and is commonly isolated from soil, air and plants [164–166]. The majority of cutaneous and subcutaneous infections are by *Alternaria alternata* followed by *Alternaria infectoria*, *Alternaria tenuissima*, *Alternaria alternatum* and *Alternaria tenuis* [55,167].

Clinical manifestations. Clinical manifestations of *Alternaria* infections are usually cutaneous or subcutaneous lesions mainly in immunosuppressed individuals [41,52,55,167]. To a lesser extent immunocompetent subjects can be affected following traumatic inoculation with plant debris and/or soil [168–171]. In cutaneous alternariosis, skin and soft tissue of the dorsal part of the hands and feet, fingers, elbows, knees and pretibial areas are the most commonly affected [55]. Most cases of subcutaneous alternariosis present with erythema, desquamation of skin, crusted ulcers, erythematous macules, yellow papules or violaceous nodules. Rarely sinusitis, keratitis and allergic bronchopulmonary mycosis have been reported, and disseminated infections occur with painless papulo-nodular lesions or cutaneous nodules. Cerebral infections due to *Alternaria* species are very rare [55,160,172]. The major predisposing factor is organ transplantation, reported in 40% of cases [39,42,55,167,173]. Bone marrow recipients are particularly at risk of sinusitis, whereas lung transplant recipients have a risk of cerebral infection [55,174]. In cutaneous/subcutaneous diseases Cushing syndrome is a major risk factor [175,176]. Other risk factors are long-term corticosteroid therapy, surgery, diabetes, human immunodeficiency virus infection, tuberculosis, neutropenia and haematological malignancies [29,31,43,47,177,178].

Diagnosis. Specific diagnosis is based on the microscopic detection of yellowish-brown hyphae with or without budding cells in tissue biopsies, aspirated pus, surgical drainage or skin scrapings. Culture and microscopic examination are mandatory for the correct identification of *Alternaria* spp. Amplification of DNA targets can be required for identification of uncommon *Alternaria* spp. [164,179].

Antifungal susceptibility and treatment. Cutaneous alternariosis usually requires the combination of wide excisional surgery, prolonged antifungal therapy, and reduction of immunosuppression [39,180]. In the case of well-delimited lesions, excision alone can lead to a total resolution of the disease, but antifungal therapy is required to avoid relapse. Itraconazole, voriconazole, posaconazole and amphotericin B constitute the cornerstones of the antifungal management of cutaneous and subcutaneous alternariosis based on clinical data available [38,55,56,167,181]. Also, a solitary case report on the successful use of intravenous caspofungin for the treatment of cutaneous alternariosis has been described [39]. As clinical trials are lacking, the optimal treatment strategy for patients with deep-seated *Alternaria* infections remains unclear [44,176]. Combination antifungal therapy can be recommended in disseminated cases [159,177,182]. *In vitro* susceptibility data suggest that the susceptibility of *Alternaria* species to antifungal agents appears to be species dependent (Table 2) [38]. Most of the species are susceptible to amphotericin B, itraconazole, voriconazole and posaconazole, and with high MIC values of echinocandins, fluconazole and flucytosine. Terbinafine also has been used successfully in the treatment of cutaneous alternariosis [31,46,173]. The role of echinocandins as part of combination therapy for alternariosis remains to be clarified.

Acrophialophora

The genus *Acrophialophora* comprises three species but only *Acrophialophora fusispora* is of clinical interest. *Acrophialophora fusispora* is a thermotolerant fungus with a wide distribution in tropical and temperate regions [164].

Clinical manifestations. Only five cases of phaeohyphomycosis have been reported so far, which include two cases of brain abscess attributed to *Acrophialophora fusispora* and three other cases involving the lung in two and cornea in one case [183–185].

Diagnosis. This fungus is similar to *Paecilomyces* spp. and sometimes misidentified as *Scedosporium prolificans* [186] but can be differentiated by the presence of pigmented, warted conidiophores, basally inflated verticillate phialides and pigmented fusiform conidia ornamented in spiral bands.

Antifungal susceptibility and treatment. Due to the small number of cases reported, the optimal treatment and management of these infections are unknown. The isolates tested have shown variable susceptibility to itraconazole, voriconazole, posaconazole, amphotericin B and resistance to echinocandins. Response *in vivo* has been unpredictable [183–185].

Aureobasidium

Aureobasidium is a genus of black yeasts that ubiquitously colonize smooth surfaces of plant leaves, glass and rocks, and may contaminate metal, glassware and tubing systems in the hospital [187]. These fungi are commonly found as contaminants in the clinical laboratory. Clinically significant species are *Aureobasidium pullulans*, *Aureobasidium proteae* and *Aureobasidium mansoni*, all of which are associated with cerebral phaeohyphomycosis [164,188].

Clinical manifestations. *Aureobasidium pullulans* has an affinity for synthetic materials and surgically implanted silastic devices, as the fungus has been isolated from indwelling peritoneal dialysis catheters and central venous lines [189–193]. In severely compromised patients deep infections are encountered, and the fungus has been isolated from blood, bronchoalveolar lavage, lymph nodes, splenic abscess or cerebrospinal fluid [187,194–203]. Infections are caused mostly by traumatic inoculation of the skin or eye, and intrathecal administration of cytotoxic drugs [204–210].

Diagnosis. Black yeasts are observed by microscopy. Classification of this fungus can be done easily by conventional methods and also by DNA sequencing.

Susceptibility testing and treatment. No standard treatment exists for *Aureobasidium* infections but amphotericin B is recommended because it has been successfully used to treat systemic infection, meningitis and peritonitis [190–192]. However, two cases of fungaemia reported to have amphotericin B treatment failure are on record [187,197]. Other alternative treatment options which are reported to be effective in localized infections could be fluconazole and flucytosine [192,199]. *In vitro* studies revealed that this organism showed variable degrees of susceptibility to commonly used antifungals (Table 2) [211]. Apart from amphotericin B in invasive cases, voriconazole could be added concomitantly because it completely cured a chronic meningitis case caused by *Aureobasidium proteae* [188].

Bipolaris

Bipolaris spp. are ubiquitous in nature and found in soil and decaying matter [212]. The commonest species in human infections are *Bipolaris australiensis*, *Bipolaris hawaiiensis* and *Bipolaris spicifera* [12,213]; however, these three species have recently been transferred to *Curvularia* [214]. *Bipolaris* spp. previously classified as *Drechslera* or *Helminthosporium* are emerging as important aetiological agents of phaeohyphomycosis in humans [164].

Clinical manifestations. *Bipolaris* spp. are associated with serious infections in immunocompetent and immunocompromised hosts, such as pansinusitis [215], endophthalmitis and orbital cellulitis [216,217], necrotizing pneumonia and allergic bronchopulmonary mycosis [160,162,218], peritonitis [219], ascending aorta endarteritis [220] and encephalitis [221,222]. Dissemination to the central nervous system via the nasal sinuses has been described [114,223–225]. Dissemination to other deep sites may occur in debilitated or compromised patients such as those having undergone either organ transplantation or other surgical procedures [226–230]. Superficial disease involving cutaneous, subcutaneous and corneal regions afflicts mainly immunocompetent patients [115,231–233].

Diagnosis. Diagnostic procedures of cutaneous and invasive infections are summarized in Table 3 and are similar for most black fungi. Molecular identification based on PCR and sequencing of the internal transcribed spacer (ITS) and D1/D2 regions of rDNA is recommended for accurate identification [234]. Direct detection of *Bipolaris* DNA by PCR has been reported [235,236]. As with all fungi in this class, the Fontana–Masson stain is helpful for diagnosis [237].

Antifungal susceptibility and therapy. Treatment involves a combination of surgical debridement and antifungal treatment, typically with amphotericin B or an azole [238–241]. With the exception of fluconazole and flucytosine, amphotericin B, itraconazole, posaconazole and voriconazole showed good activity against species of *Bipolaris* [213,242]. Surgical interventions such as removal of foreign objects, catheter tips or sinus debridement are usually necessary as adjunctive therapy, especially in localized infections and those associated with foreign implants [243,244].

Chaetomium

The genus *Chaetomium* is a large genus of saprobic ascomycetes including >180 species. *Chaetomium* species are generally found in warm, dry, cellulose-rich media, such as animal dung, straw, seeds, plant debris, bird feathers and many other substrates [245,246]. They are rarely implicated in human disease; the clinically significant species include *Chaetomium globosum*, followed by *Chaetomium strumarium*, *Chaetomium atrobrunneum*, *Chaetomium funicola* and *Chaetomium perlucidum* [247–255].

Clinical manifestations. The spectrum of mycoses caused by *Chaetomium* species includes onychomycosis, chromoblastomycosis and sinusitis in immunocompetent individuals [249,253], and empyema, pneumonia, and fatal disseminated cerebral disease in immunocompromised hosts and intravenous drug users [247,248,250–252,254,255]. The majority of reports have involved patients with haematological malignancies and/or immunosuppression secondary to bone marrow or solid organ transplantation [102,248,252,254,255].

Diagnosis. Diagnostic procedures are similar to those previously described. The main characteristic of *Chaetomium* species is the presence of hairs or setae covering the ascomata. They are differentiated by the size and shape of ascomata, the type

of setae they possess, and the size and shape of their brownish ascospores [143,164,256].

Susceptibility testing and treatment. Most patients with reported invasive disease received either conventional or lipid-based amphotericin B empirically during their treatment course [247–255]. *Chaetomium perlucidum* isolates have low MICs of amphotericin B, itraconazole, voriconazole and posaconazole, but high MICs of caspofungin. Amphotericin B had varied susceptibility profiles while itraconazole and voriconazole exhibited good activity against *Chaetomium globosum* [143,257,258].

Cladophialophora

The genus includes neurotropic fungi such as *Cladophialophora bantiana* and *Cladophialophora modesta* causing mainly brain infections [259]. While *Cladophialophora bantiana* is reported worldwide, a general preference for warm climates with high humidity is apparent [260]. *Cladophialophora carrionii* is prevalent in dry countries and desert zones, and other rarely reported species *Cladophialophora devriesii* and *Cladophialophora arxii* cause disseminated disease, while *Cladophialophora boppii*, *Cladophialophora emmonsii* and *Cladophialophora saturnica* cause mild cutaneous infections [164,245,261–263].

Clinical manifestations. Human infections, due to *Cladophialophora* range from mild cutaneous lesions to fatal cerebral infection. In a review in 2004, *Cladophialophora bantiana* was the most common species responsible for cerebral disease and accounted for 48 of 101 cases of cerebral phaeohyphomycosis [127]. Single lesions were present in the majority of cases of brain abscess. Also, no evidence of dissemination outside the central nervous system has been observed. Patients with central nervous system phaeohyphomycosis are often immunocompetent and have no known underlying diseases [123,124,264,265]. These species also cause superficial and subcutaneous diseases. Most of the aetiological agents produce only localized disease restricted to skin and subcutaneous tissue. Chromoblastomycosis due to *Cladophialophora* is mainly caused by *Cladophialophora carrionii* [12,266]. Risk factors or underlying diseases associated with infection due to *Cladophialophora* are organ transplantation, diabetes, systemic lupus erythematosus, pulmonary tuberculosis, primary immunodeficiency of unknown origin, recurrent cytomegalovirus viraemia, pneumonitis, neutropenia and nephrectomy [105,126,128,267,268].

Diagnosis. Cladophialophora is a genus related to black yeast-like fungi but in routine cultures it grows strictly monomorphically as a mould with long, delicate, branching chains of hydrophobic conidia and lacking yeast cells [164]. In cerebral phaeohyphomycosis and other infections a KOH preparation of pus from the lesion may show lightly pigmented yeast-like forms or more often short chains of spores and hyphae. Histopathology is essential for confirmation of subcutaneous infections. Culture is recommended and for species identification, sequencing of ITS regions of rDNA is most appropriate [245]. Although there are no specific clinical or radiological features for the diagnosis of cerebral phaeohyphomycosis, a computed tomography scan of the cranium often reveals unilateral well-circumscribed single or multiple mass lesions localized within the cerebral cortex [117,260,269]. Purulent meningitis, with or without brain abscess, may also be seen [265].

Susceptibility testing and treatment. When possible, complete surgical removal of the encapsulated abscess combined with antifungal therapy is recommended, but so far success in treating cerebral phaeohyphomycosis due to *Cladophialophora* is limited regardless of the immune status of the patient (>70% mortality) [12,127]. Adding antifungal monotherapy or combination therapy might improve survival [270,271]. When there are multiple cerebral abscesses and surgery is not practicable, combination therapy with amphotericin B, flucytosine, caspofungin and terbinafine, or an extended spectrum triazole, has been proposed as a regimen [12,128]. Itraconazole and posaconazole had the best activity *in vitro*, while voriconazole has better central nervous system penetration and better bioavailability [272–275]. Echinocandins and amphotericin B have shown also activity *in vitro* [87,123]. The newer drug isavuconazole reveals low MICs for *Cladophialophora carrionii*. In murine models of *Cladophialophora bantiana* infections, the combination of the three drugs flucytosine, micafungin and posaconazole was the only therapy that prolonged survival time [276].

Curvularia

The genus *Curvularia* comprises nearly 100 species. Most are saprobes in soil, on dead plant material or plant pathogens mainly infecting grasses [212]. The clinically relevant species are *Curvularia aeria*, *Curvularia geniculata*/*Curvularia senegalensis* and *Curvularia lunata*; less frequently implicated species are *Curvularia brachyspora*, *Curvularia clavata*, *Curvularia inaequalis*, *Curvularia pallescens* and *Curvularia verruculosa* [164,212,277].

Clinical manifestations. More commonly, species of *Curvularia* cause allergic sinusitis [278,279], but they can disseminate to the brain even in immunocompetent patients [113]. Other manifestations include subcutaneous infections following traumatic implantation [280,281], onychomycosis [282], keratitis

[283,284], endophthalmitis [285,286], mycetoma [287], invasive sinusitis [288,289], peritonitis [290,291], invasive cerebral infections [292,293], endocarditis [294] and disseminated infections [295–297].

Diagnosis. Colonies of *Curvularia* are blackish, expanding and hairy; the conidiophores are erect and the conidia are ellipsoidal, brown, usually curved and generally with three or four septa. Recent studies have demonstrated that molecular confirmation of species is usually required by sequencing the ITS regions of rDNA and the glyceraldehyde-3-phosphate dehydrogenase gene [164,212,277,298].

Antifungal susceptibility and treatment. The *in vitro* antifungal susceptibility of different clinical isolates of *Curvularia* has been determined in several studies (Table 2) [113,277,284,299]. In general, amphotericin B showed potent *in vitro* activity and triazoles and echinocandins had less *in vitro* activity. Clinical experience with the treatment of *Curvularia* infections is scarce and mainly based on a few case reports where amphotericin B and azoles have been the most frequently used drugs in monotherapy or combination therapy with variable results (Table 4) [110,279,280,286,293,295,297,300,301].

Exophiala

The genus *Exophiala* comprises the most clinically relevant black yeasts, often isolated from environmental substrates, including soil, wood and other plant material [164,298]. The species commonly involved in human infections are *Exophiala dermatitidis*, *Exophiala xenobiotica* and *Exophiala oligosperma*, followed by *Exophiala lecaniicorni*, *Exophiala phaeomuriformis*, *Exophiala jeanselmei*, *Exophiala bergeri*, *Exophiala mesophila*, *Exophiala spinifera*, *Exophiala xenobiotica* and *Exophiala oligosperma* [302–304]. Although distributed worldwide, *Exophiala dermatitidis*, a neurotropic agent, is reported mainly from Asia, whereas *Exophiala spinifera* is reported from various parts of the world as the causative agent of phaeohyphomycosis and chromoblastomycosis [259,264,304,305].

Clinical manifestations. Most of the infections caused by *Exophiala* are cutaneous and subcutaneous [306–308] whereas fatal systemic infections can occur, including rare cerebral infections [139,140,164,298,309]. *Exophiala* species produce pustules or verrucous plaques in the skin or subcutaneous tissue. These lesions can enlarge and impair mobility but rarely disseminate to the internal organs [35,305,310,311]. Chromoblastomycosis or eumycotic mycetoma is rarely caused by this genus [60,74]. Besides subcutaneous infections, this species can cause pulmonary colonization of the lungs in patients with cystic fibrosis [312] and brain abscess and disseminated, eventually fatal, disease in patients without recognized underlying diseases [304,313,314]. Disseminated disease generally affects elderly and immunosuppressed patients such as individuals with AIDS or those on prolonged use of immunosuppressive drugs, chemotherapy treatment or systemic corticosteroids [267,315–317]. Additionally, intestinal colonization by the fungus has been reported [318,319].

Diagnosis. The histological characteristics of *Exophiala* for a cutaneous deep fungal infection include epidermal hyperkeratosis, hyperplasia, acanthosis, pseudoepitheliomatous and intraepidermal pustule formation. Pigmented fungal elements can be detected most frequently in areas of inflammation, within or adjoining to multinucleate giant cells. Diagnostic techniques are shown in Table 3. Molecular methods of detection and classification have also been reported [303,320].

Susceptibility testing and treatment. Apart from surgical resection, which in some cases is curative, treatment requires antifungal agents such as itraconazole or terbinafine alone or in combination [267,321,322]. As an alternative to the prolonged, expensive pharmacological treatments, some authors propose Mohs micrographic surgery as an effective therapeutic option with the important benefit of minimal tissue loss [26]. Other antifungal agents have also been used, and brain and disseminated infections are infections that are difficult to treat [141,323–333]. *In vitro* susceptibility studies demonstrated variable activity of posaconazole, itraconazole, voriconazole and amphotericin B [334–338]. In animal models of disseminated infection by *Exophiala dermatitidis* posaconazole was more effective than amphotericin B and itraconazole [339].

Exserohilum

The anamorphic genus *Exserohilum* comprises around 35 species, which are common saprobic fungi on plant debris [164]. Three species *Exserohilum rostratum*, *Exserohilum longirostratum* and *Exserohilum mcginnisii* have been reported in the past as opportunistic pathogens for humans. However, several molecular studies have demonstrated that they belong to a single species, *Exserohilum rostratum* being the accepted one [340].

Clinical manifestations. Exserohilum is a rare clinically significant pathogen causing invasive infections mainly in immunocompromised patients [222,341–356], keratitis [357–361] or localized infections in immunocompetent individuals usually after accidental inoculation [362–364]. The risk factors for *Exserohilum* infections include aplastic anaemia [345,365] and haematopoietic stem cell transplantation [341,356].

Recently, *Exserohilum rostratum* has been implicated in a fungal meningitis outbreak that was traced back to contami-

nated steroid injections [366–369]. As of 23 October 2013 there were 718 cases of fungal meningitis, stroke due to presumed fungal meningitis, **and/or** spinal or paraspinal infections; 33 cases of peripheral joint infections and 64 deaths (http://www.cdc.gov/hai/outbreaks/meningitis-map-large.html, accessed 9 December 2013).

Diagnosis. Exserohilum species are mainly identified by the conidial morphology when growing in its natural substratum [164]. *In vitro* identification is more difficult, the conidia tending to be smaller and the isolates often losing the ability to sporulate. At the generic level, the most useful microscopic characteristics are the conidial shape with the presence of a protruding scar or hilum. Sequencing of the ITS region of rDNA for molecular identification has been used. In the context of the above mentioned outbreak, species-specific real-time PCR assays were developed for rapid molecular diagnosis [370,371].

Antifungal susceptibility and treatment. There are limited data on the treatment of infections due to *Exserohilum*. Experience from the recent meningitis outbreak [368] and case reviews of sinusitis and cutaneous infections by these fungi reveal successful outcomes with amphotericin B [341,346,372] and more recently with itraconazole and voriconazole [347,353]. Based on historical data, amphotericin B might be the first choice in severe infections [340,373,374] but an expert group coordinated by the US Centers for Disease Control advised voriconazole because of its excellent pharmacokinetics/pharmacodynamics in cerebral infections [366,375]. However, clinical failures with voriconazole have been reported [376]. *In vitro* studies showed itraconazole, posaconazole and amphotericin B to be the most potent followed by voriconazole [340,375]. Animal models of *Exserohilum* central nervous system infection have not yet been developed for therapeutic and prophylactic studies [377].

Fonsecaea

Fonsecaea is one of the classical genera of fungi causing human chromoblastomycosis. A small group of three closely related species include *Fonsecaea pedrosoi*, *Fonsecaea monophora* and *Fonsecaea nubica* [378]. *Fonsecaea* particularly occurs in tropical climate zones, especially South America and Japan [379–381]. Most cases outside endemic zones are assumed to have been imported. However, cases that were likely to be autochthonous were reported even in northern Europe [382]. Other *Fonsecaea* species are saprobes in the environment, and occasionally cause infections in animals [383].

Clinical manifestations. The classical presentation of chromoblastomycosis caused by *Fonsecaea* is similar to that described previously above [74]. The disease is probably acquired by traumatic inoculation of plant debris and possibly hydrocarbon-rich plant material, such as coconut shells, which are preferentially infested by *Fonsecaea* species [384]. *Fonsecaea* infections other than chromoblastomycosis are rare and mainly concern brain infections by *Fonsecaea monophora* [385–387]. The portal of entry of these infections is unknown but dissemination from a pulmonary focus is likely.

Diagnosis. Fonsecaea species are recognized by poorly differentiated conidiophores apically producing short, branched chains of conidia [74,298,370]. For species distinction, sequencing of rDNA ITS regions is necessary [378,386]. Genus-specific PCR for detection of *Fonsecaea* species has been applied [71,388]. Detection of 1,3-β-D-glucan was used to diagnose and monitor therapy against cerebral phaeohyphomycosis by *Fonsecaea monophora* in a transplant recipient [125].

Susceptibility testing and treatment. Therapy for chromoblastomycosis has already been commented on (Table 4). Surgery plus antifungal therapy is the standard of therapy. In addition, combination therapy with itraconazole plus terbinafine or flucytosine has been successfully used in severe disease [72,83]. *In vitro* susceptibility data of these species revealed lowest MICs for posaconazole followed by itraconazole, voriconazole, terbinafine, amphotericin B and caspofungin [378]. A refractory case of chromoblastomycosis caused by *Fonsecaea monophora* failed treatment with itraconazole and terbinafine. Photodynamic therapy and combination therapy with voriconazole plus terbinafine led to improvement of the lesions [37].

Hortaea werneckii

The melanized, polymorphic and yeast-like fungus *Hortaea werneckii*, previously known as *Exophiala werneckii* or *Cladosporium werneckii*, is the black yeast responsible for tinea nigra. *Hortaea werneckii* is best known from tropical climates and lives in saline environments such as seawater and natural or man-made saltpans [389,390]. Most cases of infection originate from rural areas in tropical and humid regions characterized by abundant vegetation and had close contact with plants and grasses with substrata of high salinity.

Clinical manifestations. Tinea nigra is a superficial mycosis of one or both hands and sometime affects the sole. The disease has no preference for age or sex, with cases equally occurring

in adults and children, and males and females [391–393]. Most cases are unilateral but bilateral infections can be observed [394], probably resulting from autoinoculation. The first human case not involving the skin was reported from an immunocompromised patient with endophthalmitis following cataract surgery [395]. *Hortaea werneckii* has been recovered from blood and splenic abscess of two patients with acute myelomonocytic leukaemia [396].

Diagnosis. Conidia of *Hortaea werneckii* appear as pigmented yeast cells with a dark central septum, the outer wall later becoming thick-walled and heavily pigmented. Conidia finally germinate with hyphae resulting in yeast-like colonies that gradually change into filaments. Molecular identification of *Hortaea werneckii* has been reported [388,390,397].

Susceptibility testing and treatment. The treatment of tinea nigra is simple and effective. Most cases resolve with only keratinolytic agents like urea, salicylic acid and Whitfield ointment, applied once or twice a day [391]. *In vitro* antifungal susceptibility testing showed variable MICs of itraconazole, voriconazole, posaconazole, isavuconazole and amphotericin B (Meis J.F., unpublished data). There are reports available of high MICs of this fungus to amphotericin B, fluconazole, flucytosine and caspofungin [396].

Neoscytalidium dimidiatum

Neoscytalidium dimidiatum (formerly *Scytalidium dimidiatum*) is a known plant pathogen in tropical areas that can also be found in soil and wood and can infect humans [398,399]. *Scytalidium hyalinum*, previously considered a non-pigmented species similar to *Neoscytalidium dimidiatum* is in fact only a mutant variant [400]. The fungus is endemic in tropical and subtropical areas of South America, the Caribbean, Asia and Africa but has been increasingly reported from other non-endemic regions owing to immigration and travel [401]. It was reported that in Jamaica up to 40% of the population suffer from this infection [402].

Clinical manifestations. Neoscytalidium dimidiatum causes mainly onychomycosis and tinea pedis, and in endemic areas may rival dermatophytes as the leading cause of superficial fungal infection. This fungus most often causes chronic superficial infections of the skin and nails, clinically resembling dermatophytosis [399,403]. Rarely mycetoma, subcutaneous lesions, cerebral infections, fungaemia and other deep-seated infections mainly affecting immunocompromised patients [399] have also been reported. Invasive infections have been seen mostly in immunosuppressed patients [399,401,404]. The underlying conditions reported are similar to those of other opportunistic invasive mycoses.

Diagnosis. Traditionally, the fungus has been characterized by producing dark arthroconidia when grown in culture whereas in older cultures some isolates developed a picnidial form called *Nattrassia mangiferae* (formerly *Hendersonula toruloidea*) [405]. However, molecular studies have demonstrated that they are two different species, and *Nattrassia mangiferae* is now accommodated in a different genus with non-pathogenic species [406]. *Neoscytalidium dimidiatum* is distinguished from dermatophytes by its characteristic sinuous, irregular hyphal appearance and by brown pigmentation on direct microscopy of cutaneous specimens, its fast-growing colonies, and its sensitivity to cycloheximide [401]. On microscopy of cultures, characteristic pigmented hyphae and long chains of barrel-shaped arthroconidia are seen. In deeper tissue the fungus has been described as producing yeast-like cells with short hyphae [404].

Susceptibility testing and treatment. Antifungal therapy with amphotericin B, voriconazole, posaconazole or ketoconazole has been used with variable results [399–404,407,408]. *In vitro* studies have shown that amphotericin B was the most active drug followed by terbinafine, whereas voriconazole and posaconazole showed less activity [400,409]. The best treatment of systemic infections by this fungus is unknown; however, in a murine model, amphotericin B, voriconazole and posaconazole had efficacy in the treatment of a disseminated infection [410].

Ochroconis

Ochroconis encompasses several species including *Ochroconis constricta*, *Ochroconis gallopava*, recently transferred to the new genus *Verruconis*, and *Ochroconis humicola* [136,144,411]. Members of the genus have been isolated worldwide from soil, thermal springs, decaying vegetation, in chicken litter and the effluents of thermal nuclear reactors [101,412–417]. Although the organism has a worldwide distribution, many cases of human infections have been described in the southeastern USA [418,419]. Its exact mode of transmission is unclear, but it is hypothesized that *Ochroconis* might be acquired from penetrating trauma or via inhalation of conidia [70,420,421]. Although *Ochroconis* spp. have traditionally been regarded as a cause of deep infections in birds and other animals there have been multiple reports implicating these fungi, particularly *Verruconis gallopava* and *Ochroconis constricta*, as pathogens in humans [104,144,422–427].

Clinical manifestations. The majority of these reports have been in two patient populations: those that have received transplants [415,423,424,426–431], and those with haematological malignancies undergoing chemotherapy [418,419,422,432]. Infections in these two groups presented as a combination of both pulmonary and extra-pulmonary disease, particularly involving the brain, spleen, skin and other organ sites. Although a number of patients with extra-pulmonary disease have survived [101,433], it is more frequently associated with poor clinical outcomes [418,422,424,426]. Other risk factors are HIV and chronic granulomatous disease [144,420,434]. The minority of cases of *Ochroconis* infections have been in immunocompetent patients [435,436].

Diagnosis. The colonies of *Ochroconis* species are brown-olive, and have a velvety texture. Microscopically, they are characterized by brown septate hyphae, unbranched conidiophores with apical denticles arranged sympodially, and club-shaped conidia with one to three transverse septa [164,411]. The paucity of *Ochroconis* infections in humans has two potential consequences. First, clinicians may fail to consider it in their differential diagnosis. Second, the microbiology laboratory may mistakenly dismiss the organism as a contaminant, rather than acknowledging it as a true pathogen [127,413,418]. Similar to other black fungi, sequencing of ITS and D1/D2 regions of rDNA can be used for molecular identification [234].

Susceptibility testing and treatment. Due to the high mortality rate reported in patients (estimated at 50%), proper recognition and treatment of *Ochroconis* infections are paramount [426,430]. Several studies suggest that posaconazole and itraconazole may be an optimal therapy for *Ochroconis* infection, with amphotericin B and voriconazole as valid alternatives. Flucytosine and fluconazole are the least effective drugs [423,427,430,434]. *Ochroconis gallopava* has low MICs for most antifungal drugs with terbinafine, posaconazole and voriconazole showing the best *in vitro* activity [434,437].

Phaeoacremonium

The genus *Phaeoacremonium* initially accommodated species with features similar to those seen in both *Acremonium* and *Phialophora* [406]. A recent morphological and molecular characterization of the genus using β-tubulin sequences [438] has more clearly defined the genus and provided differential features for clinically significant species. Human pathogens include *Phaeoacremonium parasiticum* (obsolete *Phialophora parasitica*), *Phaeoacremonium alvesii*, *Phaeoacremonium amstelodamense*, *Phaeoacremonium griseorubrum*, *Phaeoacremonium krajdenii*, *Phaeoacremonium rubrigenum*, *Phaeoacremonium inflatipes*, *Phaeoacremonium tardicrescens* and *Phaeoacremonium venezuelense* [30,438–440].

Clinical manifestations. Recently, *Phaeoacremonium* infections have been increasingly reported in humans including subcutaneous abscesses, cysts, or chronic or acute osteoarthritis and disseminated infection mostly in immunocompromised patients (solid organ transplantation and haematological diseases) [28–30,441–443]. Colonization of cracked skin on the extremities has also been described [438]. In the majority of cases, a preceding trauma leading to inoculation from the environment was reported [30,442,443]. In immunocompromised patients with disseminated infections, endocarditis, brain abscess and fungaemia have been reported [12,438,440].

Diagnosis. Infections by *Phaeoacremonium* are diagnosed by biopsy of the cysts. Direct examination reveals medium brown hyphae, which become pale brown to hyaline and verrucous in the aspirated pus, biopsy material or skin scrapings [30,164]. The phialides have a funnel-shaped collarette and show a wide variety of conidia with diverse forms, including ellipsoidal, obovate, cylindrical or allantoid (sausage-like) [438,439]. PCR amplifying ITS regions of rDNA followed by sequencing was shown to be able to detect and identify species of *Phaeoacremonium* [444].

Susceptibility testing and treatment. The most active drugs *in vitro* against *Phaeoacremonium parasiticum* isolates were voriconazole, posaconazole and itraconazole whereas reduced susceptibility to amphotericin B was reported [445,446]. When possible, complete surgical removal of the encapsulated abscess combined with antifungal therapy such as posaconazole and itraconazole is the recommended treatment [28–30]. However, antifungal therapy for infections caused by some of the species of *Phaeoacremonium* in immunocompromised hosts is at present unsatisfactory [438,440,441].

Phoma

Phoma species are ubiquitous saprobes on plant material found worldwide [164,447]. Of the more than 200 species of *Phoma* currently accepted, fewer than 10 species have occasionally been found in human infections [164,448].

Clinical manifestations. Phaeohyphomycosis caused by *Phoma* has been sporadically described in the literature. Most reported cases are subcutaneous [449–456] and ocular infections [457,458]. Systemic infection with *Phoma* spp. is generally seen in severely immunocompromised patients and generally has a poor outcome [459–461]. Often the aetiological agent is not identified to the species level. The risk factors

or underlying diseases associated with *Phoma* infections may include diabetes mellitus, corticosteroid therapy and cancer chemotherapy [450,456,459–461].

Diagnosis. Phoma species produce slow-growing, dark-grey-olive, or dark-brown colonies. The fungus produces ostiolated fruiting bodies known as pycnidia and numerous, small, asexual conidia. Pycnidia are black, globose, subglobose, or pyriform and either submerged or on the surface of agar. Conidia (pycnidiospores) are produced from the phialides that line the inner wall of pycnidia and are hyaline, one-celled, elliptical, rod shaped or curved [164,460]. A PCR assay for detecting *Phoma exigua* DNA in deparaffinized lung biopsy material has been developed [459].

Susceptibility testing and treatment. Excision of phaeomycotic cysts without antifungal treatment is usually curative. For the treatment of cutaneous lesions triazoles (itraconazole and voriconazole) [451,457] and amphotericin B [450] are recommended. *In vitro* susceptibility data on *Phoma* species is based on sporadic case reports with itraconazole and voriconazole MICs ranging from 0.25 to 8 mg/L and amphotericin B MICs from 0.5 to 1 mg/L [457,459].

Pyrenochaeta

Pyrenochaeta is a genus that comprises pycnidial coelomycetes that are widely distributed in the environment, being found in soil, on wood and on plant debris and also as plant pathogens [462]. The species implicated in human infections include *Pyrenochaeta keratinophila*, *Pyrenochaeta unguis-hominis*, *Pyrenochaeta romeroi* and *Pyrenochaeta mackinnonii* [463–468]. In a recent phylogenetic study based on the analysis of large subunit, ITS, small subunit, β-tubulin and chitin synthase 1 sequences, *Pyrenochaeta romeroi* and *Pyrenochaeta mackinnonii* were accommodated in the new genera *Medicopsis* and *Nigrograna* as *Medicopsis romeroi* and *Nigrograna mackinnonii*, respectively [469].

Clinical manifestations. Pyrenochaeta keratinophila and *Pyrenochaeta unguis-hominis* are rarely reported as agents of keratitis and onychomycosis, respectively [464,465]. *Pyrenochaeta romeroi* and *Pyrenochaeta mackinnonii* have a higher clinical relevance as agents of mycetoma and subcutaneous infections in tropical areas [462,466–472].

Diagnosis. Colonies grow fairly rapidly, and are flat, velvety or floccose and produce dark olive-grey aerial hyphae with an olivaceous-black reverse. Pycnidia are produced after 2–3 weeks and are submerged, ostiolate, olivaceous to black, spherical to pyriform, with thick walls, and often covered with erect, stiff, dark hyphae. Conidia are produced from ampulliform phialides lining the innermost pycnidial wall and oozing out of the ostiolum in slimy drops, and are hyaline, one-celled and ellipsoidal to bacilliform [164,473]. Sequencing of ITS and D1/D2 regions of rDNA was successfully used for molecular identification [234].

Susceptibility testing and treatment. No standard therapy is available for infection with *Pyrenochaeta* and little is known about the relation between MIC and clinical outcome in this disease. Itraconazole has so far been used in the treatment of cases with mycetoma due to *Pyrenochaeta romeroi* [182]. Ketoconazole, itraconazole and terbinafine appear active *in vitro* against *Pyrenochaeta romeroi*, although systemic ketoconazole would not be the first choice due to unfavourable side effects [473].

Rhinocladiella

The genus *Rhinocladiella* is a small, polyphyletic genus comprising a few clinically significant species, *Rhinocladiella aquaspersa*, *Rhinocladiella similis*, *Rhinocladiella basitona*, *Rhinocladiella mackenziei* and *Rhinocladiella obovoideum* [164,474]. *Rhinocladiella mackenziei* and *Rhinocladiella obovoideum* are the neurotropic fungi affecting only the central nervous system [122,474–476]. *Rhinocladiella mackenziei* has never been isolated from the environment so the natural niche of this organism remains unknown [477]. Most of cases are restricted to the Middle East, Persian Gulf, Somalia and Pakistan [118,120,130,478,479]. *Rhinocladiella aquaspersa* is an agent of chromoblastomycosis reported from South America, and *Rhinocladiella similis* and *Rhinocladiella basitona* are occasional opportunists [480–482].

Clinical manifestations. Most patients (60%) with *Rhinocladiella mackenziei* brain abscess presented with solitary brain abscesses and the remainder had multiple brain lesions [109]. Among all reported cases of *Rhinocladiella mackenziei* infections, 25% of patients had no reported underlying conditions [130,477,479]. Diabetes mellitus was the predominant risk factor seen in some patients followed by solid organ failure and/or transplant [120,130,477–484]. *Rhinocladiella mackenziei* infections are associated with poor outcome and nearly 100% mortality in both immunocompetent and immunocompromised individuals despite surgical intervention and antifungal therapy [12,122,130]. Nine cerebral cases due to *Rhinocladiella obovoideum*, of which five were fatal, despite administration of amphotericin B in three of them, have been reported so far [482].

Diagnosis. General diagnostic recommendations for cerebral infections are stated in previous sections. These species appear

in culture as olive dark colonies that on microscopic examination show erect, thick-walled and darkly pigmented conidiophores that give rise to conidia only at their distal portions [298,474]. Definitive identification of the species requires sequencing of ITS and or D1/D2 regions of the rDNA gene [118].

Susceptibility testing and treatment. There is no standard therapy for cerebral infections and surgical drainage as opposed to aspiration alone did not improve survival. Medical treatment mostly involved high-dose lipid amphotericin B, itraconazole and flucytosine, or a combination of these drugs [118,120,122,130,477–484]. *In vitro* antifungal susceptibility studies of the most common pathogenic species showed that this organism has high MICs to amphotericin B and echinocandins, and low MICs to itraconazole, posaconazole and voriconazole [130,478,485]. There are many reported fatal cases of cerebral abscess where patients failed to respond to antifungal therapy with amphotericin B [109,130,480]. A single case of successful treatment of *Rhinocladiella mackenziei* brain abscess was reported in which the patient showed improvement after switching from itraconazole to posaconazole [122]. The *in vitro* data are also consistent with animal studies of a murine model of *Rhinocladiella mackenziei* cerebral phaeohyphomycosis, where posaconazole was found to be superior to amphotericin B and itraconazole and reduced the brain fungal burden [121].

Veronaea

The genus *Veronaea*, defined by its type species *Veronaea botryosa*, is a small group containing several opportunistic species infecting vertebrates [164]. *Veronaea botryosa* is an environmental fungus but with a currently undiscovered ecological niche. The phylogenetically nearest neighbours of *Veronaea botryosa* are found in *Exophiala* species inhabiting water and causing opportunistic infections in waterborne animals [245].

Clinical manifestations. The clinical presentation of the infection is a cutaneous lesion or nodular subcutaneous infection, resembling that of chromoblastomycosis, with muriform cells in tissue but with a strong tendency to disseminate. The infection has been described in both immunocompetent patients [85,486–492], and those with debilitated immunity such as liver [40] and heart transplant recipients [493].

Diagnosis. Veronaea botryosa is readily recognizable by its microscopical morphology. Its large, erect conidiophores with sympodial, uni-septate conidia on flat scars give easy clues for identification in culture [164,298]. Molecular identification using sequencing of the ITS rDNA region is applicable [494].

Antifungal susceptibility and treatment. Published cases of cutaneous and subcutaneous infections show much variation in therapeutic regimens with effective treatment mostly involving itraconazole [40,489]. There were cases that failed to respond to treatment with terbinafine, itraconazole and amphotericin B, but some showed significant improvement with posaconazole [85,487,494]. Very few studies on the *in vitro* susceptibility of this pathogen have been reported; it demonstrates high MICs for most antifungal drugs (Table 2) with the exception of posaconazole and itraconazole [487,494].

Conclusion

Although previously reported as rare agents of infections the melanized fungi are now emerging as an important fungal disease in humans and animals. These infections have not been studied in clinical trials and so far the available therapeutic data are primarily based on sporadic case reports. Furthermore, the diagnosis depends on a high index of clinical suspicion along with accurate mycological findings. There are no standardized therapies for infections caused by dematiaceous fungi but voriconazole, posaconazole, itraconazole and in some cases amphotericin B demonstrate the most consistent *in vitro* activity against this group of fungi. Oral itraconazole had been considered the drug of choice for most situations, given the extensive clinical experience with this agent. However, voriconazole may have advantages for central nervous system infections because of its ability to achieve good cerebrospinal fluid levels, unlike itraconazole. Posaconazole is a broad-spectrum alternative that is well-tolerated, though backed by less clinical experience but with excellent salvage treatment results after failure of other antifungal agents. Amphotericin B has been useful in some cases. As a result of the large variability in the spectrum of dematiaceous fungi, it is important to obtain *in vitro* susceptibilities of the individual patient's fungal isolate although it has not been firmly established that results obtained from susceptibility testing translate into better clinical outcomes.

Transparency Declaration

AnC has no conflicts of interest to declare. JaM has received research grants from Astellas, Merck and MSD, is a consultant to Astellas, Basilea, Merck and MSD, received travel support from Astellas, and received lecture honoraria from Merck. JoG has no conflicts of interest to declare. SdH has no conflicts of interest to declare. SK has no conflicts of interest to declare.

MCA has received research grants from Astellas, Gilead, Merck/Schering and Pfizer, is a consultant to Merck, Gilead, Pfizer, received travel support from Astellas, Merck/Schering and Pfizer and received lecture honoraria from Astellas, Gilead, Merck/Schering, and Pfizer. SAA has received research grants from Pfizer, is a consultant to Pfizer, and received lecture honoraria from Merck, and Pfizer. MA has received research grants from Gilead, Merck and Pfizer, is a consultant to Gilead, Merck and Pfizer, has received travel support from Merck, Gilead, and Pfizer, and received lecture honoraria from Gilead, Merck, and Pfizer. TB has received royalties from Elsevier. MoC has no conflicts of interest to declare. JeG has received research grants from Basilea, BioMerieux, Astellas, Pfizer, Fundacion Mutua Madrilena, Fondo de Investigacion Sanitaria (FIS), and received lecture honoraria from Astellas, Pfizer, Gilead, MSD, and Hickma Pharma. ArC has no conflict of interest to declare. ED has received research grants from BioRad, Gilead and Pfizer, is a consultant to Astellas and Innothera, received travel support from Merck/Schering, Astellas and Gilead, and received lecture honoraria from Gilead and Merck/Schering. AvD has no conflict of interest to declare. TF is a consultant to Hutman AG. AHG has received research grants from Gilead and Merck Sharp & Dohme, is a consultant to Astellas, Gilead, Merck Sharp & Dohme and Schering-Plough, and received lecture honoraria from Astellas, Gilead, Merck Sharp & Dohme, Schering-Plough, and Zeneus/Cephalon. WH has received research grants from Pfizer, Astellas, Gilead and F2G, is a consultant to Pfizer, Astellas, Gilead and F2G, and received lecture honoraria from Astellas, Gilead, Merck/Schering, and Pfizer. EJ is a consultant to Astellas, Gilead, Merck/Schering and Pfizer, received travel support from Astellas, Merck/Schering and Pfizer, received payment for development of educational presentations from Astellas, Merck/Schering and Pfizer, and received lecture honoraria from Astellas, Gilead, Merck/Schering, and Pfizer. ML has no conflicts of interest to declare. KL has received research grants from Gilead, MSD and Pfizer, has given expert testimony for Merck/Schering and Pfizer, is a consultant to Gilead, Merck/Schering and Pfizer, received travel support from MSD, Pfizer and Gilead and received lecture honoraria from Gilead, Merck/Schering, and Pfizer. FL has received research grants from Gilead, received travel support from Gilead, MSD and Schering, and received lecture honoraria from Gilead. CLF has received research grants from Astellas, Gilead, Pfizer, Schering-Plough and MSD, is a consultant to Gilead, MSD, Pfizer and Schering-Plough, received payment for development of educational presentations from Pfizer, received travel support from Gilead, MSD, Pfizer, Astellas and Schering-Plough, and received lecture honoraria from Astellas, Gilead, Merck/Schering, and Pfizer. OL is a consultant to Astellas and Gilead, and received lecture honoraria from Astellas, Gilead, Merck/Schering, and Pfizer. JoM has received research grants from Gilead, Merck/Schering and Pfizer, and received lecture honoraria from Gilead, Pfizer, and Liofilchem. PM is a consultant to Astellas, Gilead, Merck/Schering and Pfizer, received payment for development of educational presentations from Merck, and received lecture honoraria from Astellas, Gilead, Merck/Schering, and Pfizer. LP is a board member of Gilead and Merck is a consultant to Gilead, Merck and Pfizer, and received lecture honoraria from Astellas, Gilead, Merck, and Pfizer. GP has received research grants from Pfizer, Gilead, AstraZeneca, Novartis, Astellas, GSK, is a consultant to MSD, received travel support from Gilead, Astellas and Pfizer and received lecture honoraria from MSD, and Astellas. MR has received payment for development of educational presentations from Pfizer, received royalties from Blackwell Publishing, received travel support from Astellas, is a consultant to Gilead and MSD, and received lecture honoraria from Astellas, and Pfizer. ER has received research grants from Enzon, Gilead, Pfizer and Schering, is a consultant to Astellas, Gilead, Merck, Pfizer and Schering, and received lecture honoraria from Astellas, Aventis, Cephalon, Gilead, Merck, Pfizer, Schering, and Wyeth. AS has received travel support from Merck, Gilead, Astellas, and Pfizer. AT has received research grants from Astellas and MSD, and received lecture honoraria from Astellas, Gilead, and MSD. AJU has received research grants from Astellas, Gilead, Merck/Schering and Pfizer, is a consultant to Astellas, Basilea, Gilead, Merck/Schering and Pfizer, received payment for development of educational presentations from Gilead, and received lecture honoraria from Astellas, Gilead, Merck/Schering, and Pfizer. PV has received research grants from Astellas, Gilead, Merck/Schering and Pfizer, is a consultant to Astellas, Gilead, Merck and Pfizer, received payment for development of educational presentations from Merck and Pfizer, and received lecture honoraria from Astellas, Gilead, Merck/Schering, and Pfizer. OAC is supported by the German Federal Ministry of Research and Education (BMBF 01KN1106), has received research grants from 3M, Actelion, Astellas, Basilea, Bayer, Celgene, Cubist, F2G, Genzyme, Gilead, GSK, Merck/MSD, Miltenyi, Optimer, Pfizer, Quintiles, and Viropharma, is a consultant to 3M, Astellas, Basilea, Cubist, F2G, Gilead, GSK, Merck/MSD, Optimer, Pfizer and Sanofi Pasteur, and received lecture honoraria from Astellas, Gilead, Merck/MSD, and Pfizer. MCE has received research grants from MSD, Astellas, Pfizer, Gilead and Ferrer, is a consultant to MSD, Astellas, Pfizer, Gilead and Ferrer, has provided expert testimony for MSD, Astellas, Pfizer, Gilead and Ferrer and received lecture honoraria from MSD, Astellas, Pfizer, Gilead, and Ferrer.

References

1. Ullmann AJ, Cornely OA, Donnelly JP *et al.* ESCMID guideline for the diagnosis and management of *Candida* diseases 2012: developing European guidelines in clinical microbiology and infectious diseases. *Clin Microbiol Infect* 2012; 18(suppl 7): 1–8.
2. Cornely OA, Bassetti M, Calandra T *et al.* ESCMID guideline for the diagnosis and management of *Candida* diseases 2012: non-neutropenic adult patients. *Clin Microbiol Infect* 2012; 18(suppl 7): 19–37.
3. Cuenca-Estrella M, Verweij PE, Arendrup MC *et al.* ESCMID guideline for the diagnosis and management of *Candida* diseases 2012: diagnostic procedures. *Clin Microbiol Infect* 2012; 18(suppl 7): 9–18.
4. Hope WW, Castagnola E, Groll AH *et al.* ESCMID guideline for the diagnosis and management of *Candida* diseases 2012: prevention and management of invasive infections in neonates and children caused by *Candida* spp. *Clin Microbiol Infect* 2012; 18(suppl 7): 38–52.
5. Lortholary O, Petrikkos G, Akova M *et al.* ESCMID guideline for the diagnosis and management of *Candida* diseases 2012: patients with HIV infection or AIDS. *Clin Microbiol Infect* 2012; 18(suppl 7): 68–77.
6. Ullmann AJ, Akova M, Herbrecht R *et al.* ESCMID guideline for the diagnosis and management of *Candida* diseases 2012: adults with haematological malignancies and after haematopoietic stem cell transplantation (HCT). *Clin Microbiol Infect* 2012; 18(suppl 7): 53–67.
7. Arendrup MC, Boekhout T, Akova M *et al.* ESCMID/ECMM Joint clinical guideline for the diagnosis and management of rare invasive yeast infections. *Clin Microbiol Infect* 2013; doi: 10.1111/1469-0691.12360 [Epub ahead of print].
8. Cornely OA, Arikan-Akdagli S, Dannaoui E *et al.* ESCMID and ECMM joint clinical guidelines for the diagnosis and management of mucormycosis. *Clin Microbiol Infect* 2013; in press.
9. Cuenca-Estrella M, Bassetti M, Lass-Florl C, Racil Z, Richardson M, Rogers TR. Detection and investigation of invasive mould disease. *J Antimicrob Chemother* 2011; 66(suppl 1): i15–i24.
10. Lass-Florl C. Zygomycosis: conventional laboratory diagnosis. *Clin Microbiol Infect* 2009; 15(suppl 5): 60–65.
11. Jensen HE, Salonen J, Ekfors TO. The use of immunohistochemistry to improve sensitivity and specificity in the diagnosis of systemic mycoses in patients with haematological malignancies. *J Pathol* 1997; 181: 100–105.
12. Revankar SG, Sutton DA. Melanized fungi in human disease. *Clin Microbiol Rev* 2010; 23: 884–928.
13. Richardson M, Ellis M. Clinical and laboratory diagnosis. *Hosp Med* 2000; 61: 610–614.
14. Balajee SA, Borman AM, Brandt ME *et al.* Sequence-based identification of *Aspergillus*, *Fusarium*, and *Mucorales* species in the clinical mycology laboratory: where are we and where should we go from here? *J Clin Microbiol* 2009; 47: 877–884.
15. Arendrup MC, Cuenca-Estrella M, Lass-Florl C, Hope W. EUCAST technical note on the EUCAST definitive document EDef 7.2: method for the determination of broth dilution minimum inhibitory concentrations of antifungal agents for yeasts EDef 7.2 (EUCAST-AFST). *Clin Microbiol Infect* 2012; 18: E246–E247.
16. Clinical Laboratory Standards Institute. *Reference method for broth dilution antifungal susceptibility testing of filamentous fungi; approved standard-second edition*. CLSI document M38-A2. Wayne, PA: Clinical Laboratory Standards Institute, 2008.
17. Subcommittee on Antifungal Susceptibility Testing (AFST) of the ESCMID European Committee for Antimicrobial Susceptibility Testing (EUCAST). EUCAST Technical Note on the method for the determination of broth dilution minimum inhibitory concentrations of antifungal agents for conidia-forming moulds. *Clin Microbiol Infect* 2008; 14: 982–984.
18. Cuenca-Estrella M, Gomez-Lopez A, Mellado E, Monzon A, Buitrago MJ, Rodriguez-Tudela JL. Activity profile *in vitro* of micafungin against Spanish clinical isolates of common and emerging species of yeasts and molds. *Antimicrob Agents Chemother* 2009; 53: 2192–2195.
19. Cuenca-Estrella M, Rodriguez-Tudela JL. The current role of the reference procedures by CLSI and EUCAST in the detection of resistance to antifungal agents *in vitro*. *Expert Rev Anti Infect Ther* 2010; 8: 267–276.
20. Cuetara MS, Alhambra A, Moragues MD, Gonzalez-Elorza E, Ponton J, del Palacio A. Detection of (1→3)-β-D-glucan as an adjunct to diagnosis in a mixed population with uncommon proven invasive fungal diseases or with an unusual clinical presentation. *Clin Vaccine Immunol* 2009; 16: 423–426.
21. Koo S, Bryar JM, Page JH, Baden LR, Marty FM. Diagnostic performance of the (1→3)-β-D-glucan assay for invasive fungal disease. *Clin Infect Dis* 2009; 49: 1650–1659.
22. Onishi A, Sugiyama D, Kogata Y *et al.* Diagnostic accuracy of serum 1,3-β-D-glucan for *Pneumocystis jiroveci* pneumonia, invasive candidiasis, and invasive aspergillosis: systematic review and meta-analysis. *J Clin Microbiol* 2012; 50: 7–15.
23. Buitrago MJ, Aguado JM, Ballen A *et al.* Efficacy of DNA amplification in tissue biopsy samples to improve the detection of invasive fungal disease. *Clin Microbiol Infect* 2013; 19: E271–E277.
24. Lau A, Chen S, Sorrell T *et al.* Development and clinical application of a panfungal PCR assay to detect and identify fungal DNA in tissue specimens. *J Clin Microbiol* 2007; 45: 380–385.
25. Marchetti O, Lamoth F, Mikulska M, Viscoli C, Verweij P, Bretagne S. ECIL recommendations for the use of biological markers for the diagnosis of invasive fungal diseases in leukemic patients and hematopoietic SCT recipients. *Bone Marrow Transplant* 2012; 47: 846–854.
26. Bogle MA, Rabkin MS, Joseph AK. Mohs micrographic surgery for the eradication of phaeohyphomycosis of the hand. *Dermatol Surg* 2004; 30: 231–233.
27. Diaz M, Puente R, Trevino MA. Response of long-running *Alternaria alternata* infection to fluconazole. *Lancet* 1990; 336: 513.
28. Farina C, Gotti E, Mouniee D, Boiron P, Goglio A. *Phaeoacremonium parasiticum* subcutaneous infection in a kidney-transplanted patient successfully treated by surgery. *Transpl Infect Dis* 2007; 9: 253–255.
29. Gene J, Azon-Masoliver A, Guarro J *et al.* Cutaneous phaeohyphomycosis caused by *Alternaria longipes* in an immunosuppressed patient. *J Clin Microbiol* 1995; 33: 2774–2776.
30. Guarro J, Alves SH, Gene J *et al.* Two cases of subcutaneous infection due to *Phaeoacremonium* spp. *J Clin Microbiol* 2003; 41: 1332–1336.
31. Machet L, Machet MC, Maillot F *et al.* Cutaneous alternariosis occurring in a patient treated with local intrarectal corticosteroids. *Acta Derm Venereol* 1995; 75: 328–329.
32. Salido R, Linares-Sicilia MJ, Garnacho-Saucedo G *et al.* Subcutaneous phaeohyphomycosis due to *Alternaria infectoria* in a renal transplant patient: surgical treatment with no long-term relapse. *Rev Iberoam Micol* 2012; Epub ahead of print.
33. Gugnani HC, Ramesh V, Sood N *et al.* Cutaneous phaeohyphomycosis caused by *Cladosporium oxysporum* and its treatment with potassium iodide. *Med Mycol* 2006; 44: 285–288.
34. Pereiro M Jr, Pereiro Ferreiros MM, De Hoog GS, Toribio J. Cutaneous infection caused by *Alternaria* in patients receiving tacrolimus. *Med Mycol* 2004; 42: 277–282.
35. Suh MK, Lee YH. Infections caused by dematiaceous fungi. *Korean J Med Mycol* 2005; 10: 77–82.
36. Torres-Rodriguez JM, Gonzalez MP, Corominas JM, Pujol RM. Successful thermotherapy for a subcutaneous infection due to *Alternaria alternata* in a renal transplant recipient. *Arch Dermatol* 2005; 141: 1171–1173.

37. Yang Y, Hu Y, Zhang J *et al.* A refractory case of chromoblastomycosis due to *Fonsecaea monophora* with improvement by photodynamic therapy. *Med Mycol* 2012; 50: 649–653.
38. Badali H, De Hoog GS, Curfs-Breuker I, Andersen B, Meis JF. *In vitro* activities of eight antifungal drugs against 70 clinical and environmental isolates of *Alternaria* species. *J Antimicrob Chemother* 2009; 63: 1295–1297.
39. Boyce RD, Deziel PJ, Otley CC *et al.* Phaeohyphomycosis due to *Alternaria* species in transplant recipients. *Transpl Infect Dis* 2010; 12: 242–250.
40. Foulet F, Duvoux C, de Bièvre C, Hézode C, Bretagne S. Cutaneous phaeohyphomycosis caused by *Veronaea botryosa* in a liver transplant recipient successfully treated with itraconazole. *Clin Infect Dis* 1999; 29: 689–690.
41. Halaby T, Boots H, Vermeulen A *et al.* Phaeohyphomycosis caused by *Alternaria infectoria* in a renal transplant recipient. *J Clin Microbiol* 2001; 39: 1952–1955.
42. Miele PS, Levy CS, Smith MA *et al.* Primary cutaneous fungal infections in solid organ transplantation: a case series. *Am J Transplant* 2002; 2: 678–683.
43. Mirkin LD. *Alternaria alternata* infection of skin in a 6-year-old boy with aplastic anemia. *Pediatr Pathol* 1994; 14: 757–761.
44. Yehia M, Thomas M, Pilmore H, Van Der MW, Dittmer I. Subcutaneous black fungus (phaeohyphomycosis) infection in renal transplant recipients: three cases. *Transplantation* 2004; 77: 140–142.
45. Agger WA, Andes D, Burgess JW. *Exophiala jeanselmei* infection in a heart transplant recipient successfully treated with oral terbinafine. *Clin Infect Dis* 2004; 38: e112–e115.
46. Altomare GF, Capella GL, Boneschi V, Viviani MA. Effectiveness of terbinafine in cutaneous alternariosis. *Br J Dermatol* 2000; 142: 840–841.
47. Bartolome B, Valks R, Fraga J, Buendía V, Fernández-Herrera J, García-Díez A. Cutaneous alternariosis due to *Alternaria chlamydospora* after bone marrow transplantation. *Acta Derm Venereol* 1999; 79: 244.
48. Calabro G, Nino M, Gallo L, Scalvenzi M. Cutaneous alternariosis in a kidney transplantation recipient: report of a case. *J Dermatol Treat* 2008; 19: 246–248.
49. Calista D, Leardini M, Arcangeli F. Subcutaneous *Exophiala jeanselmei* infection in a heart transplant patient. *Eur J Dermatol* 2003; 13: 489.
50. Ioannidou DJ, Stefanidou MP, Maraki SG, Panayiotides JG, Tosca AD. Cutaneous alternariosis in a patient with idiopathic pulmonary fibrosis. *Int J Dermatol* 2000; 39: 293–295.
51. Ioannidou D, Maraki S, Krüger Krasagakis S *et al.* Cutaneous alternariosis revealing acute myeloid leukaemia in an adult patient. *Mycoses* 2004; 47: 227–230.
52. Lo Cascio G, Ligozzi M, Maccacaro L, Fontana R. Utility of molecular identification in opportunistic mycotic infections: a case of cutaneous *Alternaria infectoria* infection in a cardiac transplant recipient. *J Clin Microbiol* 2004; 42: 5334–5336.
53. Magina S, Lisboa C, Santos P *et al.* Cutaneous alternariosis by *Alternaria chartarum* in a renal transplanted patient. *Br J Dermatol* 2000; 142: 1261–1262.
54. Merino E, Bañuls J, Boix V *et al.* Relapsing cutaneous alternariosis in a kidney transplant recipient cured with liposomal amphotericin B. *Eur J Clin Microbiol Infect Dis* 2003; 22: 51–53.
55. Pastor FJ, Guarro J. *Alternaria* infections: laboratory diagnosis and relevant clinical features. *Clin Microbiol Infect* 2008; 14: 734–746.
56. Rammaert B, Aguilar C, Bougnoux ME *et al.* Success of posaconazole therapy in a heart transplanted patient with *Alternaria infectoria* cutaneous infection. *Med Mycol* 2012; 50: 518–521.
57. Tambasco D, D'Ettorre M, Bracaglia R *et al.* A suspected squamous cell carcinoma in a renal transplant recipient revealing a rare cutaneous phaeohyphomycosis by *Alternaria infectoria*. *J Cutan Med Surg* 2012; 16: 131–134.
58. Zhang YQ, Xu XG, Li FQ, Wei H, Chen HD, Li YH. Co-existence of cutaneous alternariosis and tinea corporis in a renal transplant recipient. *Med Mycol* 2011; 49: 435–438.
59. Ahmed AOA, van Leeuwen W, Fahal A, van de Sande W, Verbrugh H, van Belkum A. Mycetoma caused by *Madurella mycetomatis*: a neglected infectious burden. *Lancet Infect Dis* 2004; 4: 566–574.
60. Al-Tawfiq JA, Amr SS. Madura leg due to *Exophiala jeanselmei* successfully treated with surgery and itraconazole therapy. *Med Mycol* 2009; 47: 648–652.
61. Capoor MR, Khanna G, Nair D *et al.* Eumycetoma pedis due to *Exophiala jeanselmei*. *Indian J Med Microbiol* 2007; 25: 155–157.
62. Castro LG, Piquero-Casals J. Clinical and mycologic findings and therapeutic outcome of 27 mycetoma patients from Sao Paulo, Brazil. *Int J Dermatol* 2008; 47: 160–163.
63. Hay RJ, Mahgoub ES, Leon G, Al Sogair S, Welsh O. Mycetoma. *J Med Vet Mycol* 1992; 30 (suppl 1): 41–49.
64. Severo LC, Geyer G, Souza AL, Balbinotti M. *Feohifomicose subcutanea*: relato dos tres primeiros casos do Rio Grande do Sul, Brasil. *An Bras Dermatol* 1987; 62: 37–40.
65. Hood SV, Moore CB, Cheesbrough JS, Mene A, Denning DW. Atypical eumycetoma caused by *Phialophora parasitica* successfully treated with itraconazole and flucytosine. *Br J Dermatol* 1997; 136: 953–956.
66. Lacroix C, de Kerviler E, Morel P, Derouin F, Feuilhade de Chavin M. *Madurella mycetomatis* mycetoma treated successfully with oral voriconazole. *Br J Dermatol* 2005; 152: 1067–1068.
67. Lee DK, Schwartz AK. Primary mycetoma osteomyelitis of the calcaneus with active subcutaneous nodules. *J Foot Ankle Surg* 2007; 46: 302–306.
68. Loulergue P, Hot A, Dannaoui E *et al.* Successful treatment of black-grain mycetoma with voriconazole. *Am J Trop Med Hyg* 2006; 75: 1106–1107.
69. Negroni R, Tobon A, Bustamante B, Shikanai-Yasuda MA, Patino H, Restrepo A. Posaconazole treatment of refractory eumycetoma and chromoblastomycosis. *Rev Inst Med Trop Sao Paulo* 2005; 47: 339–346.
70. McGinnis MR. Chromoblastomycosis and phaeohyphomycosis: new concepts, diagnosis, and mycology. *J Am Acad Dermatol* 1983; 8: 1–16.
71. Andrade TS, Castro LG, Nunes RS, Gimenes VM, Cury AE. Susceptibility of sequential *Fonsecaea pedrosoi* isolates from chromoblastomycosis patients to antifungal agents. *Mycoses* 2004; 47: 216–221.
72. Bonifaz A, Paredes-Solis V, Saul A. Treating chromoblastomycosis with systemic antifungals. *Expert Opin Pharmacother* 2004; 5: 247–254.
73. Queiroz-Telles F, Purim KS, Fillus JN *et al.* Itraconazole in the treatment of chromoblastomycosis due to *Fonsecaea pedrosoi*. *Int J Dermatol* 1992; 31: 805–812.
74. Queiroz-Telles F, Esterre P, Perez-Blanco M, Vitale RG, Salgado CG, Bonifaz A. Chromoblastomycosis: an overview of clinical manifestations, diagnosis and treatment. *Med Mycol* 2009; 47: 3–15.
75. Queiroz-Telles F, Santos DW. Challenges in the therapy of chromoblastomycosis. *Mycopathologia* 2013; 175: 477–488.
76. Restrepo A, Gonzalez A, Gomez I, Arango M, de Bedout C. Treatment of chromoblastomycosis with itraconazole. *Ann N Y Acad Sci* 1988; 544: 504–516.
77. Attapattu MC. Chromoblastomycosis—a clinical and mycological study of 71 cases from Sri Lanka. *Mycopathologia* 1997; 137: 145–151.
78. Minotto R, Bernardi CD, Mallmann LF, Edelweiss MI, Scroferneker ML. Chromoblastomycosis: a review of 100 cases in the state of Rio Grande do Sul, Brazil. *J Am Acad Dermatol* 2001; 44: 585–592.
79. Bansal AS, Prabhakar R. Chromomycosis: a twenty-year-analysis of histologically confirmed cases in Jamaica. *Trop Geogr Med* 1989; 41: 222–226.
80. Bonifaz A, Carrasco-Gerard E, Saúl A. Chromoblastomycosis: clinical and mycologic experience of 51 cases. *Mycoses* 2001; 44: 1–7.

81. Castro LG, Pimentel ER, Lacaz CS. Treatment of chromomycosis by cryosurgery with liquid nitrogen: 15 years' experience. *Int J Dermatol* 2003; 42: 408–412.
82. Bassas-Vila J, Fuente MJ, Guinovart R, Ferrándiz C. Chromoblastomycosis: response to combination therapy with cryotherapy and terbinafine. *Actas Dermosifiliogr* 2013; pii: S0001-7310(13)00105-1. doi: 10.1016/j.ad.2013.02.008 [Epub ahead of print].
83. Gupta AK, Taborda PR, Sanzovo AD. Alternate week and combination itraconazole and terbinafine therapy for chromoblastomycosis caused by *Fonsecaea pedrosoi* in Brazil. *Med Mycol* 2002; 40: 529–534.
84. Kullavanijaya P, Rojanavanich V. Successful treatment of chromoblastomycosis due to *Fonsecaea pedrosoi* by the combination of itraconazole and cryotherapy. *Int J Dermatol* 1995; 34: 804–807.
85. Bonifaz A, Davoudi MM, de Hoog GS *et al.* Severe disseminated phaeohyphomycosis in an immunocompetent patient caused by *Veronaea botryosa*. *Mycopathologia* 2013; 175: 497–503.
86. Calvo E, Pastor FJ, Salas V, Mayayo E, Capilla J, Guarro J. Histopathology and antifungal treatment of experimental murine chromoblastomycosis caused by *Cladophialophora carrionii*. *J Antimicrob Chemother* 2012; 67: 666–670.
87. Deng S, de Hoog GS, Badali H *et al. In vitro* antifungal susceptibility of *Cladophialophora carrionii*, an agent of human chromoblastomycosis. *Antimicrob Agents Chemother* 2013; 57: 1974–1977.
88. Dupont C, Duong TA, Mallet S *et al.* Unusual presentation of chromoblastomycosis due to *Cladophialophora carrionii* in a renal and pancreas transplant recipient patient successfully treated with posaconazole and surgical excision. *Transpl Infect Dis* 2010; 12: 180–183.
89. Gopinathan U, Garg P, Fernandes M, Sharma S, Athmanathan S, Rao GN. The epidemiological features and laboratory results of fungal keratitis: a 10-year review at a referral eye care center in South India. *Cornea* 2002; 21: 555–559.
90. Thomas PA. Fungal infections of the cornea. *Eye* 2003; 17: 852–862.
91. Thomas PA, Kaliamurthy J. Mycotic keratitis: epidemiology, diagnosis and management. *Clin Microbiol Infect* 2013; 19: 210–220.
92. Garg P, Gopinathan U, Choudhary K, Rao GN. Keratomycosis: clinical and microbiologic experience with dematiaceous fungi. *Ophthalmology* 2000; 107: 574–580.
93. Wilhelmus KR, Jones DB. *Curvularia* keratitis. *Trans Am Ophthalmol Soc* 2001; 99: 111–130.
94. Wilhelmus KR. Climatology of dematiaceous fungal keratitis. *Am J Ophthalmol* 2005; 140: 1156–1157.
95. Ozbek Z, Kang S, Sivalingam J, Rapuano CJ, Cohen EJ, Hammersmith KM. Voriconazole in the management of *Alternaria* keratitis. *Cornea* 2006; 25: 242–244.
96. Sharma N, Chacko J, Velpandian T *et al.* Comparative evaluation of topical versus intrastromal voriconazole as an adjunct to natamycin in recalcitrant fungal keratitis. *Ophthalmology* 2013; 120: 677–681.
97. Tu EY. *Alternaria* keratitis: clinical presentation and resolution with topical fluconazole or intrastromal voriconazole and topical caspofungin. *Cornea* 2009; 28: 116–119.
98. Siatiri H, Daneshgar F, Siatiri N, Khodabande A. The effects of intrastromal voriconazole injection and topical voriconazole in the treatment of recalcitrant *Fusarium* keratitis. *Cornea* 2011; 30: 872–875.
99. Borges MC Jr, Warren S, White W, Pellettiere EV. Pulmonary phaeohyphomycosis due to *Xylohypha bantiana*. *Arch Pathol Lab Med* 1991; 115: 627–629.
100. Brenner SA, Morgan J, Rickert PD, Rimland D. *Cladophialophora bantiana* isolated from an AIDS patient with pulmonary infiltrates. *J Med Vet Mycol* 1996; 34: 427–429.
101. Burns KE, Ohori NP, Iacono AT. *Dactylaria gallopava* infection presenting as a pulmonary nodule in a single-lung transplant recipient. *J Heart Lung Transplant* 2000; 19: 900–902.
102. Al-Aidaroos A, Bin-Hussain I, El Solh H *et al.* Invasive *Chaetomium* infection in two immunocompromised pediatric patients. *Pediatr Infect Dis J* 2007; 26: 456–458.
103. Elinav H, Izhar U, Benenson S *et al.* Invasive *Scytalidium dimidiatum* infection in an immunocompetent adult. *J Clin Microbiol* 2009; 47: 1259–1263.
104. Hollingsworth JW, Shofer S, Zaas A. Successful treatment of *Ochroconis gallopavum* infection in an immunocompetent host. *Infection* 2007; 35: 367–369.
105. Lastoria C, Cascina A, Bini F *et al.* Pulmonary *Cladophialophora boppii* infection in a lung transplant recipient: case report and literature review. *J Heart Lung Transplant* 2009; 28: 635–637.
106. Mullane K, Toor AA, Kalnicky C, Rodriguez T, Klein J, Stiff P. Posaconazole salvage therapy allows successful allogeneic hematopoietic stem cell transplantation in patients with refractory invasive mold infections. *Transpl Infect Dis* 2007; 9: 89–96.
107. Woo PC, Lau SK, Ngan AH, Tse H, Tung ET, Yuen KY. *Lasiodiplodia theobromae* pneumonia in a liver transplant recipient. *J Clin Microbiol* 2008; 46: 380–384.
108. Greig JR, Khan MA, Hopkinson NS, Marshall BG, Wilson PO, Rahman SU. Pulmonary infection with *Scedosporium prolificans* in an immunocompetent individual. *J Infect* 2001; 43: 15–17.
109. Al-Tawfiq JA, Boukhamseen A. Cerebral phaeohyphomycosis due to *Rhinocladiella mackenziei* (formerly *Ramichloridium mackenziei*): case presentation and literature review. *J Infect Public Health* 2011; 4: 96–102.
110. Carter E, Boudreaux C. Fatal cerebral phaeohyphomycosis due to *Curvularia lunata* in an immunocompetent patient. *J Clin Microbiol* 2004; 42: 5419–5423.
111. Chang X, Li R, Yu J, Bao X, Qin J. Phaeohyphomycosis of the central nervous system caused by *Exophiala dermatitidis* in a 3-year-old immunocompetent host. *J Child Neurol* 2009; 24: 342–345.
112. Delfino D, De Hoog S, Polonelli L *et al.* Survival of a neglected case of brain abscess caused by *Cladophialophora bantiana*. *Med Mycol* 2006; 44: 651–654.
113. Ebright JR, Chandrasekar PH, Marks S, Fairfax MR, Aneziokoro A, McGinnins MR. Invasive sinusitis and cerebritis due to *Curvularia clavata* in an immunocompetent adult. *Clin Infect Dis* 1999; 28: 687–689.
114. Filizzola MJ, Martinez F, Rauf SJ. Phaeohyphomycosis of the central nervous system in immunocompetent hosts: report of a case and review of the literature. *Int J Infect Dis* 2003; 7: 282–286.
115. Flanagan KL, Bryceson AD. Disseminated infection due to *Bipolaris australiensis* in a young immunocompetent man: case report and review. *Clin Infect Dis* 1997; 25: 311–313.
116. Revankar SG. *Cladophialophora bantiana* brain abscess in an immunocompetent patient. *Can J Infect Dis Med Microbiol* 2011; 22: 149–150.
117. Garg N, Devi IB, Vajramani GV *et al.* Central nervous system cladosporiosis: an account of ten culture-proven cases. *Neurol India* 2007; 55: 282–288.
118. Jabeen K, Farooqi J, Zafar A *et al. Rhinocladiella mackenziei* as an emerging cause of cerebral phaeohyphomycosis in Pakistan: a case series. *Clin Infect Dis* 2011; 52: 213–217.
119. Li DM, de Hoog GS. Cerebral phaeohyphomycosis—a cure at what lengths? *Lancet Infect Dis* 2009; 9: 376–383.
120. Pedersen MB, Zhao Y, Arendrup MC *et al.* Co-existence of cerebral infection with *Rhinocladiella mackenziei* and primary central nervous system lymphoma in a HIV-negative patient. *APMIS* 2011; 119: 221–223.
121. Al-Abdely HM, Najvar L, Bocanegra R *et al.* SCH 56592, amphotericin B, or itraconazole therapy of experimental murine cerebral phaeohyphomycosis due to *Ramichloridium obovoideum* (*Ramichloridium mackenziei*). *Antimicrob Agents Chemother* 2000; 44: 1159–1162.
122. Al-Abdely HM, Alkhunaizi AM, Al-Tawfiq JA, Hassounah M, Rinaldi M, Sutton DA. Successful therapy of cerebral phaeohyphomycosis due to

Ramichloridium mackenziei with the new triazole posaconazole. *Med Mycol* 2005; 43: 91–95.
123. Badali H, de Hoog GS, Curfs-Breuker I, Klaassen CH, Meis JF. Use of amplified fragment length polymorphism to identify 42 *Cladophialophora* strains related to cerebral phaeohyphomycosis with *in vitro* antifungal susceptibility. *J Clin Microbiol* 2010; 48: 2350–2356.
124. Fica A, Diaz MC, Luppi M *et al.* Unsuccessful treatment with voriconazole of a brain abscess due to *Cladophialophora bantiana*. *Scand J Infect Dis* 2003; 35: 892–893.
125. Koo S, Klompas M, Marty FM. *Fonsecaea monophora* cerebral phaeohyphomycosis: case report of successful surgical excision and voriconazole treatment and review. *Med Mycol* 2010; 48: 769–774.
126. Levin TP, Baty DE, Fekete T, Truant AL, Suh B. *Cladophialophora bantiana* brain abscess in a solid-organ transplant recipient: case report and review of the literature. *J Clin Microbiol* 2004; 42: 4374–4378.
127. Revankar SG, Sutton DA, Rinaldi MG. Primary central nervous system phaeohyphomycosis: a review of 101 cases. *Clin Infect Dis* 2004; 38: 206–216.
128. Trinh JV, Steinbach WJ, Schell WA, Kurtzberg J, Giles SS, Perfect JR. Cerebral phaeohyphomycosis in an immunodeficient child treated medically with combination antifungal therapy. *Med Mycol* 2003; 41: 339–345.
129. Harrison DK, Moser S, Palmer CA. Central nervous system infections in transplant recipients by *Cladophialophora bantiana*. *South Med J* 2008; 101: 292–296.
130. Taj-Aldeen SJ, Almaslamani M, Alkhalf A *et al.* Cerebral phaeohyphomycosis due to *Rhinocladiella mackenziei* (formerly *Ramichloridium mackenziei*): a taxonomic update and review of the literature. *Med Mycol* 2010; 48: 546–556.
131. Karuppal R, Kumaran CM, Marthya A *et al.* Tibial osteomyelitis due to *Fonsecaea pedrosoi* in an immunocompetent patient: case report. *J Foot Ankle Surg* 2009; 48: 569–572.
132. Shigemura T, Agematsu K, Yamazaki T *et al.* Femoral osteomyelitis due to *Cladophialophora arxii* in a patient with chronic granulomatous disease. *Infection* 2009; 37: 469–473.
133. Greig J, Harkness M, Taylor P, Hashmi C, Liang S, Kwan J. Peritonitis due to the dermatiaceous mold *Exophiala dermatitidis* complicating continuous ambulatory peritoneal dialysis. *Clin Microbiol Infect* 2003; 9: 713–715.
134. Kerr CM, Perfect JR, Craven PC *et al.* Fungal peritonitis in patients on continuous ambulatory peritoneal dialysis. *Ann Intern Med* 1983; 99: 334–336.
135. Reiss-Levy E, Clingan P. Peritonitis caused by *Alternaria alternata*. *Med J Aust* 1981; 2: 44.
136. Rossmann SN, Cernoch PL, Davis JR. Dematiaceous fungi are an increasing cause of human disease. *Clin Infect Dis* 1996; 22: 73–80.
137. Shin JH, Lee SK, Suh SP *et al.* Fatal *Hormonema dematioides* peritonitis in a patient on continuous ambulatory peritoneal dialysis: criteria for organism identification and review of other known fungal etiologic agents. *J Clin Microbiol* 1998; 36: 2157–2163.
138. Revankar SG, Patterson JE, Sutton DA, Pullen R, Rinaldi MG. Disseminated phaeohyphomycosis: review of an emerging mycosis. *Clin Infect Dis* 2002; 34: 467–476.
139. Li DM, Li RY, De Hoog GS, Wang YX, Wang DL. *Exophiala asiatica*, a new species from a fatal case in China. *Med Mycol* 2009; 47: 101–109.
140. Li DM, Li RY, de Hoog GS, Sudhadham M, Wang DL. Fatal *Exophiala* infections in China, with a report of seven cases. *Mycoses* 2011; 54: e136–e142.
141. Al-Obaid I, Ahmad S, Khan ZU, Dinesh B, Hejab HM. Catheter-associated fungemia due to *Exophiala oligosperma* in leukemic child and review of fungemia cases caused by *Exophiala* species. *Eur J Clin Microbiol Infect Dis* 2006; 25: 729–732.
142. Alabaz D, Kibar F, Arikan S *et al.* Systemic phaeohyphomycosis due to *Exophiala* (*Wangiella*) in an immunocompetent child. *Med Mycol* 2009; 47: 653–657.
143. Barron MA, Sutton DA, Veve R *et al.* Invasive mycotic infections caused by *Chaetomium perlucidum*, a new agent of cerebral phaeohyphomycosis. *J Clin Microbiol* 2003; 41: 5302–5307.
144. Boggild AK, Poutanen SM, Mohan S, Ostrowski MA. Disseminated phaeohyphomycosis due to *Ochroconis gallopavum* in the setting of advanced HIV infection. *Med Mycol* 2006; 44: 777–782.
145. Brandt ME, Warnock DW. Epidemiology, clinical manifestations, and therapy of infections caused by dematiaceous fungi. *J Chemother* 2003; 15(suppl 2): 36–47.
146. Oztas E, Odemis B, Kekilli M *et al.* Systemic phaeohyphomycosis resembling primary sclerosing cholangitis caused by *Exophiala dermatitidis*. *J Med Microbiol* 2009; 58: 1243–1246.
147. Negroni R, Helou SH, Petri N, Robles AM, Arechavala A, Bianchi MH. Case study: posaconazole treatment of disseminated phaeohyphomycosis due to *Exophiala spinifera*. *Clin Infect Dis* 2004; 38: e15–e20.
148. Howden BP, Slavin MA, Schwarer AP, Mijch AM. Successful control of disseminated *Scedosporium prolificans* infection with a combination of voriconazole and terbinafine. *Eur J Clin Microbiol Infect Dis* 2003; 22: 111–113.
149. Tong SY, Peleg AY, Yoong J, Handke R, Szer J, Slavin M. Breakthrough *Scedosporium prolificans* infection while receiving voriconazole prophylaxis in an allogeneic stem cell transplant recipient. *Transpl Infect Dis* 2007; 9: 241–243.
150. Whyte M, Irving H, O'Regan P, Nissen M, Siebert D, Labrom R. Disseminated *Scedosporium prolificans* infection and survival of a child with acute lymphoblastic leukemia. *Pediatr Infect Dis J* 2005; 24: 375–377.
151. Rinaldi MG, Phillips P, Schwartz JG *et al.* Human *Curvularia* infections. Report of five cases and review of the literature. *Diagn Microbiol Infect Dis* 1987; 6: 27–39.
152. Rupa V, Jacob M, Mathews MS, Seshadri MS. A prospective, randomised, placebo-controlled trial of postoperative oral steroid in allergic fungal sinusitis. *Eur Arch Otorhinolaryngol* 2010; 267: 233–238.
153. Rupa V, Thomas M. Different types of fungal sinusitis occurring concurrently: implications for therapy. *Eur Arch Otorhinolaryngol* 2013; 270: 603–608.
154. Taj-Aldeen SJ, Hilal AA, Schell WA. Allergic fungal rhinosinusitis: a report of 8 cases. *Am J Otolaryngol* 2004; 25: 213–218.
155. Kuhn FA, Javer AR. Allergic fungal rhinosinusitis: perioperative management, prevention of recurrence, and role of steroids and antifungal agents. *Otolaryngol Clin North Am* 2000; 33: 419–433.
156. Chan KO, Genoway KA, Javer AR. Effectiveness of itraconazole in the management of refractory allergic fungal rhinosinusitis. *J Otolaryngol Head Neck Surg* 2008; 37: 870–874.
157. Erwin GE, Fitzgerald JE. Case report: allergic bronchopulmonary aspergillosis and allergic fungal sinusitis successfully treated with voriconazole. *J Asthma* 2007; 44: 891–895.
158. Seiberling K, Wormald PJ. The role of itraconazole in recalcitrant fungal sinusitis. *Am J Rhinol Allergy* 2009; 23: 303–306.
159. Maloney AM, Ethier MC, Mitchell D, Zaoutis T, Sung L, Childhood Acute Myeloid Leukemia Infection Research Group. *Alternaria* sinusitis in children with acute myeloid leukemia: case reports from the Childhood Acute Myeloid Leukemia Infection Research Group. *Leuk Lymphoma* 2010; 51: 345–347.
160. Chowdhary A, Agarwal K, Kathuria S, Gaur SN, Randhawa HS, Meis JF. Allergic bronchopulmonary mycosis due to fungi other than *Aspergillus*: a global overview. *Crit Rev Microbiol* 2013; in press.
161. Halwig JM, Brueske DA, Greenberger PA, Dreisin RB, Sommers HM. Allergic bronchopulmonary curvulariosis. *Am Rev Respir Dis* 1985; 132: 186–188.

162. Saenz RE, Brown WD, Sanders CV. Allergic bronchopulmonary disease caused by *Bipolaris hawaiiensis* presenting as a necrotizing pneumonia: case report and review of literature. *Am J Med Sci* 2001; 321: 209–212.
163. Agarwal R, Chakrabarti A, Shah A *et al.* Allergic bronchopulmonary aspergillosis: review of literature and proposal of new diagnostic and classification criteria. *Clin Exp Allergy* 2013; 43: 850–873.
164. De Hoog GS, Guarro J, Gene J, Figueras MJ. *Atlas of clinical fungi*, 2nd edn. Virgili: Centraalbureau voor Schimmelcultures, 2000; 645–668.
165. De Lucca AJ. Harmful fungi in both agriculture and medicine. *Rev Iberoam Micol* 2007; 24: 3–13.
166. Tournas VH. Spoilage of vegetable crops by bacteria and fungi and related health hazards. *Crit Rev Microbiol* 2005; 31: 33–44.
167. Lyke KE, Miller NS, Towne L, Merz WG. A case of cutaneous ulcerative alternariosis: rare association with diabetes mellitus and unusual failure of itraconazole treatment. *Clin Infect Dis* 2001; 32: 1178–1187.
168. Mirhendi H, Fatemi MJ, Bateni H *et al.* First case of disseminated phaeohyphomycosis in an immunocompetent individual due to *Alternaria malorum*. *Med Mycol* 2013; 51: 196–202.
169. Ono M, Nishigori C, Tanaka C, Tanaka S, Tsuda M, Miyachi Y. Cutaneous alternariosis in an immunocompetent patient: analysis ofthe internal transcribed spacer region of rDNA and Brm2 of isolated *Alternaria alternata*. *Br J Dermatol* 2004; 150: 773–775.
170. Sood N, Gugnani HC, Guarro J, Paliwal-Joshi A, Vijayan VK. Subcutaneous phaeohyphomycosis caused by *Alternaria alternata* in an immunocompetent patient. *Int J Dermatol* 2007; 46: 412–413.
171. Williams C, Layton AM, Kerr K, Kibbler C, Barton RC. Cutaneous infection with an *Alternaria* sp. in an immunocompetent host. *Clin Exp Dermatol* 2008; 33: 440–442.
172. Hipolito E, Faria E, Alves AF, de Hoog GS, Anjos J, Gonçalves T. *Alternaria infectoria* brain abscess in a child with chronic granulomatous disease. *Eur J Clin Microbiol Infect Dis* 2009; 28: 377–380.
173. Gilaberte M, Bartralot R, Torres JM *et al.* Cutaneous alternariosis in transplant recipients: clinicopathologic review of 9 cases. *J Am Acad Dermatol* 2005; 52: 653–659.
174. Morrison VA, Weisdorf DJ. *Alternaria*: a sinonasal pathogen of immunocompromised hosts. *Clin Infect Dis* 1993; 16: 265–270.
175. Del Palacio A, Gomez-Hernando C, Revenga F *et al.* Cutaneous *Alternaria alternata* infection successfully treated with itraconazole. *Clin Exp Dermatol* 1996; 21: 241–243.
176. Bourlond A, Alexandre G. Dermal alternariasis in a kidney transplant recipient. *Dermatologica* 1984; 168: 152–156.
177. Kpodzo DS, Calderwood MS, Ruchelsman DE *et al.* Primary subcutaneous *Alternaria alternata* infection of the hand in an immunocompromised host. *Med Mycol* 2011; 49: 543–547.
178. Loveless MO, Winn RE, Campbell M, Jones SR. Mixed invasive infection with *Alternaria* species and *Curvularia* species. *Am J Clin Pathol* 1981; 76: 491–493.
179. Woudenberg JH, Groenewald JZ, Binder M, Crous PW. *Alternaria* redefined. *Stud Mycol* 2013; 75: 171–212.
180. Ben-Ami R, Lewis RE, Raad II, Kontoyiannis DP. Phaeohyphomycosis in a tertiary care cancer center. *Clin Infect Dis* 2009; 48: 1033–1041.
181. Luque P, García-Gil FA, Larraga J *et al.* Treatment of cutaneous infection by *Alternaria alternata* with voriconazole in a liver transplant patient. *Transplant Proc* 2006; 38: 2514–2515.
182. Sharkey PK, Graybill JR, Rinaldi MG *et al.* Itraconazole treatment of phaeohyphomycosis. *J Am Acad Dermatol* 1990; 23: 577–586.
183. Al-Mohsen IZ, Sutton DA, Sigler L *et al. Acrophialophora fusispora* brain abscess in a child with acute lymphoblastic leukemia: review of cases and taxonomy. *J Clin Microbiol* 2000; 38: 4569–4576.
184. Guarro J, Mendiratta DK, De Sequeira H *et al. Acrophialophora fusispora*: an emerging agent of human mycoses. A report of 3 new clinical cases. *Diagn Microbiol Infect Dis* 2007; 59: 85–88.
185. Li CW, Lee HC, Chang TC *et al. Acrophialophora fusispora* brain abscess in a patient with acquired immunodeficiency syndrome: a case report and review of the literature. *Diagn Microbiol Infect Dis* 2013; 76: 368–371.
186. Guarro J, Gené J. *Acrophialophora fusispora* misidentified as *Scedosporium prolificans*. *J Clin Microbiol* 2002; 40: 3544.
187. Girardi LS, Malowitz R, Tortora GT, Spitzer ED. *Aureobasidium pullulans* septicemia. *Clin Infect Dis* 1993; 16: 338–339.
188. Kutleša M, Mlinarić-Missoni E, Hatvani L *et al.* Chronic fungal meningitis caused by *Aureobasidium proteae*. *Diagn Microbiol Infect Dis* 2012; 73: 271–272.
189. Caporale NE, Calegari L, Perez D, Gezuele E. Peritoneal catheter colonization and peritonitis with *Aureobasidium pullulans*. *Perit Dial Int* 1996; 16: 97–98.
190. Clark EC, Silver SM, Hollick GE, Rinaldi MG. Continuous ambulatory peritoneal dialysis complicated by *Aureobasidium pullulans* peritonitis. *Am J Nephrol* 1995; 15: 353–355.
191. Hawkes M, Rennie R, Sand C, Vaudry W. *Aureobasidium pullulans* infection: fungemia in an infant and a review of human cases. *Diagn Microbiol Infect Dis* 2005; 51: 209–213.
192. Ibañez Perez R, Chacón J, Fidalgo A, Martin J, Paraiso V, Muñoz-Bellido JL. Peritonitis by *Aureobasidium pullulans* in continuous ambulatory peritoneal dialysis. *Nephrol Dial Transplant* 1997; 12: 1544–1545.
193. Mise N, Ono Y, Kurita N *et al. Aureobasidium pullulans* peritonitis: case report and review of the literature. *Perit Dial Int* 2008; 28: 679–681.
194. Arranz Sánchez DM, de la Calle MC, Martín-Díaz MA *et al.* Subcutaneous mycosis produced by *Aureobasidium pullulans* in a renal transplant recipient. *J Eur Acad Dermatol Venereol* 2006; 20: 229–230.
195. Bolignano G, Criseo G. Disseminated nosocomial fungal infection by *Aureobasidium pullulans* var. *melanigenum*: a case report. *J Clin Microbiol* 2003; 41: 4483–4485.
196. Joshi A, Singh R, Shah MS, Umesh S, Khattry N. Subcutaneous mycosis and fungemia by *Aureobasidium pullulans*: a rare pathogenic fungus in a post allogeneic BM transplant patient. *Bone Marrow Transplant* 2010; 45: 203–204.
197. Kaczmarski EB, Liu Yin JA, Tooth JA, Love EM, Delamore IW. Systemic infection with *Aureobasidium pullulans* in a leukaemic patient. *J Infect* 1986; 13: 289–291.
198. Koppang HS, Olsen I, Stuge U, Sandven P. *Aureobasidium* infection of the jaw. *J Oral Pathol Med* 1991; 20: 191–195.
199. Krcméry V Jr, Spánik S, Danisovicová A, Jesenská Z, Blahová M. *Aureobasidium mansoni* meningitis in a leukemia patient successfully treated with amphotericin B. *Chemotherapy* 1994; 40: 70–71.
200. Mershon-Shier KL, Deville JG, Delair S *et al. Aureobasidium pullulans* var. *melanigenum* fungemia in a pediatric patient. *Med Mycol* 2011; 49: 80–83.
201. Morais OO, Porto C, Coutinho AS, Reis CM, Teixeira Mde M, Gomes CM. Infection of the lymphatic system by *Aureobasidium pullulans* in a patient with erythema nodosum leprosum. *Braz J Infect Dis* 2011; 15: 288–292.
202. Salkin IF, Martinez JA, Kemna ME. Opportunistic infection of the spleen caused by *Aureobasidium pullulans*. *J Clin Microbiol* 1986; 23: 828–831.
203. Tan HP, Wahlstrom HE, Zamora JU, Hassanein T. *Aureobasidium pneumonia* in a post liver transplant recipient: a case report. *Hepatogastroenterology* 1997; 44: 1215–1218.
204. Chawla B, Sharma N, Titiyal JS, Nayak N, Satpathy G. *Aureobasidium pullulans* keratitis following automated lamellar therapeutic keratoplasty. *Ophthalmic Surg Lasers Imaging* 2010; 9: 1–3.
205. Gupta V, Chawla R, Sen S. *Aureobasidium pullulans* scleritis following keratoplasty: a case report. *Ophthalmic Surg Lasers* 2001; 32: 481–482.
206. Huang YT, Liaw SJ, Liao CH *et al.* Catheter-related septicemia due to *Aureobasidium pullulans*. *Int J Infect Dis* 2008; 12: e137–e139.

207. Maverick KJ, Conners MS. *Aureobasidium pullulans* fungal keratitis following LASEK. *J Refract Surg* 2007; 23: 727–729.
208. Panda A, Das H, Deb M, Khanal B, Kumar S. *Aureobasidium pullulans* keratitis. *Clin Experiment Ophthalmol* 2006; 34: 260–264.
209. Pikazis D, Xynos ID, Xila V, Velegraki A, Aroni K. Extended fungal skin infection due to *Aureobasidium pullulans*. *Clin Exp Dermatol* 2009; 34: e892–e894.
210. Redondo-Bellón P, Idoate M, Rubio M, Ignacio Herrero J. Chromoblastomycosis produced by *Aureobasidium pullulans* in an immunosuppressed patient. *Arch Dermatol* 1997; 133: 663–664.
211. Cuenca-Estrella M, Gomez-Lopez A, Mellado E, Buitrago MJ, Monzon A, Rodriguez-Tudela JL. Head-to-head comparison of the activities of currently available antifungal agents against 3,378 Spanish clinical isolates of yeasts and filamentous fungi. *Antimicrob Agents Chemother* 2006; 50: 917–921.
212. Sivanesan A. Graminicolous species of *Bipolaris*, *Curvularia*, *Drechslera*, *Exserohilum*, and their teleomorphs. *Mycol Pap* 1987; 158: 1–261.
213. Da Cunha KC, Sutton DA, Fothergill AW *et al.* Diversity of *Bipolaris* species in clinical samples in the United States and their antifungal susceptibility profiles. *J Clin Microbiol* 2012; 50: 4061–4066.
214. Manamgoda DS, Cai L, McKenzie EHC *et al.* A phylogenetic and taxonomic re-evaluation of the *Bipolaris–Cochliobolus–Curvularia* complex. *Fungal Divers* 2012; 56: 131–144.
215. Toul P, Castillo L, Hofman V, Bouchara JP, Chanalet S, Gari-Toussaint M. A pseudo tumoral sinusitis caused by *Bipolaris* sp. *J Infect* 2006; 53: e235–e237.
216. Newell CK, Steinmetz RL, Brooks HL Jr. Chronic postoperative endophthalmitis caused by *Bipolaris australiensis*. *Retina* 2006; 26: 109–110.
217. Sheyman AT, Cohen BZ, Friedman AH, Ackert JM. An outbreak of fungal endophthalmitis after intravitreal injection of compounded combined bevacizumab and triamcinolone. *JAMA Ophthalmol* 2013; 131: 864–869.
218. Chowdhary A, Randhawa HS, Singh V *et al. Bipolaris hawaiiensis* as etiologic agent of allergic bronchopulmonary mycosis: first case in a paediatric patient. *Med Mycol* 2011; 49: 760–765.
219. Bava AJ, Fayad A, Céspedes C, Sandoval M. Fungal peritonitis caused by *Bipolaris spicifera*. *Med Mycol* 2003; 41: 529–531.
220. Ogden PE, Hurley DL, Cain PT. Fatal fungal endarteritis caused by *Bipolaris spicifera* following replacement of the aortic valve. *Clin Infect Dis* 1992; 14: 596–598.
221. Morton SJ, Midthun K, Merz WG. Granulomatous encephalitis caused by *Bipolaris hawaiiensis*. *Arch Pathol Lab Med* 1986; 110: 1183–1185.
222. Pauzner R, Goldschmied-Reouven A, Hay I *et al.* Phaeohyphomycosis following cardiac surgery: case report and review of serious infection due to *Bipolaris* and *Exserohilum* species. *Clin Infect Dis* 1997; 25: 921–923.
223. Castelnuovo P, De Bernardi F, Cavanna C *et al.* Invasive fungal sinusitis due to *Bipolaris hawaiiensis*. *Mycoses* 2004; 47: 76–81.
224. Rosow L, Jiang JX, Deuel T *et al.* Cerebral phaeohyphomycosis caused by *Bipolaris spicifera* after heart transplantation. *Transpl Infect Dis* 2011; 13: 419–423.
225. Viola GM, Sutton R. Allergic fungal sinusitis complicated by fungal brain mass. *Int J Infect Dis* 2010; 14(suppl 3): e299–e301.
226. Bilu D, Movahedi-Lankarani S, Kazin RA, Shields C, Moresi M. Cutaneous *Bipolaris* infection in a neutropenic patient with acute lymphoblastic leukemia. *J Cutan Med Surg* 2004; 8: 446–449.
227. Dubey A, Patwardhan RV, Sampth S, Santosh V, Kolluri S, Nanda A. Intracranial fungal granuloma: analysis of 40 patients and review of the literature. *Surg Neurol* 2005; 63: 254–260.
228. Karim M, Sheikh H, Alam M, Sheikh Y. Disseminated *Bipolaris* infection in an asthmatic patient: case report. *Clin Infect Dis* 1993; 17: 248–253.
229. Khan JA, Hussain ST, Hasan S, McEvoy P, Sarwari A. Disseminated *Bipolaris* infection in an immunocompetent host: an atypical presentation. *J Pak Med Assoc* 2000; 50: 68–71.
230. Moore ML, Collins GR, Hawk BJ, Russell TS. Disseminated *Bipolaris spicifera* in a neonate. *J Perinatol* 2001; 21: 399–401.
231. Buzina W, Braun H, Schimpl K, Stammberger H. *Bipolaris spicifera* causes fungus balls of the sinuses and triggers polypoid chronic rhinosinusitis in an immunocompetent patient. *J Clin Microbiol* 2003; 41: 4885–4887.
232. Costa AR, Porto E, Tabuti AH *et al.* Subcutaneous phaeohyphomycosis caused by *Bipolaris hawaiiensis*. A case report. *Rev Inst Med Trop Sao Paulo* 1991; 33: 74–79.
233. Ambrosetti D, Hofman V, Castillo L, Gari-Toussaint M, Hofman P. An expansive paranasal sinus tumour-like lesion caused by *Bipolaris spicifera* in an immunocompetent patient. *Histopathology* 2006; 49: 660–662.
234. Santos DW, Padovan AC, Melo AS *et al.* Molecular identification of melanised non-sporulating moulds: a useful tool for studying the epidemiology of phaeohyphomycosis. *Mycopathologia* 2013; 175: 445–454.
235. El-Morsy SM, Khafagy YW, El-Naggar MM, Beih AA. Allergic fungal rhinosinusitis: detection of fungal DNA in sinus aspirate using polymerase chain reaction. *J Laryngol Otol* 2010; 124: 152–160.
236. Shin EJ, Guertler N, Kim E, Lalwani AK. Screening of middle ear effusion for the common sinus pathogen *Bipolaris*. *Eur Arch Otorhinolaryngol* 2003; 260: 78–80.
237. Kimura M, McGinnis MR. Fontana–Masson-stained tissue from culture-proven mycoses. *Arch Pathol Lab Med* 1998; 122: 1107–1111.
238. Adam RD, Paquin ML, Petersen EA *et al.* Phaeohyphomycosis caused by the fungal genera *Bipolaris* and *Exserohilum*. A report of 9 cases and review of the literature. *Medicine (Baltimore)* 1986; 65: 203–217.
239. Durkin SR, Henderson T, Raju R, Ellis D. Successful treatment of phaeohyphomycotic keratitis caused by *Bipolaris australiensis*. *Clin Exp Ophthalmol* 2008; 36: 697–699.
240. Frenkel L, Kuhls TL, Nitta K *et al.* Recurrent *Bipolaris* sinusitis following surgical and antifungal therapy. *Pediatr Infect Dis J* 1987; 6: 1130–1132.
241. McGinnis MR, Campbell G, Gourley WK, Lucia HL. Phaeohyphomycosis caused by *Bipolaris spicifera*: an informative case. *Eur J Epidemiol* 1992; 8: 383–386.
242. Gonzalez GM. *In vitro* activities of isavuconazole against opportunistic filamentous and dimorphic fungi. *Med Mycol* 2009; 47: 71–76.
243. Gadallah MF, White R, El-Shahawy MA, Abreo F, Oberle A, Work J. Peritoneal dialysis complicated by *Bipolaris hawaiiensis* peritonitis: successful therapy with catheter removal and oral itraconazole without the use of amphotericin-B. *Am J Nephrol* 1995; 15: 348–352.
244. Vartivarian SE, Anaissie EJ, Bodey GP. Emerging fungal pathogens in immunocompromised patients: classification, diagnosis, and management. *Clin Infect Dis* 1993; 17(suppl 2): 487–491.
245. De Hoog GS, Vitale RG. *Bipolaris*, *Exophiala*, *Scedosporium*, *Sporothrix* and other dematiaceous fungi. Chaper 125. In: Murray PR, Baron EJ, Jorgenson JH, Landry ML, Pfaller MA, eds, *Manual of clinical microbiology*, Vol. 2, 9th edn. Washington, DC: ASM Press, 2007; 1898–1917.
246. Guarro J. Comments on recent human infections caused by ascomycetes. *Med Mycol* 1998; 36: 349–350.
247. Abbott SP, Sigler L, McAleer R, McGough DA, Rinaldi MG, Mizell G. Fatal cerebral mycoses caused by the ascomycete *Chaetomium strumarium*. *J Clin Microbiol* 1995; 33: 2692–2698.
248. Anandi V, John TJ, Walter A *et al.* Cerebral phaeohyphomycosis caused by *Chaetomium globosum* in a renal transplant recipient. *J Clin Microbiol* 1989; 27: 2226–2229.
249. Aru A, Munk-Nielsen L, Federspiel BH. The soil fungus *Chaetomium* in the human paranasal sinuses. *Eur Arch Otorhinolaryngol* 1997; 254: 350–352.
250. Guppy KH, Thomas C, Thomas K, Anderson D. Cerebral fungal infections in the immunocompromised host: a literature review and a

new pathogen—*Chaetomium atrobrunneum*: case report. *Neurosurgery* 1998; 43: 1463–1469.
251. Hoppin EC, McCoy EL, Rinaldi MG. Opportunistic mycotic infection caused by *Chaetomium* in a patient with acute leukemia. *Cancer* 1983; 52: 555–556.
252. Lesire V, Hazouard E, Dequin PF, Delain M, Therizol-Ferly M, Legras A. Possible role of *Chaetomium globosum* in infection after autologous bone marrow transplantation. *Intensive Care Med* 1999; 25: 124–125.
253. Stiller MJ, Rosenthal S, Summerbell RC, Pollack J, Chan A. Onychomycosis of the toenails caused by *Chaetomium globosum*. *J Am Acad Dermatol* 1992; 26: 775–776.
254. Thomas C, Mileusnic D, Carey RB, Kampert M, Anderson D. Fatal *Chaetomium* cerebritis in a bone marrow transplant patient. *Hum Pathol* 1999; 30: 874–879.
255. Yeghen T, Fenelon L, Campbell CK *et al. Chaetomium* pneumonia in a patient with acute myeloid leukaemia. *J Clin Pathol* 1996; 49: 184–186.
256. von Arx JA, Figueras MJ, Guarro J. Sordariaceous ascomycetes without ascospore ejaculation. *Beih Nova Hedwigia* 1988; 94: 1–104.
257. Guarro J, Soler L, Rinaldi MG. Pathogenicity and antifungal susceptibility of *Chaetomium* species. *Eur J Clin Microbiol Infect Dis* 1995; 14: 613–618.
258. Serena C, Ortoneda M, Capilla J *et al. In vitro* activities of new antifungal agents against *Chaetomium* spp. and inoculum standardization. *Antimicrob Agents Chemother* 2003; 47: 3161–3164.
259. Horre R, de Hoog GS. Primary cerebral infections by melanized fungi: a review. *Stud Mycol* 1999; 43: 176–193.
260. Jayakeerthi SR, Dias M, Nagarathna S, Anandh B, Mahadevan A, Chandramuki A. Brain abscess due to *Cladophialophora bantiana*. *Indian J Med Microbiol* 2004; 22: 193–195.
261. Badali H, Gueidan C, Najafzadeh MJ, Bonifaz A, van den Ende AH, de Hoog GS. Biodiversity of the genus *Cladophialophora*. *Stud Mycol* 2008; 61: 175–191.
262. Chakrabarti A. Epidemiology of central nervous system mycoses. *Neurol India* 2007; 55: 191–197.
263. Feng PY, de Hoog GS, Najafzadeh MJ *et al. Cladophialophora abundans*, a novel species of Chaetothyriales isolated from the natural environment. *Mycol Prog* 2013. doi: 10.1007/s11557-013-0924-4.
264. Kantarcioglu AS, de Hoog GS. Infection of the central nervous system by melanized fungi: a review of cases presented between 1999 and 2004. *Mycoses* 2004; 47: 4–13.
265. Walz R, Bianchin M, Chaves ML, Cerski MR, Severo LC, Londero AT. Cerebral phaeohyphomycosis caused by *Cladophialophora bantiana* in a Brazilian drug abuser. *J Med Vet Mycol* 1997; 35: 427–431.
266. Parente JN, Talhari C, Ginter-Hanselmayer G *et al.* Subcutaneous phaeohyphomycosis in immunocompetent patients: two new cases caused by *Exophiala jeanselmei* and *Cladophialophora carrionii*. *Mycoses* 2011; 54: 265–269.
267. Silveira F, Nucci M. Emergence of black moulds in fungal disease: epidemiology and therapy. *Curr Opin Infect Dis* 2001; 14: 679–684.
268. Singh N, Chang FY, Gayowski T, Marino IR. Infections due to dematiaceous fungi in organ transplant recipients: case report and review. *Clin Infect Dis* 1997; 24: 369–374.
269. Patterson TF, Andriole VT, Zervos MJ, Therasse D, Kauffman CA. The epidemiology of pseudallescheriasis complicating transplantation: nosocomial and community-acquired infection. *Mycoses* 1990; 33: 297–302.
270. Revankar SG. Phaeohyphomycosis. *Infect Dis Clin North Am* 2006; 20: 609–620.
271. Lyons MK, Blair JE, Leslie KO. Successful treatment with voriconazole of fungal cerebral abscess due to *Cladophialophora bantiana*. *Clin Neurol Neurosurg* 2005; 107: 532–534.
272. Groll AH, Piscitelli SC, Walsh TJ. Clinical pharmacology of systemic antifungal agents: a comprehensive review of agents in clinical use, current investigational compounds, and putative targets for antifungal drug development. *Adv Pharmacol* 1998; 44: 343–499.
273. McGinnis MR, Pasarell L. *In vitro* evaluation of terbinafine and itraconazole against dematiaceous fungi. *Med Mycol* 1998; 36: 243–246.
274. McGinnis MR, Pasarell L. *In vitro* testing of susceptibilities of filamentous ascomycetes to voriconazole, itraconazole, and amphotericin B, with consideration of phylogenetic implications. *J Clin Microbiol* 1998; 36: 2353–2355.
275. Johnson LB, Kauffman CA. Voriconazole: a new triazole antifungal agent. *Clin Infect Dis* 2003; 36: 630–637.
276. Marine M, Pastor FJ, Guarro J. Combined antifungal therapy in a murine model of disseminated infection by *Cladophialophora bantiana*. *Med Mycol* 2009; 47: 45–49.
277. Da Cunha K, Sutton DA, Fothergill AW *et al. In vitro* antifungal susceptibility and molecular identity of 99 clinical isolates of the opportunistic fungal genus *Curvularia*. *Diagn Microbiol Infect Dis* 2013; 76: 168–174.
278. Bartynski JM, McCaffrey TV, Frigas E. Allergic fungal sinusitis secondary to dematiaceous fungi: *Curvularia lunata* and *Alternaria*. *Otolaryngology* 1990; 103: 32–39.
279. Posterano B, Scarano E, La Sorda M *et al.* Eosinophilic fungal rhinosinusitis due to the unusual pathogen *Curvularia inaequalis*. *Mycoses* 2010; 53: 84–88.
280. Moody MN, Tschen J, Mesko M. Cutaneous *Curvularia* infection of the forearm. *Cutis* 2012; 89: 65–68.
281. Tanabe K, Seino M, Senda S. Superficial mycoses of the breast caused by *Curvularia inaequalis*. *Eur J Dermatol* 2010; 20: 658–659.
282. Barde AK, Singh SM. A case of onychomycosis caused by *Curvularia lunata* (Wakker) Boedijn. *Mykosen* 1983; 26: 311–316.
283. Alvarez VC, Guelfand L, Pidone JC, Soloaga R, Ontivero P, Margari A. Allergic fungal rhinosinusitis caused by *Curvularia* sp. *Rev Iberoam Micol* 2011; 28: 104–106.
284. Guarro J, Akiti T, Horta RA *et al.* Mycotic keratitis due to *Curvularia senegalensis* and *in vitro* antifungal susceptibilities of *Curvularia* spp. *J Clin Microbiol* 1999; 37: 4170–4173.
285. Berbel RF, Casella AM, de Freitas D, Höfling-Lima AL. *Curvularia lunata* endophthalmitis. *J Ocul Pharmacol Ther* 2011; 27: 535–537.
286. Ehlers JP, Chavala SH, Woodward JA, Postel EA. Delayed recalcitrant fungal endophthalmitis secondary to *Curvularia*. *Can J Ophthalmol* 2011; 46: 199–200.
287. Janaki C, Sentamilselvi G, Janaki G, Devesh VR, Ajithados K. Eumycetoma due to *Curvularia lunata*. *Mycoses* 1999; 42: 345–346.
288. Berry AJ, Kerkering TM, Giordano AM, Chiancone J. Phaeomycotic sinusitis. *Pediatr Infect Dis J* 1984; 3: 150–152.
289. Ismail Y, Johnson RH, Wells MV, Pusavat J, Douglas K, Arsura EL. Invasive sinusitis with intracranial extension caused by *Curvularia lunata*. *Arch Intern Med* 1993; 153: 1604–1606.
290. Pimentel JD, Mahadevan K, Woodgyer A *et al.* Peritonitis due to *Curvularia inaequalis* in an elderly patient undergoing peritoneal dialysis and a review of six cases of peritonitis associated with other *Curvularia* spp. *J Clin Microbiol* 2005; 43: 4288–4292.
291. Unal A, Sipahioglu MH, Atalay MA *et al.* Tenckhoff catheter obstruction without peritonitis caused by *Curvularia* species. *Mycoses* 2011; 54: 363–364.
292. Killingsworth SM, Wetmore SJ. *Curvularia/Drechslera* sinusitis. *Laryngoscope* 1990; 100: 932–937.
293. Singh H, Irwin S, Falowski S *et al. Curvularia* fungi presenting as a large cranial base meningioma: case report. *Neurosurgery* 2008; 63: E177.
294. Bryan CS, Smith CW, Berg DE, Karp RB. *Curvularia lunata* endocarditis treated with terbinafine: case report. *Clin Infect Dis* 1993; 16: 30–32.
295. Lampert RP, Hotto JH, Donnelly WH, Shulman ST. Pulmonary and cerebral mycetoma caused by *Curvularia pallescens*. *J Pediatr* 1977; 91: 603–605.

296. de la Monte SM, Hutchins GM. Disseminated *Curvularia* infection. *Arch Pathol Lab Med* 1985; 109: 872–874.
297. Tessari G, Forni A, Ferretto R, Solbiati M, Faggian G, Mazzucco A. Lethal systemic dissemination from a cutaneous infection due to *Curvularia lunata* in a heart transplant recipient. *J Eur Acad Dermatol Venereol* 2003; 17: 440–442.
298. Ellis MB. *More dematiaceous hyphomycetes*. Kew, UK: Commonwealth Mycological Institute, 1976.
299. Brubaker LH, Steele JC Jr, Rissing JP. Cure of *Curvularia* pneumonia by amphotericin B in a patient with megakaryocytic leukemia. *Arch Pathol Lab Med* 1988; 112: 1178–1179.
300. Varughese S, David VG, Mathews MS, Tamilarasi V. A patient with amphotericin-resistant *Curvularia lunata* peritonitis. *Perit Dial Int* 2011; 31: 108–109.
301. Rohwedder JJ, Simmons JL, Colfer H, Gatmaitan B. Disseminated *Curvularia lunata* infection in a football player. *Arch Intern Med* 1978; 19: 940–941.
302. de Hoog GS, Vicente V, Caligiorne RB *et al.* Species diversity and polymorphism in the *Exophiala spinifera* clade containing opportunistic black yeast-like fungi. *J Clin Microbiol* 2003; 41: 4767–4778.
303. Zeng JS, Sutton DA, Fothergill AW, Rinaldi MG, Harrak MJ, de Hoog GS. Spectrum of clinically relevant *Exophiala* species in the United States. *J Clin Microbiol* 2007; 45: 3713–3720.
304. Badali H, Najafzadeh MJ, van Esbroeck M *et al.* The clinical spectrum of *Exophiala jeanselmei*, with a case report and *in vitro* antifungal susceptibility of the species. *Med Mycol* 2010; 48: 318–327.
305. Harris JE, Sutton DA, Rubin A, Wickes B, De Hoog GS, Kovarik C. *Exophiala spinifera* as a cause of cutaneous phaeohyphomycosis: case study and review of the literature. *Med Mycol* 2009; 47: 87–93.
306. Allred BJ. Subcutaneous phaeohyphomycosis due to *Exophiala jeanselmei* in an immunosuppressed patient: case report. *N Z Med J* 1990; 103: 321–322.
307. Aoyama Y, Nomura M, Yamanaka S, Ogawa Y, Kitajima Y. Subcutaneous phaeohyphomycosis caused by *Exophiala xenobiotica* in a non-Hodgkin lymphoma patient. *Med Mycol* 2009; 47: 95–99.
308. Aranegui B, Feal C, García CP *et al.* Subcutaneous phaeohyphomycosis caused by *Exophiala jeanselmei* treated with wide surgical excision and posaconazole: case report. *Int J Dermatol* 2013; 52: 255–256.
309. Rajendran C, Khaitan BK, Mittal R, Ramam M, Bhardwaj M, Datta KK. Phaeohyphomycosis caused by *Exophiala spinifera* in India. *Med Mycol* 2003; 41: 437–441.
310. Revankar SG. Dematiaceous fungi. *Mycoses* 2007; 50: 91–101.
311. Badali H, Chander J, Bayat M *et al.* Multiple subcutaneous cysts due to *Exophiala spinifera* in an immunocompetent patient. *Med Mycol* 2012; 50: 207–213.
312. Haase G, Skopnik H, Groten T, Kusenbach G, Posselt HG. Long-term fungal cultures from sputum of patients with cystic fibrosis. *Mycoses* 1991; 34(suppl 1): 373–376.
313. Chang CL, Kim DS, Park DJ, Kim HJ, Lee CH, Shin JH. Acute cerebral phaeohyphomycosis due to *Wangiella dermatitidis* accompanied by cerebrospinal fluid eosinophilia. *J Clin Microbiol* 2000; 38: 1965–1966.
314. Murayama N, Takimoto R, Kawai M, Hiruma M, Takamori K, Nishimura K. A case of subcutaneous phaeohyphomycotic cyst due to *Exophiala jeanselmei* complicated with systemic lupus erythematous. *Mycoses* 2003; 46: 145–148.
315. Duvic M, Lowe L, Rios A, MacDonald E, Vance P. Superficial phaeohyphomycosis of the scrotum in a patient with acquired immunodeficiency syndrome. *Arch Dermatol* 1987; 123: 1597–1599.
316. Silva MRR, Fernandes OFL, Costa CR *et al.* Subcutaneous phaeohyphomycosis by *Exophiala jeanselmei* in a cardiac transplant recipient. *Rev Inst Med Trop Sao Paulo* 2005; 47: 55–57.
317. Rallis E, Frangoulis E. Successful treatment of subcutaneous phaeohyphomycosis owing to *Exophiala jeanselmei* with oral terbinafine. *Int J Dermatol* 2006; 45: 1369–1370.
318. De Hoog GS, Matos T, Sudhadham M, Luijsterburg KF, Haase G. Intestinal prevalence of the neurotropic black yeast *Exophiala dermatitidis* in healthy and impaired individuals. *Mycoses* 2005; 48: 142–145.
319. Nweze EI, Ezute S. Isolation and antifungal susceptibility of *Exophiala dermatitidis* isolates from human stool samples in Nigeria. *Mycopathologia* 2010; 169: 201–206.
320. Najafzadeh MJ, Suh MK, Lee MH *et al.* Subcutaneous phaeohyphomycosis caused by *Exophiala equina*, with susceptibility to eight antifungal drugs. *J Med Microbiol* 2013; 62: 797–800.
321. Al-Abdely HM. Management of rare fungal infections. *Curr Opin Infect Dis* 2004; 17: 527–532.
322. Chuan MT, Wu MC. Subcutaneous phaeohyphomycosis caused by *Exophiala jeanselmei*: successful treatment with itraconazole. *Int J Dermatol* 1995; 34: 563–566.
323. Ajanee N, Alam M, Holmberg K, Khan J. Brain abscess caused by *Wangiella dermatitidis*: case report. *Clin Infect Dis* 1996; 23: 197–198.
324. Chua JD, Gordon SM, Banbury J, Hall GS, Procop GW. Relapsing *Exophiala jeanselmei* phaeohyphomycosis in a lung-transplant patient. *Transpl Infect Dis* 2001; 3: 235–238.
325. Gold WL, Vellend H, Salit IE *et al.* Successful treatment of systemic and local infections due to *Exophiala* species. *Clin Infect Dis* 1994; 19: 339–341.
326. Kan T, Takahagi S, Kamegashira A, Ooiwa H, Yaguchi T, Hide M. Disseminated subcutaneous phaeohyphomycosis caused by *Exophiala oligosperma* in a patient with Wegener's granulomatosis. *Acta Derm Venereol* 2013; 93: 356–357.
327. Kenney RT, Kwon-Chung KJ, Waytes AT *et al.* Successful treatment of systemic *Exophiala dermatitidis* infection in a patient with chronic granulomatous disease. *Clin Infect Dis* 1992; 14: 235–242.
328. Morio F, Berre JY, Garcia-Hermoso D *et al.* Phaeohyphomycosis due to *Exophiala xenobiotica* as a cause of fungal arthritis in an HIV-infected patient. *Med Mycol* 2012; 50: 513–517.
329. Mukaino T, Koga T, Oshita Y, Narita Y, Obata S, Aizawa H. *Exophiala dermatitidis* infection in non-cystic fibrosis bronchiectasis. *Respir Med* 2006; 100: 2069–2071.
330. Nachman S, Alpan O, Malowitz R, Spitzer ED. Catheter-associated fungemia due to *Wangiella* (*Exophiala*) *dermatitidis*. *J Clin Microbiol* 1996; 34: 1011–1013.
331. Patel AK, Patel KK, Darji P, Singh R, Shivaprakash MR, Chakrabarti A. *Exophiala dermatitidis* endocarditis on native aortic valve in a postrenal transplant patient and review of literature on *E. dermatitidis* infections. *Mycoses* 2013; 56: 365–372.
332. Tintelnot K, de Hoog GS, Thomas E, Steudel WI, Huebner K, Seeliger HP. Cerebral phaeohyphomycosis caused by an *Exophiala* species. *Mycoses* 1991; 34: 239–244.
333. Woo PC, Ngan AH, Tsang CC *et al.* Clinical spectrum of *Exophiala infections* and a novel *Exophiala* species, *Exophiala hongkongensis*. *J Clin Microbiol* 2013; 51: 260–267.
334. Badali H, de Hoog GS, Sudhadham M, Meis JF. Microdilution *in vitro* antifungal susceptibility of *Exophiala dermatitidis*, a systemic opportunist. *Med Mycol* 2011; 49: 819–824.
335. Espinel-Ingroff A. *In vitro* fungicidal activities of voriconazole, itraconazole, and amphotericin B against opportunistic moniliaceous and dematiaceous fungi. *J Clin Microbiol* 2001; 39: 954–958.
336. Fothergill AW, Rinaldi MG, Sutton DA. Antifungal susceptibility testing of *Exophiala* spp.: a head-to-head comparison of amphotericin B, itraconazole, posaconazole and voriconazole. *Med Mycol* 2009; 47: 41–43.
337. Meletiadis J, Meis JF, de Hoog GS, Verweij PE. *In vitro* susceptibilities of 11 clinical isolates of *Exophiala* species to six antifungal drugs. *Mycoses* 2000; 43: 309–312.
338. Vitale RG, De Hoog GS, Verweij PE. *In vitro* activity of amphotericin B, itraconazole, terbinafine and 5-flucytosine against *Exophiala spinifera*

and evaluation of post-antifungal effects. *Med Mycol* 2003; 41: 301–307.
339. Calvo E, Pastor FJ, Guarro J. Antifungal therapies in murine disseminated phaeohyphomycoses caused by *Exophiala* species. *J Antimicrob Chemother* 2010; 65: 1455–1459.
340. Da Cunha KC, Sutton DA, Gené J, Capilla J, Cano J, Guarro J. Molecular identification and *in vitro* response to antifungal drugs of clinical isolates of *Exserohilum*. *Antimicrob Agents Chemother* 2012; 56: 4951–4954.
341. Adler A, Yaniv I, Samra Z *et al.* *Exserohilum*: an emerging human pathogen. *Eur J Clin Microbiol Infect Dis* 2006; 25: 247–253.
342. Agarwal A, Singh SM. A case of cutaneous phaeohyphomycosis caused by *Exserohilum rostratum*, its *in vitro* sensitivity and review of literature. *Mycopathologia* 1995; 131: 9–12.
343. Al-Attar A, Williams CG, Redett RJ. Rare lower extremity invasive fungal infection in an immunosuppressed patient: *Exserohilum longirostratum*. *Plast Reconstr Surg* 2006; 117: 44e–47e.
344. Anandi V, George JA, Thomas R, Brahmadathan KN, John TJ. Phaeohyphomycosis of the eye caused by *Exserohilum rostratum* in India. *Mycoses* 1991; 34: 489–491.
345. Aquino VM, Norvell JM, Krisher K, Mustafa MM. Fatal disseminated infection due to *Exserohilum rostratum* in a patient with aplastic anemia: case report and review. *Clin Infect Dis* 1995; 20: 176–178.
346. Bhigjee AI, Parmanand V, Hoosen AA *et al.* Disseminated *Exserohilum* infection. *J Infect* 1993; 26: 336–337.
347. Derber C, Elam K, Bearman G. Invasive sinonasal disease due to dematiaceous fungi in immunocompromised individuals: case report and review of the literature. *Int J Infect Dis* 2010; 14(suppl 3): e329–e332.
348. Douer D, Goldschmied-Reouven A, Segev S, Ben-Bassat I. Human *Exserohilum* and *Bipolaris* infections: report of *Exserohilum* nasal infection in a neutropenic patient with acute leukemia and review of the literature. *J Med Vet Mycol* 1987; 25: 235–241.
349. Hsu MM, Lee JY. Cutaneous and subcutaneous phaeohyphomycosis caused by *Exserohilum rostratum*. *J Am Acad Dermatol* 1993; 28: 340–344.
350. Juhas E, Reyes-Mugica M, Michaels MG, Grunwaldt LJ, Gehris RP. *Exserohilum* infection in an immunocompromised neonate. *Pediatr Dermatol* 2013; 30: e232–e233.
351. Lavoie SR, Espinel-Ingroff A, Kerkering T. Mixed cutaneous phaeohyphomycosis in a cocaine user. *Clin Infect Dis* 1993; 17: 114–116.
352. Levy I, Stein J, Ashkenazi S, Samra Z, Livni G, Yaniv I. Ecthyma gangrenosum caused by disseminated *Exserohilum* in a child with leukemia: a case report and review of the literature. *Pediatr Dermatol* 2003; 20: 495–497.
353. Lin SC, Sun PL, Ju YM, Chan YJ. Cutaneous phaeohyphomycosis caused by *Exserohilum rostratum* in a patient with cutaneous T-cell lymphoma. *Int J Dermatol* 2009; 48: 295–298.
354. McGinnis MR, Rinaldi MG, Winn RE. Emerging agents of phaeohyphomycosis: pathogenic species of *Bipolaris* and *Exserohilum*. *J Clin Microbiol* 1986; 24: 250–259.
355. Saint-Jean M, St-Germain G, Laferrière C, Tapiero B. Hospital-acquired phaeohyphomycosis due to *Exserohilum rostratum* in a child with leukemia. *Can J Infect Dis Med Microbiol* 2007; 18: 200–202.
356. Togitani K, Kobayashi M, Sakai M *et al.* Ethmoidal sinusitis caused by *Exserohilum rostratum* in a patient with malignant lymphoma after non-myeloablative allogeneic peripheral blood stem cell transplantation. *Transpl Infect Dis* 2007; 9: 137–141.
357. Bouchon CL, Greer DL, Genre CF. Corneal ulcer due to *Exserohilum longirostratum*. *Am J Clin Pathol* 1994; 101: 452–455.
358. Joseph NM, Kumar MA, Stephen S, Kumar S. Keratomycosis caused by *Exserohilum rostratum*. *Indian J Pathol Microbiol* 2012; 55: 248–249.
359. Kanungo R, Srinivasan R. Corneal phaeohyphomycosis due to *Exserohilum rostratum*. A case report and brief review. *Acta Ophthalmol Scand* 1996; 74: 197–199.
360. Mathews MS, Maharajan SV. *Exserohilum rostratum* causing keratitis in India. *Med Mycol* 1999; 37: 131–132.
361. Peerapur BV, Rao SD, Patil S, Mantur BG. Keratomycosis due to *Exserohilum rostratum*—a case report. *Indian J Med Microbiol* 2004; 22: 126–127.
362. Burges GE, Walls CT, Maize JC. Subcutaneous phaeohyphomycosis caused by *Exserohilum rostratum* in an immunocompetent host. *Arch Dermatol* 1987; 123: 1346–1350.
363. Colton R, Zeharia A, Karmazyn B *et al.* *Exserohilum* sinusitis presenting as proptosis in a healthy adolescent male. *J Adolesc Health* 2002; 30: 73–75.
364. Tieman JM, Furner BB. Phaeohyphomycosis caused by *Exserohilum rostratum* mimicking hemorrhagic herpes zoster. *J Am Acad Dermatol* 1991; 25: 852–854.
365. Lasala PR, Smith MB, McGinnis MR, Sackey K, Patel JA, Qiu S. Invasive *Exserohilum* sinusitis in a patient with aplastic anemia. *Pediatr Infect Dis J* 2005; 24: 939–941.
366. Lockhart SR, Pham CD, Gade L *et al.* Preliminary laboratory report of fungal infections associated with contaminated methylprednisolone injections. *J Clin Microbiol* 2013; 51: 2654–2661.
367. Lyons JL, Gireesh ED, Trivedi JB *et al.* Fatal *Exserohilum* meningitis and central nervous system vasculitis after cervical epidural methyl prednisolone injection. *Ann Intern Med* 2012; 157: 835–836.
368. Ritter JM, Muehlenbachs A, Blau DM *et al.* *Exserohilum* infections associated with contaminated steroid injections: a clinicopathologic review of 40 cases. *Am J Pathol* 2013; 183: 881–892.
369. Smith RM, Schaefer MK, Kainer MA *et al.* Fungal infections associated with contaminated methylprednisolone injections. *N Engl J Med* 2013; 369: 1598–1609.
370. Gade L, Scheel CM, Pham CD *et al.* Detection of fungal DNA in human body fluids and tissues during a multistate outbreak of fungal meningitis and other infections. *Eukaryot Cell* 2013; 12: 677–683.
371. Zhao Y, Petraitiene R, Walsh TJ, Perlin DS. A real-time PCR assay for rapid detection and quantification of *Exserohilum rostratum*, a causative pathogen of fungal meningitis associated with injection of contaminated methylprednisolone. *J Clin Microbiol* 2013; 51: 1034–1036.
372. Moneymaker CS, Shenep JL, Pearson TA *et al.* Primary cutaneous phaeohyphomycosis due to *Exserohilum rostratum* (*Drechslera rostrata*) in a child with leukemia. *Pediatr Infect Dis J* 1986; 5: 380–382.
373. Avivi I, Oren I, Haddad N *et al.* Stem cell transplantation post invasive fungal infection is a feasible risk. *Am J Hematol* 2004; 75: 6–11.
374. Stevens DA. Reflections on the approach to treatment of a mycologic disaster. *Antimicrob Agents Chemother* 2013; 57: 1567–1572.
375. Pappas PG, Kontoyiannis DP, Perfect JR, Chiller TM. Real-time treatment guidelines: considerations during the *Exserohilum rostratum* outbreak in the United States. *Antimicrob Agents Chemother* 2013; 57: 1573–1576.
376. Smith RM, Tipple M, Chaudry MN, Schaefer MK, Park BJ. Relapse of fungal meningitis associated with contaminated methylprednisolone. *N Engl J Med* 2013; 368: 2535–2536.
377. Kontoyiannis DP, Perlin DS, Roilides E, Walsh TJ. What can we learn and what do we need to know amidst the iatrogenic outbreak of *Exserohilum rostratum* meningitis? *Clin Infect Dis* 2013; 57: 853–859.
378. Najafzadeh MJ, Badali H, Illnait-Zaragozi MT, De Hoog GS, Meis JF. *In vitro* activities of eight antifungal drugs against 55 clinical isolates of *Fonsecaea* spp. *Antimicrob Agents Chemother* 2010; 54: 1636–1638.
379. Badali H, Fernández-González M, Mousavi B *et al.* Chromoblastomycosis due to *Fonsecaea pedrosoi* and *F. monophora* in Cuba. *Mycopathologia* 2013; 175: 439–444.
380. De Hoog GS, Attili-Angelis D, Vicente VA *et al.* Molecular ecology and pathogenic potential of *Fonsecaea* species. *Med Mycol* 2004; 42: 405–416.

381. Kondo M, Hiruma M, Nishioka Y *et al.* A case of chromomycosis caused by *Fonsecaea pedrosoi* and a review of reported cases of dematiaceous fungal infection in Japan. *Mycoses* 2005; 48: 221–225.
382. Pindycka-Piaszczyńska M, Krzyściak P, Piaszczyński M *et al.* Chromoblastomycosis as an endemic disease in temperate Europe: first confirmed case and review of the literature. *Eur J Clin Microbiol Infect Dis* 2013; Epub ahead of print.
383. Guerra RS, do Nascimento MM, Miesch S *et al.* Black yeast biota in the mangrove, in search of the origin of the lethargic crab disease (LCD). *Mycopathologia* 2013; 175: 421–430.
384. Marques SG, Silva Cde MP, Saldanha PC *et al.* Isolation of *Fonsecaea pedrosoi* from the shell of the Babassu coconut (*Orbignya phalerata* Martius) in the Amazon region of Maranhao Brazil. *Japan J Med Mycol* 2006; 47: 305–311.
385. Najafzadeh MJ, Rezusta A, Cameo MI *et al.* Successful treatment of chromoblastomycosis of 36 years duration caused by *Fonsecaea monophora*. *Med Mycol* 2010; 48: 390–393.
386. Najafzadeh MJ, Sun J, Vicente V *et al. Fonsecaea nubica* sp. nov, a new agent of human chromoblastomycosis revealed using molecular data. *Med Mycol* 2010; 48: 800–806.
387. Surash S, Tyagi A, De Hoog GS *et al.* Cerebral phaeohyphomycosis caused by *Fonsecaea monophora*. *Med Mycol* 2005; 43: 465–472.
388. Abliz P, Fukushima K, Takizawa K, Nishimura K. Identification of pathogenic dematiaceous fungi and related taxa based on large subunit ribosomal DNA D1/D2 domain sequence analysis. *FEMS Immunol Med Microbiol* 2004; 40: 41–49.
389. Gunde-Cimerman N, Zalar P, de Hoog GS, Plemenitas A. Hypersaline waters in salterns—natural ecological niches for halophilic black yeasts. *FEMS Microbiol Ecol* 2000; 32: 235–240.
390. Zalar P, de Hoog GS, Gunde-Cimerman N. Ecology of halotolerant dothideaceous black yeasts. *Stud Mycol* 1999; 43: 38–48.
391. Bonifaz A, Badali H, de Hoog GS *et al.* Tinea nigra by *Hortaea werneckii*, a report of 22 cases from Mexico. *Stud Mycol* 2008; 61: 77–82.
392. Pegas JR, Criado PR, Lucena SK, de Oliveira MA. Tinea nigra: report of two cases in infants. *Pediatr Dermatol* 2003; 20: 315–317.
393. Ruiz-Maldonado R, Duran-McKinster C, Tamayo-Sanchez L, Orozco-Covarrubias ML. Dermatosis neglecta: dirt crusts simulating verrucous nevi. *Arch Dermatol* 1999; 135: 728–729.
394. Tseng SS, Whittier S, Miller SR, Zalar GL. Bilateral tinea nigra plantaris and tinea nigra plantaris mimicking melanoma. *Cutis* 1999; 64: 265–268.
395. Huber CE, La Berge T, Schwiesow T, Carroll K, Bernstain PS, Mamalis N. *Exophiala werneckii* endophthalmitis following cataract surgery in an immunocompetent individual. *Ophthalmic Surg Lasers* 2000; 31: 417–422.
396. Ng KP, Soo-Hoo TS, Na SL *et al.* The mycological and molecular study of *Hortaea werneckii* isolated from blood and splenic abscess. *Mycopathologia* 2005; 159: 495–500.
397. Uijthof JM, de Cock AW, de Hoog GS, Quint WG, van Belkum A. Polymerase chain reaction-mediated genotyping of *Hortaea werneckii*, causative agent of tinea nigra. *Mycoses* 1994; 37: 307–312.
398. Punithalingam E, Waterston JM. *CMI descriptions of pathogenic fungi and bacteria no. 274. Hendersonula toruloidea*. Kew, UK: Commonwealth Mycological Institute, 1970.
399. Sigler L, Summerbell RC, Poole L *et al.* Invasive *Nattrassia mangiferae* infections: case report, literature review, and therapeutic and taxonomic appraisal. *J Clin Microbiol* 1997; 35: 433–440.
400. Madrid H, Ruiz-Cendoya M, Cano J, Stchigel A, Orofino R, Guarro J. Genotyping and *in vitro* antifungal susceptibility of *Neoscytalidium dimidiatum* isolates from different origins. *Int J Antimicrob Agents* 2009; 34: 351–354.
401. Tan DH, Sigler L, Gibas CF, Fong IW. Disseminated fungal infection in a renal transplant recipient involving *Macrophomina phaseolina* and *Scytalidium dimidiatum*: case report and review of taxonomic changes among medically important members of the Botryosphaeriaceae. *Med Mycol* 2008; 46: 285–292.
402. Hay RJ, Moore MK. Clinical features of superficial fungal infections caused by *Hendersonula toruloidea* and *Scytalidium hyalinum*. *Br J Dermatol* 1984; 110: 673–683.
403. Mariat F, Liautaud B, Liautaud M, Marill FG. *Hendersonula toruloidea*, causative agent of a fungal verrucous dermatitis observed in Algeria. *Sabouraudia* 1978; 16: 133–140.
404. Moutran R, Maatouk I, Wehbé J, Abadjian G, Obeid G. Subcutaneous infection spread by *Scytalidium* (*Neoscytalidium*) *dimidiatum*. *Ann Dermatol Venereol* 2012; 139: 204–208.
405. Nattrass RM. A new species of *Hendersonula* (*H. toruloidea*) on deciduous trees in Egypt. *Trans Br Mycol Soc* 1933; 18: 189–198.
406. Crous PW, Slippers B, Wingfield MJ *et al.* Phylogenetic lineages in the *Botriosphaeriaceae*. *Stud Mycol* 2006; 55: 235–253.
407. Barua P, Barua S, Borkakoty B, Mahanta J. Onychomycosis by *Scytalidium dimidiatum* in green tea leaf pluckers: report of two cases. *Mycopathologia* 2007; 164: 193–195.
408. Cursi IB, Silva RT, Succi IB, Bernardes-Engemann AR, Orofino-Costa R. Onychomycosis due to *Neoscytalidium* treated with oral terbinafine, ciclopirox nail lacquer and nail abrasion: a pilot study of 25 patients. *Mycopathologia* 2013; 175: 75–82.
409. Guarro J, Pujol I, Aguilar C, Ortoneda M. *In vitro* antifungal susceptibility of nondermatophytic keratinophilic fungi. In: Kushwaha RKS, Guarro J, eds, *Biology of dermatophytes and other keratinophilic fungi*. Bilbao, Spain: Revista Iberoamericana de Micologia, 2000; 142–147.
410. Ruíz-Cendoya M, Madrid H, Pastor J, Guarro J. Evaluation of antifungal therapy in a neutropenic murine model of *Neoscytalidium dimidiatum* infection. *Int J Antimicrob Agents* 2010; 35: 152–155.
411. Samerpitak K, Van der Linde E, Choi HJ *et al.* Taxonomy of *Ochroconis*, genus including opportunistic pathogens on humans and animals. *Fungal Divers* 2013. doi: 10.1007/s13225-013-0253-6.
412. Odell JA, Alvarez S, Cvitkovich DG, Cortese DA, McComb BL. Multiple lung abscesses due to *Ochroconis gallopavum*, a dematiaceous fungus, in a nonimmunocompromised wood pulp worker. *Chest* 2000; 118: 1503–1505.
413. Kralovic SM, Rhodes JC. Pheohyphomycosis caused by *Dactylaria* (human Dactylariosis)—report of a case with review of the literature. *J Infect* 1995; 31: 107–113.
414. Rippon JW, Gerhold R, Heath M. Thermophillic and thermotolerant fungi isolated from the thermal effluent of nuclear power generating reactors: dispersal of human opportunistic and veterinary pathogenic fungi. *Mycopathologia* 1980; 70: 169–179.
415. Shoham S, Pic-Aluas L, Taylor J *et al.* Transplant-associated *Ochroconis gallopava* infections. *Transpl Infect Dis* 2008; 10: 442–448.
416. Tansey MR, Fliermans CB, Kern CD. Aerosol dissemination of veterinary pathogenic and human opportunistic thermophilic and thermotolerant fungi from thermal effluents of nuclear production reactors. *Mycopathologia* 1979; 69: 91–115.
417. Waldrip DW, Padhye AA, Ajello L *et al.* Isolation of *Dactylaria gallopava* from broiler-house litter. *Avian Dis* 1974; 18: 445–451.
418. Sides EH III, Benson JD, Padhye AA. Phaeohyphomycotic brain abscess due to *Ochroconis gallopavum* in a patient with malignant lymphoma of a large cell type. *J Med Vet Mycol* 1991; 29: 317–322.
419. Terreni AA, Disalvo AF, Baker AS *et al.* Disseminated *Dactylaria gallopava* infection in a diabetic patient with chronic lymphocytic leukemia of the T-cell type. *Am J Clin Pathol* 1990; 94: 104–107.
420. Bravo LO, Ngamy V. *Ochroconis gallopavum* and *Mycobacterium avium* intracellulare in an immunocompetent patient. *Chest* 2004; 126: 975S.
421. Fader RC, McGinnis MR. Infections caused by dematiaceous fungi: chromoblastomycosis and phaeohyphomycosis. *Infect Dis Clin North Am* 1988; 2: 925–938.

422. Fukushima N, Mannen K, Okamoto S, Shinogi T, Nishimoto K *et al.* Disseminated *Ochroconis gallopavum* infection in a chronic lymphocytic leukemia: a case report and review of the literature on hematological malignancies. *Intern Med* 2005; 44: 879–882.
423. Jenney A, Maslen M, Bergin P, Tang SK, Esmore D, Fuller A. Pulmonary infection due to *Ochroconis gallopavum* treated successfully after orthotopic heart transplantation. *Clin Infect Dis* 1998; 26: 236–237.
424. Malani PN, Bleicher JJ, Kauffman CA *et al.* Disseminated *Dactylaria constricta* infection in a renal transplant recipient. *Transpl Infect Dis* 2001; 3: 40–43.
425. Randall CJ, Owen DM, Kirkpatrick KS. Encephalitis in broiler chickens caused by a hyphomycete resembling *Dactylaria gallopava*. *Avian Pathol* 1981; 10: 31–41.
426. Wang TK, Chiu W, Chim S, Chan TM, Wong SS, Ho PL. Disseminated *Ochroconis gallopavum* infection in a renal transplant recipient: the first reported case and a review of the literature. *Clin Nephrol* 2003; 60: 415–423.
427. Wong JS, Schousboe MI, Metcalf SS *et al.* *Ochroconis gallopava* peritonitis in a cardiac transplant patient on continuous ambulatory peritoneal dialysis. *Transpl Infect Dis* 2010; 12: 455–458.
428. Brokalaki EI, Sommerwerck U, von Heinegg EH, Hillen U. *Ochroconis gallopavum* infection in a lung transplant recipient: report of a case. *Transplant Proc* 2012; 44: 2778–2780.
429. Cardeau-Desangles I, Fabre A, Cointault O *et al.* Disseminated *Ochroconis gallopava* infection in a heart transplant patient. *Transpl Infect Dis* 2013; 15: E115–E118.
430. Mayer N, Bastani B. A case of pulmonary cavitary lesion due to *Dactylaria constricta* var. *gallopava* in a renal transplant patient. *Nephrology* 2009; 14: 262.
431. Qureshi ZA, Kwak EJ, Nguyen MH, Silveira FP. *Ochroconis gallopava*: a dematiaceous mold causing infections in transplant recipients. *Clin Transplant* 2012; 26: E17–E23.
432. Bowyer JD, Johnson EM, Horn EH *et al.* *Ochroconis gallopava* endophthalmitis in fludarabine treated chronic lymphocytic leukaemia. *Br J Ophthalmol* 2000; 84: 117.
433. Vukmir RB, Kusne S, Linden P *et al.* Successful therapy for cerebral phaeohyphomycosis due to *Dactylaria gallopava* in a liver transplant recipient. *Clin Infect Dis* 1994; 19: 714–719.
434. Meriden Z, Marr KA, Lederman HM *et al.* *Ochroconis gallopava* infection in a patient with chronic granulomatous disease: case report and review of the literature. *Med Mycol* 2012; 50: 883–889.
435. Fukushiro R, Udagawa S, Kawashima Y, Kawamura Y. Subcutaneous abscesses caused by *Ochroconis gallopavum*. *J Med Vet Mycol* 1986; 24: 175–182.
436. Kumaran MS, Bhagwan S, Savio J *et al.* Disseminated cutaneous *Ochroconis gallopava* infection in an immunocompetent host: an unusual concurrence—a case report and review of cases reported. *Int J Dermatol* 2013; doi: 10.1111/j.1365-4632.2012.05841.x.
437. Ge YP, Lv GX, Shen YN *et al.* First report of subcutaneous phaeohyphomycosis caused by *Ochroconis tshawytschae* in an immunocompetent patient. *Med Mycol* 2012; 50: 637–640.
438. Mostert L, Groenewald JZ, Summerbell RC *et al.* Species of *Phaeoacremonium* associated with infections in humans and environmental reservoirs in infected woody plants. *J Clin Microbiol* 2005; 43: 1752–1767.
439. Mostert L *et al.* Taxonomy and pathology of *Tonginia* and its *Phaeocacremonium* anamorphs. *Stud Mycol* 2006; 54: 1–113.
440. Padhye AA, Davis MS, Baer D *et al.* Phaeohyphomycosis caused by *Phaeoacremonium inflatipes*. *J Clin Microbiol* 1998; 36: 2763–2765.
441. Fincher RM, Fisher JF, Padhye AA, Ajello L, Steele JC Jr. Subcutaneous phaeohyphomycotic abscess caused by *Phialophora parasitica* in a renal allograft recipient. *J Med Vet Mycol* 1988; 26: 311–314.
442. Reyes FA, Buchman MT. *Phialophora richardsiae* infection mimicking a soft tissue mass of a finger. *J Hand Surg [Br]* 1986; 11: 274.
443. Torstrick RF, Harrison K, Heckman JD *et al.* Chronic bursitis caused by *Phialophora richardsiae*. *J Bone Joint Surg Am* 1979; 61: 772–774.
444. Aroca A, Raposo R. PCR-based strategy to detect and identify species of *Phaeoacremonium* causing grapevine diseases. *Appl Environ Microbiol* 2007; 73: 2911–2918.
445. Espinel-Ingroff A, Boyle K, Sheehan DJ. *In vitro* antifungal activities of voriconazole and reference agents as determined by NCCLS methods: review of the literature. *Mycopathologia* 2001; 150: 101–115.
446. Espinel-Ingroff A. *In vitro* antifungal activities of anidulafungin and micafungin, licensed agents and the investigational triazole posaconazole as determined by NCCLS methods for 12,052 fungal isolates: review of the literature. *Rev Iberoam Micol* 2003; 20: 121–136.
447. Tullio V, Banche G, Allizond V *et al.* Non-dermatophyte moulds as skin and nail foot mycosis agents: *Phoma herbarum*, *Chaetomium globosum* and *Microascus cinereus*. *Fungal Biol* 2010; 114: 345–349.
448. Boerema GH, de Gruytere J, Noordeloos ME, Hamers MEC. *Phoma* identification manual. Differentiation of specific and infra-specific taxa in culture. Wallingford, UK: Cabi Publishing, 2004; 470.
449. Arrese JE, Pierard-Franchimont C, Pierard GE. Unusual mould infection of the human stratum corneum. *J Med Vet Mycol* 1997; 35: 225–227.
450. Everett JE, Busick NP, Sielaff T, Wahoff DC, Dunn DL. A deeply invasive *Phoma* species infection in a renal transplant recipient. *Transplant Proc* 2003; 35: 1387–1389.
451. Hirsh AH, Schiff TA. Subcutaneous phaeohyphomycosis caused by an unusual pathogen: *Phoma* species. *J Am Acad Dermatol* 1996; 34: 679–680.
452. Rai MK. *Phoma sorghina* infection in human being. *Mycopathologia* 1989; 105: 167–170.
453. Rosen T, Rinaldi MJ, Tschen JA, Stern JK, Cernoch P. Cutaneous lesions due to *Pleurophoma* (*Phoma*) complex. *South Med J* 1996; 89: 431–433.
454. Shukla NP, Rajak RK, Agarwal GP, Gupta DK. *Phoma minutispora* as a human pathogen. *Mykosen* 1984; 27: 255–258.
455. Young NA, Kwon-Chung KJ, Freeman J. Subcutaneous abscess caused by *Phoma* sp. resembling *Pyrenochaeta romeroi*: unique fungal infection occurring in immunosuppressed recipient of renal allograft. *Am J Clin Pathol* 1973; 59: 810–816.
456. Zaitz C, Heins-Vaccari EM, de Freitas RS *et al.* Subcutaneous phaeohyphomycosis caused by *Phoma cava*. Report of a case and review of the literature. *Rev Inst Med Trop Sao Paulo* 1997; 39: 43–48.
457. Errera MH, Barale PO, Nourry H *et al.* Usefulness of voriconazole in treatment of *Phoma glomerata* after penetrating injury. *J Fr Ophtalmol* 2008; 31: 62–66.
458. Rishi K, Font RL. Keratitis caused by an unusual fungus, *Phoma* species. *Cornea* 2003; 22: 166–168.
459. Balis E, Velegraki A, Fragou A, Pefanis A, Kalabokas T, Moutokalakis T. Lung mass caused by *Phoma exigua*. *Scand J Infect Dis* 2006; 38: 552–555.
460. Roehm CE, Salazar JC, Hagstrom N, Valdez TA. *Phoma* and *Acremonium* invasive fungal rhinosinusitis in congenital acute lymphocytic leukemia and literature review. *Int J Pediatr Otorhinolaryngol* 2012; 76: 1387–1391.
461. Baker JG, Salkin IF, Forgacs P, Haines JH, Kemna ME. First report of subcutaneous phaeohyphomycosis of the foot caused by *Phoma minutella*. *J Clin Microbiol* 1987; 25: 2395–2397.
462. Badali H, Chander J, Gulati N *et al.* Subcutaneous phaeohyphomycotic cyst caused by *Pyrenochaeta romeroi*. *Med Mycol* 2010; 48: 763–768.
463. Baylet R, Camain R, Chabal J, Izarn R. Recent contribution to the study of mycetoma in Senegal. *Neotestudina rosatii*, *Pyrenochaeta romeroi*, *Aspergillus nidulans*. *Bull Soc Med Afr Noire Lang Fr* 1968; 13: 311–313.
464. English MP. Infection of the finger-nail by *Pyrenochaeta unguishominis*. *Br J Dermatol* 1980; 103: 91–93.

465. Ferrer C, Perez-Santonja JJ, Rodriguez AE *et al.* New *Pyrenochaeta* species causing keratitis. *J Clin Microbiol* 2009; 47: 1595–1598.
466. Girard C, Dereure O, Rispail P, Durand L, Guilhou JJ. Subcutaneous phaeohyphomycosis due to *Pyrenochaeta romeroi* in a patient with leprosy. *Acta Derm Venereol* 2004; 84: 154–155.
467. Serrano JA, Pisano ID, Lopez FA. Black grain minimycetoma caused by *Pyrenochaeta mackinnonii*, the first clinical case of eumycetoma reported in Barinas state, Venezuela. *J Mycol Med* 1998; 8: 34–39.
468. Thammayya A, Sanyal M, Basu N. *Pyrenochaeta romeroi* causing mycetoma pedis in India. *J Indian Med Assoc* 1979; 73: 66–67.
469. De Gruyter J, Aveskamp MM, Woudenberg JHC *et al.* Molecular phylogeny of *Phoma* and allied anamorph genera: towards a reclassification of the *Phoma* complex. *Mycol Res* 2009; 113: 508–519.
470. Andre M, Brumpt V, Destombes P, Segretain G. Fungal mycetoma with black grains due to *Pyrenochaeta romeroi* in Cambodia. *Bull Soc Pathol Exot Filiales* 1968; 61: 108–112.
471. Borelli D. Opportunistic fungi as producers of gray colonies and mycetomata. *Dermatologica* 1979; 159: 168–174.
472. David-Chausse J, Texier L, Darrasse H, Moulinier C. Autochthonous mycetoma of the foot due to *Pyrenochaeta romeroi*. *Bull Soc Fr Dermatol Syphiligr* 1968; 75: 452–453.
473. Sutton DA, Fothergill AW, Rinaldi MG. *Guide to clinically significant fungi*. Baltimore, MD: Williams & Wilkins Co., 1998.
474. de Hoog GS. *Rhinocladiella* and allied genera. *Stud Mycol* 1977; 15: 1–140.
475. Kanj SS, Amr SS, Roberts GD. *Ramichloridium mackenziei* brain abscess: report of two cases and review of the literature. *Med Mycol* 2001; 39: 97–102.
476. del Palacio-Hernanz A, Moore MK, Campbell CK, del Palacio-Medel A, Del Castillo R. Infection of the central nervous system by *Rhinocladiella atrovirens* in a patient with acquired immunodeficiency syndrome. *J Med Vet Mycol* 1989; 27: 127–130.
477. Naim UR, Mahgoub ES, Chagla AH. Fatal brain abscesses caused by *Ramichloridium obovoideum*: report of three cases. *Acta Neurochir (Wien)* 1988; 93: 92–95.
478. Badali H, Chander J, Bansal S *et al.* First autochthonous case of *Rhinocladiella mackenziei* cerebral abscess outside the Middle East. *J Clin Microbiol* 2010; 48: 646–649.
479. Campbell CK, Al-Hedaithy SSA. Phaeohyphomycosis of the brain caused by *Ramichloridium mackenziei* sp. nov. in Middle Eastern countries. *J Med Vet Mycol* 1993; 31: 325–332.
480. Badali H, Bonifaz A, Barrón-Tapia T *et al. Rhinocladiella aquaspersa*, proven agent of verrucous skin infection and a novel type of chromoblastomycosis. *Med Mycol* 2010; 48: 696–703.
481. Podnos YD, Anastasio P, De La ML, Kim RB. Cerebral phaeohyphomycosis caused by *Ramichloridium obovoideum* (*Ramichloridium mackenziei*): case report. *Neurosurgery* 1999; 45: 372–375.
482. Sutton DA, Slifkin M, Yakulis R, Rinaldi MG. U.S. case report of cerebral phaeohyphomycosis caused by *Ramichloridium obovoideum* (*R. mackenziei*): criteria for identification, therapy, and review of other known dematiaceous neurotropic taxa. *J Clin Microbiol* 1998; 36: 708–715.
483. Kashgari TQ, Al-Miniawi H, Moawad Hanna MK. Cerebral phaeohyphomycosis caused by *Ramichloridium mackenziei* in the eastern province of Saudi Arabia. *Ann Saudi Med* 2000; 20: 457–460.
484. Khan ZU, Lamdhade SJ, Johny M *et al.* Additional case of *Ramichloridium mackenziei* cerebral phaeohyphomycosis from the Middle East. *Med Mycol* 2002; 40: 429–433.
485. Badali H, de Hoog GS, Curfs-Breuker I, Meis JF. *In vitro* activities of antifungal drugs against *Rhinocladiella mackenziei*, an agent of fatal brain infection. *J Antimicrob Chemother* 2010; 65: 175–177.
486. Ayadi A, Huerre MR, de Bievre C. Phaeohyphomycosis caused by *Veronea botryosa*. *Lancet* 1995; 346: 1703–1704.
487. Chen YT, Lin HC, Huang CC, Lo YH. Cutaneous phaeohyphomycosis caused by an itraconazole and amphotericin B resistant strain of *Veronaeae botryosa*. *Int J Dermatol* 2006; 45: 429–432.
488. Cunha Filho RR, Schwartz J, Rehn M, Vettotato G, Resende MA. Feo-hifomicose causada por *Veronaea botryosa*: relato de dois casos. *An Bras Dermatol* 2005; 80: 53–56.
489. Kondo Y, Hiruma M, Matsushita A, Matsuba S, Nishimura K, Takamori K. Cutaneous phaeohyphomycosis caused by *Veronaea botryosa* observed as sclerotic cells in tissue. *Int J Dermatol* 2007; 46: 625–627.
490. Matsushita A, Jilong L, Hiruma M *et al.* Subcutaneous phaeohyphomycosis caused by *Veronaea botryosa* in the People's Republic of China. *J Clin Microbiol* 2003; 41: 2219–2222.
491. Sang H, Zheng XE, Kong QT *et al.* A rare complication of ear piercing: a case of subcutaneous phaeohyphomycosis caused by *Veronaea botryosa* in China. *Med Mycol* 2011; 49: 296–302.
492. Xue Y, Chen H, Hu S *et al.* Cutaneous phaeohyphomycosis on the auricle due to *Veronaea botryosa*. *Eur J Dermatol* 2011; 21: 418–419.
493. Sutton DA, Rinaldi MG, Kielhofner M. First U.S. report of subcutaneous phaeohyphomycosis caused by *Veronaea botryosa* in a heart transplant recipient and review of the literature. *J Clin Microbiol* 2004; 42: 2843–2846.
494. Badali H, Yazdanparast SA, Bonifaz A *et al. Veronaea botryosa*: molecular identification with amplified fragment length polymorphism (AFLP) and *in vitro* antifungal susceptibility. *Mycopathologia* 2013; 175: 505–513.