This material is protected by U.S. copyright law. Unauthorized reproduction is prohibited. To purchase quantity reprints, please e-mail reprints@ons.org or to request permission to reproduce multiple copies, please e-mail pubpermissions@ons.org.

Prevention of Systemic Mycoses by Reducing Exposure to Fungal Pathogens in Hospitalized and Ambulatory Neutropenic Patients

Constance M. Smith, PhD, RN, and Sarah H. Kagan, PhD, RN, APRN-BC, AOCN®

Downloaded on 07-05-2024. Single-user license only. Copyright 2024 by the Oncology Nursing Society. For permission to post online, reprint, adapt, or reuse, please email pubpermissions@ons.org. ONS reserves all rights.

This article has been chosen as being particularly suitable for reading and discussion in a Journal Club format. The following questions are posed to stimulate thoughtful critique and exchange of opinions, possibly leading to changes on your unit. Formulate your answers as you read the article.

1. Is this article research based? What is the level of evidence being presented?
2. Based on the risk factors presented, to what extent are the patients we care for at risk for fungal infections? What kind of fungal infections?
3. Name at least two potential sources, in our clinical setting, of fungal contamination.
4. What strategies can be explored to reduce the likelihood of patient exposure to these sources of contamination?
5. What patient education materials are available to reduce patient susceptibility in the home environment?

At the end of the session, take time to recap the discussion and make plans to follow through with suggested strategies.

Purpose/Objectives: To describe sources of fungal contamination that can incite invasive mycoses in hospitalized and ambulatory neutropenic patients and to discuss approaches to reduce exposure to pathogens.

Data Sources: Published articles, books, and brochures.

Data Synthesis: Modifications of patient environments and lifestyles include hand hygiene for patients and healthcare workers, air filtration in hospitals, and reduction in exposure to plants, soil, standing water, and dusty environments. The effectiveness of dietary restrictions is controversial, although avoidance of pepper is recommended. These restrictions should be implemented prior to, during, and following neutropenia.

Conclusions: Mycoses can be hospital or community acquired; however, although guidelines for environmental and lifestyle modifications are well documented for the institutional setting, they are more limited for ambulatory patients.

Implications for Nursing: Nurses have a key role in the early identification of outbreaks of fungal infections, evaluation of hospital and home environments for sources of pathogens, education of patients on preventive measures, and research on neutropenic diets and improved technology to reduce exposure to fungal pathogens.

Key Points . . .

- ➤ Patients with prolonged and profound neutropenia are at risk for fungal infections, which are associated with high mortality and morbidity.
- ➤ Reduction in exposure to fungal pathogens is an important means of preventing mycoses.
- ➤ Hand hygiene, hospital environmental controls, and avoidance of contact with plants and damp, dusty environments can contribute to reduced fungal exposure. Dietary restrictions are controversial.
- ➤ With the increasing trend toward outpatient therapy, greater emphasis is needed on reducing sources of contamination in the home environment.

Invasive mycoses have emerged as a major determinant of mortality and morbidity in neutropenia (Bodey, 1997; Bow, 1998), and their prevention is a priority in optimal care of hospitalized and ambulatory patients (Johnson, Gilmore, Newman, & Stephens, 2000; Manuel & Kibbler, 1998; Philpott-Howard, 1996). Reduction in exposure to fungal pathogens is one approach for decreasing the incidence of

Constance M. Smith, PhD, RN, is a master's in nursing student at the University of Pennsylvania, and Sarah H. Kagan, PhD, RN, APRN-BC, AOCN®, is an associate professor of gerontologic nursing in the School of Nursing at the University of Pennsylvania and a gerontology clinical nurse specialist at the Hospital of the University of Pennsylvania, all in Philadelphia. *(Submitted January 2004. Accepted for publication October 15, 2004.)*

Digital Object Identifier: 10.1188/05.ONF.565-579

infection, which can be hospital or community acquired (Fridkin & Jarvis, 1996; Latge, 1999; Patterson, Zidouh, Miniter, Andriole, & Patterson, 1997; Warnock, 1998). Although extensive guidelines to eliminate sources of contamination have been published for the institutional setting, recommendations for modification to the home environment, activities, and diet are more limited (Centers for Disease Control and Prevention [CDC], Infectious Disease Society of America, & American Society of Blood and Marrow Transplantation, 2000; Risi & Tomascak, 1998; Trustees of the University of Pennsylvania [TUP], 2001).

Systemic fungal infections involve severe and rapidly progressive disseminated disease of visceral sites, including the lungs, brain, liver, spleen, and kidneys (Segal, Bow, & Menichetti, 2002). Since the 1980s, such mycoses have increased in immunocompromised patients because of more aggressive anticancer therapies, inducing severe and prolonged neutropenia, as well as significant success in treatment of bacterial infections (Johnson et al., 2000; Marr, Carter, Crippa, Wald, & Corey, 2002). Currently representing one of the most serious problems associated with neutropenia (Bodey, 1997), invasive mycoses affect at-risk populations differentially. Fungal infections are reported to occur in approximately 19% of patients with acute lymphoblastic leukemia and 47% of patients with acute myeloid leukemia undergoing remission-induction therapy (Rotstein et al., 1996). In blood and hematopoietic stem cell transplant recipients, 5% of autograft recipients and 18%–45% of unrelated allograft recipients are affected. The risk of invasive mycoses can be as great as 85% with therapy for graft-versus-host disease (Jantunen et al., 1997). A high rate of mortality is observed, with estimates ranging from 30%–95% (Bow, 1998; Latge, 1999; Manuel & Kibbler, 1998; Warnock, 1998).

Prevention of fungal infections by reducing exposure of patients to pathogens is considered a key strategy to improve outcomes in neutropenia for several reasons (Kuderer, Cosler, Crawford, Dale, & Lyman, 2002). Most important is the preservation of patients' quality of life, which can be impaired severely by the symptoms and stress associated with febrile neutropenia (Feld, 1997). In addition, treatment of an infection may result in delay in therapy for the underlying disease (Kuderer et al.). The importance of prevention is underscored further by the limitations in current antimycotic therapies (Philpott-Howard, 1996). Effective treatments are not available for several fungal pathogens, resulting in high mortality (Fleming, Walsh, & Anaissie, 2002), and amphotericin B, a widely used antimycotic, can have severe adverse side effects (Warnock, 1998). Moreover, with difficulties in the diagnosis of fungal infections in neutropenic patients (Bodey, 1997), definitive identification of the pathogen may be delayed, resulting in advanced infection intractable to treatment (Fidel, Vazquez, & Sobel, 1999; Johnson et al., 2000). Finally, prevention can reduce the substantial monetary expenses that are incurred with managing infection (Kuderer et al.; Lyman & Kuderer, 1997).

Colonization by fungal pathogens can occur before, during, and after neutropenia-inducing therapy in the hospital and at home (Nucci et al., 2004; Patterson et al., 1997). The hospital setting traditionally has been targeted in preventing opportunistic infections with comprehensive guidelines and air filtration technology available to reduce exposure to fungi (CDC et al., 2000; TUP, 2001). However, attention to the ambulatory neutropenic population is needed in light of the trend toward provision of cancer treatments on an outpatient basis (Herrmann, Trent, Cooney, & Cannell, 1999; Risi & Tomascak, 1998). Moreover, the fungal pathogens to which immunocompromised patients are exposed in the home environment can be significantly different from those in the hospital, where air filtration is already in place (Denning, 1998; Lass-Florl et al., 1999). The importance of reducing exposure in the home is emphasized further by research documenting that a significant percentage, estimated in the range of 60%–80%, of opportunistic fungal infections are community acquired and occur through colonization of patients prior to or following hospitalization (Bart-Delabesse, Cordonnier, & Bretagne, 1999; Latge, 1999; Patterson et al.; Raad, Tarrand, et al., 2002). Fungal colonization before immunosuppression can result in disseminated mycoses when subsequent neutropenia occurs (Segal et al., 2002), and invasive aspergillosis (Latge; Marr, Carter, Boeckh, Martin, & Corey, 2002) and fusariosis (Nucci et al.) can occur more than two weeks after engraftment when bone marrow transplant recipients are monitored as outpatients. These findings support the need for exposure-reducing measures to target nosocomial and community-acquired mycoses that can develop during periods of susceptibility in immunocompromised patients (Patterson et al.; Raad, Tarrand, et al.; Wald, Leisenring, van Burik, & Bowden, 1997).

The purpose of this article is to review applicable literature since the early 1980s on potential sources of fungal exposure, which can result in systemic mycoses in hospitalized and ambulatory neutropenic patients (see Table 1). Implications are discussed in relation to guidelines for reducing contamination as well as the clinician's role in working with at-risk patients to minimize exposure.

Factors Associated With Fungal Infection

Multiple risk factors for the development of invasive mycoses in patients with cancer have been identified (see Table 2). These are related to the degree and duration of immunologic deficits (Pagano et al., 1999; Segal et al., 2002), certain medical therapies (Jantunen et al., 1997), and exposure to fungal pathogens (Thio et al., 2000).

Yeasts and filamentous fungi have been identified as pathogens in neutropenic patients (see Table 3). With a decline in the incidence of *Candida albicans* over the past few years, this yeast now incites only approximately half of the cases of invasive mycoses (Hobson, 2003; Warnock, 1998). Recently, infection has shifted to non-*albicans* species of *Candida* such as *C. glabrata*, *C. tropicalis*, *C. parapsilosis*, and *C. krusei* (Gudlaugsson et al., 2003; Pagano et al., 1999; Pfaller, 1996). The yeast *Trichosporon beigelii* also can cause disseminated infection (Fleming et al., 2002).

In the past decade, rates of infection by filamentous fungi have increased relative to those by *Candida* (Marr, Carter, Crippa, et al., 2002). As the most prevalent filamentous fungal pathogens in neutropenia, *Aspergillus* species (spp.) may comprise as many as 30% of invasive mycoses (Latge, 1999). In addition, *Fusarium* spp. (Nelson, Dignani, & Anaissie, 1994), Zygomycetes (Ribes, Vanover-Sams, & Baker, 2000), *Pseudallescheria boydii* or *Scedosporium apiospermum* (Fleming

Downloaded on 07-05-2024. Single-user license only. Copyright 2024 by the Oncology Nursing Society. For permission to post online, reprint, adapt, or reuse, please email pubpermissions@ons.org. ONS reserves all rights.

Table 1. Table of Evidence

Citation	Design	Sample	Fungi	Findings	Implications
***Candida* species (spp.)**					
Martino et al., 1989	Hospital patient surveillance study	424 neutropenic patients with hematologic malignancies	*Candida* spp.	Invasive candidiasis developed in 32% of patients with multiple body sites colonized by *Candida* spp. versus in 0.5%–1% of patients with zero or one colonized site.	Risk of systemic candidiasis increased with more extensive *Candida* spp. colonization.
Reagan et al., 1990	Hospital patient surveillance study	16 patients with hematologic malignancies or bone marrow transplant (BMT) with candidemia	*Candida* spp.	Colonizing and infecting isolates were identical in 94% of patients. Unique, patient-specific strains were found in 81% of patients.	Infecting *Candida* strains were acquired mainly endogenously from patients' own flora.
Vazquez et al., 1993	Hospital patient and environmental surveillance study	98 patients in the medical intensive care unit (MICU) or BMT unit (BMTU); 10 environmental surfaces	*Candida albicans*	27% of patients with hospital-acquired *C. albicans*. Identical strains were isolated from multiple patients and hospital environmental surfaces.	Exogenous nosocomial acquisition of *C. albicans* through indirect contact with environment and other patients. Infection control should target the environment.
Strausbaugh et al., 1994	Employee surveillance survey	36 nurses and 21 nonnursing staff in nursing home care unit	*Candida* spp.	58% of nurses and 38% of non-nursing staff carried *Candida* spp. on their hands.	High frequency of *Candida* spp. carriage on hands of hospital personnel with potential transmission to patients. Hand hygiene may limit transmission.
Vazquez et al., 1998	Hospital patient and environmental surveillance study	98 patients in MICU or BMTU; 10 environmental surfaces	*Candida glabrata*	17% of patients with hospital-acquired *C. glabrata*. Multiple strains found on environmental surfaces were common to several patients.	Exogenous, nosocomial acquisition of *C. glabrata* occurred through indirect contact with the environment and patients.
Gudlaugsson et al., 2003	Retrospective cohort study	108 matched pairs of patients with and without nosocomial candidemia	*Candida* spp.	Authors found high crude mortality (61%) associated with nosocomial candidemia, consistent with 40%–75% crude mortality rates in previous studies.	Mortality associated with candidemia continues to be high. Preventive strategies (e.g., education programs to improve use, placement, and care of central venous catheters) are needed.
***Aspergillus* spp.**					
Sporik et al., 1993	Environmental surveillance study	Dust and indoor air in 296 houses in the United States and United Kingdom; 35 leaf collections and outdoor air in spring and autumn in the United States	*Aspergillus fumigatus*	*A. fumigatus* was present in 65% of homes and 80% of leaf extracts. Disturbed leaves yielded high levels of spores.	*A. fumigatus* was widespread in indoor and outdoor environments. Reduce exposure through avoidance of damp, moldy environments and disturbed vegetation.
Loudon et al., 1996	Hospital patient and environmental surveillance survey	Three neutropenic patients with hematologic malignancies; air and room surfaces, wound dressings, and food	*Aspergillus niger* and *Rhizopus* sp.	Identical strains were isolated from kitchen, food, wound dressings, air, and patients. Kitchen food probably was the source of contamination.	Fungal dispersal occurred through contact, fomites, and air. Thorough cleaning can prevent fungal contamination and infection.
Patterson et al., 1997	Prospective hospital patient surveillance study	153 hospital patients tested for *Aspergillus* antigen and culture	*Aspergillus* spp.	70% of aspergillosis cases were community acquired based on timing of symptoms. Increased aspergillosis infection occurred in summer and early fall.	Home environmental control measures (e.g., avoidance of contaminated environments) may reduce community-acquired aspergillosis.
Wald et al., 1997	Retrospective cohort study	2,496 BMT recipients	*Aspergillus* spp.	Laminar air flow (LAF) prevents aspergillosis, but infection is possible after LAF discontinuation. Patients are at increased risk for infection in summer.	LAF affords protection, but alternate strategies to reduce exposure to contaminated environments are needed following LAF, particularly in summer.
Withington et al., 1998	Hospital patient and environmental surveillance study	291 neutropenic patients with hematologic malignancies; monthly airborne spore counts over five years	*Aspergillus* spp.	High-efficiency particulate air (HEPA) filtration reduced airborne *Aspergillus* contamination and eliminated new cases of invasive aspergillosis.	HEPA filtration is recommended to reduce aspergillosis.

(Continued on next page)

Downloaded on 07-05-2024. Single-user license only. Copyright 2024 by the Oncology Nursing Society. For permission to post online, reprint, adapt, or reuse, please email pubpermissions@ons.org. ONS reserves all rights.

Table 1. Table of Evidence *(Continued)*

Citation	Design	Sample	Fungi	Findings	Implications
Aspergillus* spp. *(continued)					
Lass-Florl et al., 1999	Hospital patient surveillance study	74 samples of lung tissue from 56 patients undergoing surgical intervention or autopsy	*Aspergillus* spp.	63% of samples with pulmonary fungal colonization prior to hospitalization; 39%–40% of samples with *Aspergillus* spp. colonization	Community-acquired fungal colonization may be the source of endogenous infection. Environmental modifications prior to neutropenia may limit infection.
Lass-Florl et al., 2000	Hospital patient and environmental surveillance survey	14 neutropenic patients with hematologic malignancies; samples of air (n = 67) and potted plant soil (n = 2) from patient vicinity	*Aspergillus terreus*	Identical strains were isolated from patients with aspergillosis and plant soil. No *A. terreus* isolates were recovered from air sampling.	Eliminate potted plants from area of at-risk patients to reduce aspergillosis. Poor sensitivity of air sampling may affect accuracy of airborne spore determination.
Thio et al., 2000	Case-controlled hospital patient and environmental surveillance study	29 patients with hematologic malignancies and aspergillosis; 132 environmental air samples and room pressure tests	*Aspergillus* spp.	Identical strains were isolated from air and patients. Air path testing traced spore movement from construction into patient areas. Wet mopping reduces spore dispersal.	Scrupulous cleaning with wet mopping, HEPA filtration, N95 masks, and epidemiologic surveillance promote infection control.
Alberti et al., 2001	Prospective hospital patient and environmental surveillance study	79 cases of invasive aspergillosis in BMT and hematology units; 3,100 air and 9,800 environmental surface samples	*Aspergillus* spp.	Causal correlation existed between level of environmental (air, surface) contamination and aspergillosis.	Prevent infections through HEPA, LAF, scrupulous cleaning of patient rooms and units, and efforts to eliminate contamination.
Anaissie, Stratton, Dignani, Lee, et al., 2002	Hospital environmental surveillance study	48 air samples taken before and after cleaning and disinfection of water-exposed surfaces in bathrooms in BMTU	*Aspergillus* spp., *Fusarium, Paecilomyces, Mucor* spp., and other filamentous fungi	Concentration of airborne fungi significantly decreased after cleaning and disinfection of water-exposed surfaces, especially shower floors, in bathrooms.	In hospital and home, thoroughly clean and disinfect water-exposed surfaces, particularly showers, in bathrooms immediately before high-risk patients shower to reduce airborne fungi.
Hahn et al., 2002	Retrospective cohort study; environmental surveillance study	91 patients with hematologic malignancies; weekly air samples over one year	*Aspergillus* spp.	Air sampling identified *Aspergillus* spp. contamination in moldy wall insulation and construction. Spore load correlated with aspergillosis outbreak.	Aspergillosis cases were reduced through HEPA filtration, decontamination of insulation, and isolation of construction.
Symoens et al., 2002	Hospital and home patient and environmental surveillance study	Six patients with hematologic malignancies and invasive aspergillosis; 33 clinical isolates, 14 hospital, and 34 home environmental isolates	*Aspergillus fumigatus*	*A. fumigatus* exhibited great biodiversity. 80% of aspergillosis cases were community acquired. Identical isolates were recovered from patients and their homes.	Epidemiologic studies are complex but essential in identifying source of infection.
Anaissie et al., 2003	Prospective hospital environmental study.	416 water samples, 1,311 environmental surface samples, and 283 air samples	*Aspergillus* spp., *Fusarium, Paecilomyces, Mucor,* and other filamentous fungi	Opportunistic molds were recovered from water, water tanks, bathroom surfaces, and indoor and outdoor air.	Contaminated aerosols from water sources may serve as fungal reservoirs. Encourage high-risk patients to drink sterile water and use sterile sponge baths rather than showers. Clean and disinfect water-exposed surfaces in hospital and home.
***Fusarium* spp.**					
Anaissie et al., 2001	Hospital patient and environmental surveillance study	20 patients with fusariosis; 283 water system samples and 189 bathroom surface samples	*Fusarium solani, F. oxysporum,* and *Aspergillus* spp.	*Fusarium* spp. were recovered from water systems, bathroom drains and showers, and aerosols from water. Limited matches occurred with patient fusariosis isolates.	Aerosols from water sources may result in *Fusarium* infections.
Nucci & Anaissie, 2002	Retrospective case review	259 immunocompromised and immunocompetent patients with fusariosis	*Fusarium* spp.	Infection of skin and nasal sinuses is main mode of *Fusarium* transmission. Fusariosis manifests as disseminated skin lesions, which is useful in diagnosis.	Patients should be educated to avoid activities leading to skin breakdown and onychomycoses. Before immunosuppression, evaluate and treat any fungal-contaminated skin lesions.

(Continued on next page)

Downloaded on 07-05-2024. Single-user license only. Copyright 2024 by the Oncology Nursing Society. For permission to post online, reprint, adapt, or reuse, please email pubpermissions@ons.org. ONS reserves all rights.

Table 1. Table of Evidence *(Continued)*

Citation	Design	Sample	Fungi	Findings	Implications
Fusarium* spp. *(continued)					
Raad, Tarrand, et al., 2002	Hospital patient and environmental surveillance study	70 patients with fusariosis; 77 water system samples, 376 air samples, and 120 bathroom surface samples from hospitals and homes	*Fusarium* spp.	*Fusarium* spp. were isolated from hospital and home bathroom drains and surfaces. No match occurred between environmental and clinical isolates. Seasonal clustering was reported during warm, rainy season in Houston, TX.	Fusariosis is mainly community acquired via airborne spores from external environment, including plants.
Nucci et al., 2004	Retrospective hospital patient study	61 hematopoietic stem cell transplant (HSCT) recipients with fusariosis	*Fusarium* spp.	In allogeneic HSCT, three fusariosis peaks: before engraftment, 62 days post-transplant, and >1 year post-transplant with graft-versus-host disease and adequate neutrophil counts.	Before and after HSCT, for fusariosis prevention, evaluate and treat skin lesions, particularly onychomycoses; avoid environmental exposure by controlling air and water contamination in hospital and home.
Paecilomyces lilacinus					
Orth et al., 1996	Hospital patient and environmental surveillance study	25 neutropenic patients with hematologic malignancies or BMT; 3,500 samples of patient care agents, food, clinical specimens, and hospital air and surfaces	*Paecilomyces lilacinus*	An epidemic of invasive mycoses resulted from cutaneous infection by a contaminated, commercially available, pharmaceutically prepared skin lotion, as determined by an intensive epidemiologic investigation.	Epidemiologic studies are essential in investigating all possible sources of infection and resolving mycotic outbreaks.

et al., 2002), and *Paecilomyces lilacinus* (Orth et al., 1996) can cause infection.

Epidemiology of Fungal Infections

In investigations of mycotic outbreaks, sources of clinical isolates may be difficult to identify definitely (Gangneux et al., 2002; Morris, Kokki, Anderson, & Richardson, 2000). Instead, conclusions often rely on correlations between infections and elevated airborne spore counts or isolation of the pathogen species from the patient environment (Alberti et al., 2001). However, although pathogens such as *Aspergillus* spp. may be present in patient care areas, they should not necessarily be implicated in cases of opportunistic infection because of the huge genetic diversity of many fungi (Latge, 1999; Symoens et al., 2002), the widespread environmental sources of pathogens (Bart-Delabesse et al., 1999), and limitations in environmental surveillance techniques (Lass-Florl et al., 2000). Extensive investigation often is required for full identification of the source of the causal organism (Patterson et al., 1997) as exemplified by the 3,500 microbial cultures and environmental samples required to resolve one *P. lilacinus* outbreak (Orth et al., 1996). However, despite their complexity and expense, epidemiologic studies of infectious outbreaks are indispensable to ensure optimal patient care (Thio et al., 2000).

Sources of Exposure to *Candida* Species

Historically, systemic candidiasis has been thought to develop predominately from prior endogenous colonization (Pfaller, 1996) of the skin and mucosa, particularly of the oral cavity, gastrointestinal tract, and vagina (Fridkin & Jarvis, 1996). This is suggested by studies documenting that, in 94% of the cases examined, *Candida* strains isolated from asymptomatic neutropenic patients were associated with subsequent bloodstream infections and 81% of the isolates were unique to each patient (Reagan, Pfaller, Hollis, & Wenzel, 1990). Furthermore, neutropenic patients with multiple, noncontiguous colonized sites in the oropharynx, rectum, or vagina were reported to be at significantly higher risk for systemic candidemia, compared to those without *Candida* colonization or with one colonized site (Martino et al., 1989). Thus, invasive infection appears to be related directly to the extent of colonization (Guiot, Fibbe, & van't Wout, 1994).

In addition to risk from endogenous flora, nosocomial infection by *Candida* involving transmission among patients and from inanimate reservoirs more recently has been implicated in systemic mycoses (Pfaller, 1996). *Candida* strains, which have been found in exogenous hospital environmental sources such as food, adjacent patients, and surfaces in patient rooms frequently contacted by hospital staff, subsequently have been isolated from patients who developed disseminated infection (Vazquez et al., 1993, 1998). Indirect contact among patients and fomites appears to be the major route of transmission (Fidel et al., 1999). The risk of exogenous infection is underscored further by findings that *Candida* spp. were carried on the hands of 58% of hospital nurses (Strausbaugh et al., 1994), and compliance with hand hygiene guidelines averaged only 48% among staff in one teaching hospital (Pittet, Mourouga, & Perneger, 1999). Thus, *Candida* originally acquired exogenously may colonize patients and subsequently cause disseminated infection (Vazquez et al., 1993).

In addition, central venous catheters (CVCs) may increase the risk of invasive *Candida* infections (Hobson, 2003; Stoiser et al., 2002). Candidemia via CVC may occur by disruption of colonies at the entry site or colonization of the CVC, which serves as an ongoing reservoir of fungal propagules (Pagano et al., 1999).

Downloaded on 07-05-2024. Single-user license only. Copyright 2024 by the Oncology Nursing Society. For permission to post online, reprint, adapt, or reuse, please email pubpermissions@ons.org. ONS reserves all rights.

Table 2. Factors Associated With Invasive Fungal Infection in Patients With Cancer

Risk Factor	Clinical Implications	Selected References
Chemotherapy or radiotherapy	Disruption of mucosal barrier (e.g., in gastrointestinal or sinopulmonary tracts) may facilitate fungal entry into body.	Bow, 1998; Jantunen et al., 1997; Pagano et al., 1999; Segal et al., 2002
Long-term, broad-spectrum antibiotics	Antibiotic therapy may eliminate normal body microflora (e.g., on skin, in gastrointestinal tract) to allow establishment of fungal pathogens.	Manuel & Kibbler, 1998; Pagano et al.; Philpott-Howard, 1996
Allogeneic transplant	Allograft represents a higher risk than autograft.	Bow; Jantunen et al.; Marr, Carter, Crippa, et al., 2002; Wald et al., 1997
Chronic or acute graft-versus-host disease with corticosteroid therapy	Graft-versus-host disease and corticosteroid therapy may suppress host immune response against fungal pathogens.	Guiot et al., 1994; Jantunen et al.; Latge, 1999; Marr, Carter, Crippa, et al.; Segal et al.; Wald et al.
Neutropenia	Greatest risk with absolute neutrophil count $\leq$ 100–500 mm^{-3} for more than 12–15 days. Some infections (e.g., aspergillosis) may not be associated with neutropenia.	Jantunen et al.; Latge; Marr, Carter, Crippa, et al.; Pagano et al.; Segal et al.; Wald et al.
Fungal colonization	Colonization of gastrointestinal, sinopulmonary, and/or genitourinary tracts may increase risk of systemic fungal infection.	Bow; Guiot et al.; Martino et al., 1989; Reagan et al., 1990
Prior fungal infection	Subsequent myelosuppression may reactivate latent fungal infection.	Boutati & Anaissie, 1997; Lass-Florl et al., 1999; Latge; Nelson et al., 1994; Segal et al.
IV catheters	IV catheters may facilitate systemic infection by fungal pathogens through disruption of colonies at entry site.	Hobson, 2003; Pagano et al.; Richard-Smith & Buh, 1995
Environmental contamination	Elevated airborne spore load (e.g., because of construction in the absence of air filtration) may increase infection by filamentous fungi. Exogenous acquisition of *Candida* species is possible from contaminated environment.	Hahn et al., 2002; Morris et al., 2000; Strausbaugh et al., 1994; Thio et al., 2000; Vazquez et al., 1993

Downloaded on 07-05-2024. Single-user license only. Copyright 2024 by the Oncology Nursing Society. For permission to post online, reprint, adapt, or reuse, please email pubpermissions@ons.org. ONS reserves all rights.

Recommendations to Reduce Exposure to *Candida* Species

In the hospital and at home, patients and all those involved in their care must be educated about infection risks and protective measures (Gudlaugsson et al., 2003) (see Tables 4 and 5). Such improved understanding can promote adherence to protocols to reduce infection (Richard-Smith & Buh, 1995).

Hand hygiene through appropriate hand washing or sanitation during patient care is paramount to prevent patient-to-patient as well as fomite-to-patient transmission of *Candida* spp. underlying exogenous infection (Johnson et al., 2000; Risi & Tomascak, 1998). For healthcare workers, such sanitary procedures are essential before entering and after leaving patient rooms as well as before and after any direct contact with patients. For patients, washing hands before eating, after toilet use, and before and after touching a wound is advised (CDC et al., 2000). Visitors also should observe hand hygiene before interaction with patients (Risi & Tomascak). In addition to thorough washing with antimicrobial soap and water, hand sanitizers are effective against *Candida* (Philpott-Howard, 1996). Regular cleaning of surfaces in patient rooms also can reduce the potential for exogenous transmission of *Candida* (Vazquez et al., 1993).

The risk of infection from endogenous acquisition in the hospital and at home can be reduced through suppression of *Candida* colonization of the oral cavity by optimal oral and dental hygiene, particularly in patients with dentures (Meunier, 1987). Attention also should be given to optimal skin care with daily showers or baths and perineal hygiene. Patient counseling on the importance of maintaining skin integrity, regularly inspecting for wounds, and protecting from injury is recommended because these measures may limit fungal migration into the bloodstream (CDC et al., 2000).

To minimize risk of infection by CVC, maximum sterile precautions during catheter insertion (Coopersmith et al., 2002; Gudlaugsson et al., 2003) as well as thorough patient education for optimal catheter care (Richard-Smith & Buh, 1995) and skin hygiene (CDC et al., 2000) are essential.

Sources of Exposure to Filamentous Fungi

The filamentous fungi or molds, including *Aspergillus*, *Fusarium*, and Zygomycetes, can have different modes of transmission and sources of contamination with *Candida*. For *Aspergillus*, the primary route of infection is entry of inhaled airborne spores through the respiratory tract. Its small spore size (2–3 mcm), allowing deep penetration into the lungs, facilitates pulmonary disease (Latge, 1999). Portals of entry for *Fusarium* are reported to be the sinopulmonary tree and skin secondary to trauma, onychomycosis with cellulitis, or spider bites (Boutati & Anaissie, 1997; Nucci & Anaissie, 2002). Inhalation of spores via the respiratory tract is the predominant mode of transmission for Zygomycetes, although percutaneous routes from trauma and wounds also are important (Ribes et al., 2000).

Filamentous fungi are widespread in the environment, harbored in outdoor and indoor reservoirs. In nature, these fungi proliferate in dust, soil, plants, and decomposing organic matter, with lightweight spores readily becoming airborne for dispersal (Burgess, 1981; Nelson et al., 1994; Ribes et al., 2000; Warnock, 1998). The atmospheric content of *A. fumigatus* spores is dependent on season and location.

Downloaded on 07-05-2024. Single-user license only. Copyright 2024 by the Oncology Nursing Society. For permission to post online, reprint, adapt, or reuse, please email pubpermissions@ons.org. ONS reserves all rights.

Table 3. Characteristics of Fungal Pathogens

Type of Fungus	Disease	Fungi	Setting	Sources	Mode of Transmission	Conditions Placing Patients at Risk	Selected References
Yeast	Candidemia, systemic candidiasis, candidosis	*Candida albicans, C. tropicalis, C. glabrata (Torulopsis glabrata), C. parapsilosis, C. krusei,* and *C. lusitaniae*	Hospital and home	Endogenous microflora of patient (e.g., gastrointestinal, sinopulmonary, genitourinary tracts), environmental surfaces, and hands of healthcare workers	Autoinoculation from microflora, indirect or direct contact with contaminated environmental surfaces, hand carriage by healthcare workers, intravascular catheters, and infusates	Hematologic malignancies, neutropenia, mucotoxicity, hematopoietic stem cell transplantation (HSCT), colonization by *Candida* species (spp.), and intravascular catheter use	Hobson, 2003; Martino et al., 1989; Pagano et al., 1999; Segal et al., 2002; Vazquez et al., 1993,1998
Yeast	Trichosporonosis	*Trichosporon beigelii*	Hospital and home	Endogenous microflora of patients	Autoinoculation from microflora	Hematologic malignancies, neutropenia, and graft-versus-host disease (GVHD) with corticosteriod therapy	Fleming et al., 2002; Warnock, 1998
Filamentous	Aspergillosis	*Aspergillus fumigatus, A. flavus, A. terreus, A. niger,* and *A. nidulans*	Hospital and home	Broad environmental distribution: soil, plants, decomposing vegetation, dust, moldy carpets, construction, bathroom drains, and pepper	Inhalation of airborne spores with colonization of sinopulmonary tract, reactivation of latent infection, and percutaneous transmission	Neutropenia, mucotoxicity, HSCT, GVHD with corticosteroid therapy, and exposure to environmental contaminants	Hahn et al., 2002; Lass-Florl et al., 2000; Latge, 1999; Segal et al.; Wald et al., 1997
Filamentous	Fusariosis, fusarial hyalohyphomycosis	*Fusarium solani, F. moniliforme, F. oxysporum,* and *F. proliferatum*	Hospital and home	Broad environmental distribution: soil, plants, decomposing vegetation, bathroom drains, and aerosols from water	Inhalation of airborne spores with colonization of sinopulmonary tract, infected skin lesions secondary to trauma and onychomycosis, and IV catheters	Hematologic malignancies, cytotoxic therapy, neutropenia, and HSCT, particularly allogeneic	Anaissie et al., 2001, 2003; Marr, Carter, Crippa, et al., 2002; Nucci & Anaissie, 2002
Filamentous	Zygomycosis, Mucormycosis	Zygomycetes, Mucorales, *Rhizopus arrhizus,* and *Rhizomucor* spp.	Hospital and home	Broad environmental distribution: soil, plants, decomposing vegetation, dust, and foods	Inhalation of airborne spores with colonization of sinopulmonary tract	Hematologic malignancies, neutropenia, and GVHD (> 90 days post-HSCT)	Marr, Carter, Crippa, et al.; Ribes et al., 2000
Filamentous	Hyalohyphomycosis	*Pseudallescheria boydii (Scedosporium apiospermum)*	Hospital and home	Broad environmental distribution: soil, decomposing vegetation, and dust	Inhalation of airborne spores	Hematologic malignancies, neutropenia, and HSCT	Fleming et al.; Marr, Carter, Crippa, et al.; Warnock
Filamentous	Hyalohyphomycosis	*Paecilomyces lilacinus*	Primarily hospital	Broad environmental distribution: soil, decomposing vegetation, contaminated skin lotion and irrigation solutions, and IV catheters	Inhalation of airborne spores and skin contact	Hematologic malignancies, neutropenia, chemotherapy, HSCT, and GVHD	Fleming et al.; Orth et al., 1996

Table 4. Recommendations to Reduce Exposure to Fungal Pathogens in the Hospital

Activity	Actions	Selected References
Education	Educate healthcare workers, patients, and visitors about risks for infection and procedures to minimize fungal exposure.	Fridkin & Jarvis, 1996; Gudlaugsson et al., 2003; Richard-Smith & Buh, 1995
Environmental surveillance	Implement protocols to identify and eliminate outbreaks of mycoses and sources of contamination.	Faure et al., 2002; Gangneux et al., 2002; Thio et al., 2000
Hand hygiene	Use frequent and thorough hand hygiene. • Healthcare workers and visitors should use hand hygiene before and after contact with patients and entry into rooms. • Patients should use hand hygiene before eating and before and after using the toilet and touching wounds. • Use antimicrobial soap or hygienic hand sanitizers.	Centers for Disease Control and Prevention (CDC) et al., 2000; Johnson et al., 2000; Philpott-Howard, 1996; Pittet et al., 1999; Risi & Tomascak, 1998; Strausbaugh et al., 1994; Trustees of the University of Pennsylvania (TUP), 2001; Vazquez et al., 1993
Oral and dental hygiene	Optimize oral and dental hygiene before, during, and following immunosuppression. • Use oral rinses with sterile water, saline, or sodium bicarbonate four to six times daily. • Brush with a soft-bristle toothbrush (more than two times daily).	CDC et al.; Meunier, 1987; Philpott-Howard, 1996; TUP
Skin hygiene	Optimize skin hygiene with daily showers or baths with mild soap and perineal cleaning after toilet use. Consider sterile sponge baths in place of showers if opportunistic fungi are present in water system.	Anaissie et al., 2001, 2003; CDC et al.; TUP
Skin care and assessment	Maintain skin integrity and protect skin from injury. Inspect skin and nails regularly for lesions and infections. Note any trauma or onychomycosis for infection by *Fusarium* species. Treat infections.	Boutati & Anaissie, 1997; CDC et al.; Nucci & Anaissie, 2002; Nucci et al., 2004
Invasive procedures	Use maximum aseptic technique for placement and care of intravascular catheters. Avoid rectal thermometers, enemas, suppositories, and rectal examinations.	CDC et al.; Coopersmith et al., 2002; Gudlaugsson et al.
Sterilization	Ensure sterility of instruments, biologic and disinfectant solutions, and materials applied to the skin.	Loudon et al., 1996; Orth et al., 1996; Wald et al., 1997
Environmental modifications	Minimize airborne contamination (optimally to < 0.1 colony forming unit/m^3) through establishment of protective environment using • High-efficiency particulate air (HEPA) filtration (99.97% efficient to remove particles > 0.3 mcm); > 12 air exchanges per hour. Consider Shinki bioclean rooms as an alternative to HEPA filtration. • Laminar air flow combined with HEPA filtration to achieve high rates of air changes in rooms and vestibules (100–400 exchanges per hour), particularly for high-risk patients (e.g., allogeneic hematopoietic stem cell transplant recipients) • Directed room airflow from patients to exhaust vents and positive room air pressures relative to halls, toilets, anterooms, and other hospital areas • Tightly sealed rooms with closed, well-sealed windows and electric outlets • Bird screens on air supply and exhaust ducts to eliminate accumulation of excreta. Optimize air filtration system operation through • Scheduling regular, preventive maintenance and cleaning of ducts, grids, and well-fitted filters; particulate counting; and pressure monitoring • Reviewing procedures periodically with engineers and infection control specialists.	Alberti et al., 2001; Burwen et al., 2001; CDC et al.; Faure et al.; Gangneux et al.; Hahn et al., 2002; Humphreys, 2004; Manuel & Kibbler, 1998; Morris et al., 2000; Rhame, 1991; Shinjo et al., 2002; Thio et al.; Wald et al.; Withington et al., 1998
Environmental design	Incorporate systems to minimize airborne contamination into hospital-wide designs. • Avoid false ceilings and closed spaces, which accumulate spore-containing dust. • Isolate open loading and waste disposal docks. • Construct vestibules with high air exchange rates at entrances to patient care areas.	CDC et al.; Humphreys; Manuel & Kibbler; Rhame
Isolation of construction	Implement strategies to isolate construction, renovation, or demolition. • Plan strategies in advance of construction. • Seal off patient care areas from construction with impervious dust- and spore-proof barriers. • Ensure elimination of contaminated air through ventilation systems and use of negative air pressure in construction areas. • Ensure that patient, visitor, and equipment traffic is removed from construction. • Dedicate specific routes for construction personnel. • Use high-efficiency filtration masks for patient transport during construction. • Thoroughly clean patient care areas after construction.	Burwen et al.; Hahn et al.; Humphreys; Lueg et al., 1996; Manuel & Kibbler; Morris et al.; Raad, Hanna, et al., 2002; Thio et al.

(Continued on next page)

Downloaded on 07-05-2024. Single-user license only. Copyright 2024 by the Oncology Nursing Society. For permission to post online, reprint, adapt, or reuse, please email pubpermissions@ons.org. ONS reserves all rights.

Table 4. Recommendations to Reduce Exposure to Fungal Pathogens in the Hospital *(Continued)*

Activity	Actions	Selected References
Cleaning	Clean and disinfect at least once daily when rooms are vacated, using premoistened cloths or mops with Environmental Protection Agency-approved disinfectant and vacuum cleaners (HEPA filters preferred) that do not disperse dust aerosol. Ensure thorough cleaning of • Dust-accumulating areas (e.g., all surfaces, horizontal ledges, high-level areas [ceiling lights, televisions]) in patients' rooms • Water-exposed surfaces (e.g., drains, shower walls, and curtains in patients' bathrooms) to reduce potential contaminated aerosols from water sources. Consider cleaning or disinfecting shower drains immediately before patient showering. • Mobile equipment before entry into patient care areas • Nebulizers and humidifiers and refill with sterile water.	Alberti et al.; Anaissie et al., 2001, 2003; Anaissie, Stratton, Dignani, Lee, et al., 2002; Anaissie, Stratton, Dignani, Summerbell, et al., 2002; CDC et al.; Faure et al.; Johnson et al.; Loudon et al.; Manuel & Kibbler; Philpott-Howard; Rhame; Thio et al.
Room traffic	Limit visitors and movement from contaminated areas into patient rooms. Minimize transport of patients through contaminated areas; consider use of masks.	Johnson et al.; Raad, Hanna, et al.; Rhame; Thio et al.
Elimination of contamination reservoirs	Remove sources of fungal pathogens, including • Contaminated, water-damaged, or damp wood (e.g., bathroom and kitchen cabinets with plumbing leaks), carpet, insulation, fire-proofing material from patient care areas. Repair leaks within 72 hours. • Dried and fresh flowers, plants, and potting soil from patient contact areas, including unit vestibules.	Anaissie et al., 2001, 2003; Anaissie, Stratton, Dignani, Summerbell, et al.; CDC et al.; Gerson et al., 1994; Hahn et al.; Lass-Florl et al., 2000; Meunier; Risi & Tomascak

Maximum loads occur in spring, summer, or fall in different areas of the United States, with low levels during winter snows (Rhame, 1991). Disturbance of decaying leaf debris can yield high levels of *A. fumigatus* in localized environments (Sporik, Arruda, Woodfolk, Chapman, & Platts-Mills, 1993).

In the hospital environment, reservoirs of filamentous fungi with the potential for inciting nosocomial infection are widespread. For *Aspergillus* spp. (Burwen et al., 2001) and Zygomycetes (Lueg, Ballagh, & Forte, 1996; Ribes et al., 2000), disturbed dust from construction, renovation, or demolition in the hospital or adjacent buildings frequently has been associated with increased spore loads in patient care areas and elevated rates of mycoses. As determined by air-path studies (Thio et al., 2000), spores of *Aspergillus* spp. can enter via doors and poorly sealed windows and subsequently be carried through corridors to patient units by air currents resulting from pressure differentials, pedestrian traffic, and equipment from the construction site.

In addition to construction, numerous other sources of fungal pathogens have been identified in hospitals. Ventilation ducts, often contaminated with bird excreta (Manuel & Kibbler, 1998), moldy wall insulation (Hahn et al., 2002), refrigerator condensate trays (Price, Jones, Groombridge, & Hoffman, 2002), and kitchen areas originally infested with moldy food (Loudon et al., 1996) have been documented as ongoing sources of *Aspergillus* spp., causing mycoses in neutropenic patients. In a bone marrow transplant unit, carpet tiles that were contaminated by spores from demolition of an adjacent building and sustained fungal proliferation through repeated washings served as *Aspergillus* reservoirs (Gerson, Parker, Jacobs, Creger, & Lazarus, 1994). Through molecular genotyping techniques, soil and potted plants to which neutropenic patients were exposed on a hematology ward were identified as the source of *A. terreus* that caused aspergillosis (Lass-Florl et al., 2000). Pathogenic *Fusarium* strains also have been isolated from potted plants in hospital patient care areas (Anaissie et al., 2001). In an epidemic involving *P. lilacinus* (Orth et al., 1996), immunosuppressed patients were infected through direct cutaneous exposure from contaminated commercial moisturizing skin lotion used in the hospital to treat xeroderma secondary to chemotherapy.

Hospital water systems have been implicated as reservoirs of pathogenic fungi. *Aspergillus* spp. (Anaissie, Stratton, Dignani, Summerbell, et al., 2002), *Fusarium* spp. (Alberti et al., 2001; Anaissie et al., 2001), Zygomycetes, and *P. lilacinus* (Anaissie et al., 2003) were recovered from hospital water storage tanks and patient care areas, particularly bathroom drains. Based on molecular genotyping, several clinical isolates were homologous with those from the water-related environmental sources (Anaissie et al., 2001; Anaissie, Stratton, Dignani, Summerbell, et al.); however, whether *Fusarium* from hospital water systems causes invasive mycoses in neutropenic patients is controversial (Raad, Tarrand, et al., 2002).

Many physical factors affect airborne spore loads in patient care areas as evidenced by hospital air surveillance studies. Wet mopping disperses fewer particles (30,000/m^3) into the environment than dry buffing (800,000/m^3) (Thio et al., 2000). Major spore bursts in patients' rooms have been correlated with a high number of visitors, changing a light fixture, and moving a chair to and from the corridor. Such changes in airborne spore concentrations can be explained by adherence of spores to clothing after exposure to outdoor sources (Denning, 1998; Gangneux et al., 2002; Rhame, 1991) and fungal proliferation in undisturbed dust (Sporik et al., 1993). Thus, seemingly innocuous activities may cause life-threatening infections (Morris et al., 2000).

In addition to nosocomial mycoses, studies have documented the importance of community-acquired infections of *Aspergillus* (Patterson et al., 1997) and *Fusarium* (Raad, Tarrand, et al., 2002). Although the incubation periods of these mycoses have not been determined (Denning, 1998), community-acquired infection is defined arbitrarily as clinical symptoms appearing within the week of hospital admission or more than two weeks after discharge (Patterson et al.; Raad, Tarrand, et al.). In studies investigating the source

Downloaded on 07-05-2024. Single-user license only. Copyright 2024 by the Oncology Nursing Society. For permission to post online, reprint, adapt, or reuse, please email pubpermissions@ons.org. ONS reserves all rights.

Table 5. Recommendations to Reduce Exposure to Fungal Pathogens in the Home[a]

Activity	Actions	Selected References
Education	Educate patients, caregivers, visitors, and healthcare workers about risks for infection and procedures to minimize fungal exposure.	Fridkin & Jarvis, 1996; Gudlaugsson et al., 2003; Richard-Smith & Buh, 1995
Hand hygiene	Patients and caregivers should use thorough and frequent hand hygiene, with antibacterial soap and water or hand sanitizers. • Before eating or preparing food • After going outdoors or touching plants, soil, or pets • Before and after touching wounds and using the toilet	Centers for Disease Control and Prevention (CDC) et al., 2000; Philpott-Howard, 1996; Pittet et al., 1999; Strausbaugh et al., 1994; Trustees of the University of Pennsylvania (TUP), 2001; Vazquez et al., 1993
Oral, dental, and skin hygiene	Optimize oral, dental, and skin hygiene as described in Table 4.	Anaissie et al., 2001, 2003; CDC et al.; Meunier, 1987; Philpott-Howard; TUP
Skin care and assessment	Maintain skin integrity and protect skin from injury. Inspect skin and nails regularly for lesions and infections. Note any trauma or onychomycosis for infection by *Fusarium* species. Treat infections.	Boutati & Anaissie, 1997; CDC et al.; Nucci et al., 2004; Nucci & Anaissie, 2002
Cleaning	Clean regularly and thoroughly when the patient is out of the area. Use premoistened cloths or mops and disinfectant and vacuum cleaner (high-efficiency particulate air filter preferred) that do not produce dust aerosols. Ensure that the following are cleaned. • Areas of dust accumulation (e.g., horizontal surfaces, high-level areas, including ceiling lights) and kitchens, including utensils • Water-exposed surfaces (e.g., bathroom and kitchen drains, shower walls, shower curtains) to reduce potential contaminated aerosols from water sources. Consider cleaning or disinfecting shower drains immediately before patient showers.	Alberti et al., 2001; Anaissie et al., 2001, 2003; Anaissie, Stratton, Dignani, Lee, et al., 2002; Anaissie, Stratton, Dignani, Summerbell, et al., 2002; CDC et al.; Faure et al., 2002; Johnson et al., 2000; Loudon et al., 1996; Philpott-Howard; Rhame, 1991; Thio et al., 2000
Elimination of contamination reservoirs	Reduce reservoirs of fungi. • Remove water-damaged, contaminated wood, carpet, and insulation prior to immunosuppression. • Avoid home renovation during immunosuppression. • Ensure that all drywall (e.g., around electric outlets) is sealed. • Eliminate standing water in kitchens and baths. • Use sterile water in nebulizers and humidifiers.	Anaissie et al., 2001, 2003; Anaissie, Stratton, Dignani, Summerbell, et al.; CDC et al.; Gerson et al., 1994; Hahn et al., 2002; Price et al., 2002
Exposure to contaminated areas	Reduce exposure to fungal contamination. • Avoid areas that are dusty with disturbed soil or damp or moldy areas such as construction and excavation sites, ceiling spaces, cellars, attics, and caves. • Consider use of dust-proof mattress cases and dehumidification of cellars if damp and musty. • Avoid skin contact with soil or vegetation (e.g., through walking in open sandals or barefoot) to reduce risk of skin trauma, contamination, and onychomycosis.	Boutati & Anaissie; CDC et al.; Nucci et al.; Nucci & Anaissie; Ribes et al., 2000; Sporik et al., 1993
Plant exposure	Avoid exposure to and contact with dried and fresh flowers, plants, soil, and their aerosols in home and outdoors. • Consider removal of plants and flowers from the home. • Avoid gardening and exposure to disturbed damp, decaying vegetation. • Wear gloves if handling of plants is necessary. • Eliminate exposure to marijuana smoke.	Boutati & Anaissie; CDC et al.; Lass-Florl et al., 2000; Manuel & Kibbler, 1998; Nucci & Anaissie; Meunier; Ribes et al.; TUP
Pet contact	Avoid direct pet care, minimize direct animal contact, and use hand hygiene after pet contact.	Angulo et al., 1994; CDC et al.

[a] Adherence to these guidelines is recommended before, during, and for at least six months following immunosuppressive therapy as well as during periods of immunosuppression (e.g., graft-versus-host disease, systemic steroid use, relapses of malignancy).

of aspergillosis in neutropenic patients, 60%–80% of the cases were acquired outside of the hospital (Bart-Delabesse et al., 1999; Symoens et al., 2002) with colonization possible prior to and following hospitalization (Latge, 1999). Moreover, nearly 60% of fusarioses at a major cancer center were determined to be community acquired (Raad, Tarrand, et al.). Hospitalization in laminar air flow (LAF) environments was found to protect immunosuppressed bone marrow transplant recipients against aspergillosis diagnosed within 40 days of transplant but not thereafter, suggesting that patients, initially in such protected rooms, acquired infections at home following discontinuation of LAF (Wald et al., 1997). Further evidence of exogenous fungal acquisition comes from the finding that 40% of surgical patients in one study (Lass-Florl et al., 1999) had pulmonary colonization by *Aspergillus* with no immediate prior hospitalization or clinical symptoms. Such colonization represents a potential source for invasive mycoses.

Pathogenic *Aspergillus* (Symoens et al., 2002) and *Fusarium* (Anaissie et al., 2001) have been isolated from private homes, in some cases at higher spore levels than in hospitals (Lass-Florl et al., 1999). *A. fumigatus* was common in house dust from

Downloaded on 07-05-2024. Single-user license only. Copyright 2024 by the Oncology Nursing Society. For permission to post online, reprint, adapt, or reuse, please email pubpermissions@ons.org. ONS reserves all rights.

carpets, mattresses, and damp basements as well as outdoor compost and leaves, particularly after disturbance (Sporik et al., 1993). An *Aspergillus* strain isolated from a neutropenic patient with aspergillosis was identical to that recovered in the patient's home as determined by molecular genotyping, suggesting community-acquired infection (Symoens et al.).

Seasonal clustering in opportunistic aspergillosis and fusariosis has been observed. A trend toward increased *Aspergillus* infections during autumn was noted in a study conducted in New Haven, CT (Patterson et al., 1997), whereas risk of infection in bone marrow transplant recipients in Seattle, WA, was greatest in summer (Wald et al., 1997). An investigation (Raad, Tarrand, et al., 2002) of neutropenic fusarioses conducted in Houston, TX, elucidated a temporal association between a maximum infection rate from July to September. These results suggested the importance of airborne fungal contaminants as a source of infection in non–air-filtered environments.

Recommendations to Reduce Exposure to Filamentous Fungi in the Hospital

In the hospital setting, minimizing exposure to filamentous fungi is achieved primarily by environmental control, including high-efficiency particulate air (HEPA) filtration (Hahn et al., 2002), LAF (Wald et al., 1997), Shinki bioclean rooms (Shinjo et al., 2002), and positive room air pressure (CDC et al., 2000; Gangneux et al., 2002; Humphreys, 2004). Studies (Alberti et al., 2001; Withington et al., 1998) have demonstrated that environmental modifications significantly decreased airborne *Aspergillus* spore loads and the incidence of aspergillosis in neutropenic patients compared to not using these precautions. Such strategies are important considerations in the design of new hospital units as well (Rhame, 1991). Regular maintenance and cleaning can ensure decontamination of ventilation systems (Manuel & Kibbler, 1998), whereas reservoirs of fungal contamination, such as moldy carpeting (Gerson et al., 1994) and insulation (Hahn et al.), should be removed or decontaminated.

During building construction, particular vigilance is required in application of precautionary measures to limit exposure to pathogens in light of increased potential for contamination (Burwen et al., 2001; Humphreys, 2004; Thio et al., 2000). Dust-proof barriers with airtight seals are mandatory to isolate patients from disturbed dust (CDC et al., 2000). Use of high-efficiency air filtration masks by at-risk patients during transport through the hospital has been associated with a significant decline in aspergillosis (Raad, Hanna, et al., 2002).

Because pathogenic spores are harbored in dust (Nelson et al., 1994; Ribes et al., 2000; Sporik et al., 1993), dust accumulation should be prevented on all surfaces in patient rooms. To minimize airborne spore loads, daily damp dusting with disinfectant of patient rooms as well as entire wards is advised (Alberti et al., 2001; Faure et al., 2002). Reports of growth of several opportunistic pathogens (Anaissie et al., 2001, 2003; Anaissie, Stratton, Dignani, Summerbell, et al., 2002) on bathroom walls, sinks, showers, and drains with potential aerosol transmission of spores highlight the need for cleaning and disinfection daily or immediately before use of the shower (Anaissie, Stratton, Dignani, Lee, et al., 2002). Cleaning in the patient's absence will further reduce exposure to spores (Rhame, 1991). Sterile water should be used in nebulizers because pathogenic fungi can colonize standing water (Anaissie et al., 2001, 2003).

Removing plants and flowers from patient rooms and hospital areas of patient exposure is essential (CDC et al., 2000; Risi & Tomascak, 1998) in light of the documented infection from *A. terreus* from plants (Lass-Florl et al., 2000) and the isolation of *Fusarium* (Burgess, 1981) and Zygomycetes (Ribes et al., 2000) from plants and soil. Patient care items such as skin lotion may be contaminated by pathogenic fungi, presenting potential nosocomial hazards as exemplified by *P. lilacinus* in hospital moisturizing lotion (Orth et al., 1996).

Recommendations to Reduce Exposure to Filamentous Fungi in the Home

Procedures to reduce exposure to filamentous fungi in the home should be implemented before, during, and for at least six months following neutropenia (CDC et al., 2000; Patterson et al., 1997; Wald et al., 1997) and be individualized for each patient (Johnson et al., 2000) depending on the home environment and activities. Accumulation of dust and moldy food should be prevented by frequent and thorough cleaning of surfaces with damp mopping and dusting with disinfectant (Faure et al., 2002) and should be completed in the patient's absence (Rhame, 1991). Regular carpet vacuuming with a HEPA filter-equipped cleaner will reduce spore load (Alberti et al., 2001). Bathroom walls, sinks, showers, and drains (Anaissie, Stratton, Dignani, Lee, et al., 2002) as well as refrigerator condensate trays (Price et al., 2002) should be cleaned regularly in light of documented growth of *Aspergillus* and *Fusarium* in standing water films (Anaissie et al., 2001, 2003). Potential for spore transmission through aerosols (Anaissie, Stratton, Dignani, Summerbell, et al., 2002) suggests that sterile water should be used in humidifiers or humidifiers should be avoided.

As a result of their colonization by pathogenic fungi (Lass-Florl et al., 2000; Ribes et al., 2000), the removal of indoor plants and flowers from the home should be considered (Meunier, 1987). Because disturbance of damp, decaying vegetation and soil releases aerosols of *Aspergillus* spores into the local aerial environment (Latge, 1999; Sporik et al., 1993), avoidance of exposure to outdoor decaying plant material and soil should be recommended, such as through elimination of gardening, raking of vegetation, and contact with damp wood, including firewood. Although wearing gloves while gardening (CDC et al., 2000; TUP, 2001) will prevent onychomycosis and percutaneous transmission (Nucci & Anaissie, 2002), the inhalation of airborne spores as an additional route of transmission (Boutati & Anaissie, 1997) emphasizes the need to restrict exposure to disturbed decaying vegetation and soil (CDC et al.). Damp, dusty environments (CDC et al.), such as cellars, attics, and caves, should be avoided. In light of the potential for fungal transmission by animals, clinicians may recommend that patients avoid direct pet care and reinforce hand hygiene with incidental contact (Angulo, Glaser, Juranek, Lappin, & Regnery, 1994; CDC et al.).

Food and Diet

Contact with contaminated food or water may lead to inhalation of fungal spores as well as absorption of these

Downloaded on 07-05-2024. Single-user license only. Copyright 2024 by the Oncology Nursing Society. For permission to post online, reprint, adapt, or reuse, please email pubpermissions@ons.org. ONS reserves all rights.

propagules, based on reports of gastrointestinal infection by filamentous fungi (Gangneux et al., 2002). Fungi can be present in a variety of foods and water. *Aspergillus* has been isolated from corn, peanuts, and cashews (Manuel & Kibbler, 1998); *Fusarium* is found in cereals, root vegetables, and oil seeds (Burgess, 1981); and cereals, nuts, and sweet potatoes are a source of Zygomycetes (Ribes et al., 2000). Spices, particularly black pepper, are known to carry significant levels of pathogenic fungi (McKee, 1995). Several opportunistic pathogens have been detected in some hospital water systems, including drinking water (Anaissie et al., 2001, 2003; Anaissie, Stratton, Dignani, Summerbell, et al., 2002).

Despite reports of fungal presence in foods (McKee, 1995), the frequency of contamination of hospital food and water is controversial. In an investigation by Rhame (1991), 73 food samples representing items often consumed by bone marrow transplant recipients yielded no pathogenic *Aspergillus* spp. A more recent survey of food served to neutropenic patients on a hematology ward reported the isolation of *Aspergillus* spp. or Mucorales from 100% of pepper and regular tea bag samples, 12%–66% of fruits depending on variety, 27% of herbal tea bags, and 20% of freeze-dried soups prior to adding hot water (Bouakline, Lacroix, Roux, Gangneux, & Derouin, 2000). With regard to contamination of drinking water, Anaissie, Stratton, Dignani, Summerbell , et al. (2002) found *Aspergillus* spp. in 21% of hospital water samples, in contrast to Gangneux et al. (2002) who reported < 1% of samples with this pathogen.

The use of neutropenic diets (see Table 6) to prevent mycoses varies widely among institutions (CDC et al., 2000; Smith & Besser, 2000), and their effectiveness is controversial (Todd, Schmidt, Christain, & Williams, 1999). However, several authors (Bouakline et al., 2000; Denning, 1998; Manuel & Kibbler, 1998; Philpott-Howard, 1996) recommended that ground black pepper be avoided in light of its high infestation level (see Table 7). In addition, based on their food contamination survey, Bouakline et al. suggested that water should be added to tea and soup in a kitchen prior to serving to patients to prevent formation of aerosols containing pathogenic spores; glabrous fruits, such as apples, should be disinfected by washing with soap and water and then rinsing with 70% ethanol; and pubescent fruits, including kiwis and peaches, should be eliminated from the diet because of surface fungal contamination not amenable to disinfection. For high-risk patients, Anaissie et al. (2003) advised sterile water for drinking because of contamination of some hospital water systems with pathogenic fungi.

Implications for Nursing and Research

Nurses have multiple roles in developing and implementing interventions for prevention of invasive mycoses through reduction in exposure. Because of nurses' close and ongoing interactions with patients, they are well positioned to identify early outbreaks of fungal infections and potential sources of pathogens both in the hospital and home (Johnson et al., 2000; Orth et al., 1996). Education of patients on approaches to prevent infections is a priority for nurses (Richard-Smith & Buh, 1995). These can be individualized for patients in relation to the period of susceptibility as well as hospital and home activities. Finally, nurses can assume leadership in needed research and development, including transfer of some hospital-based preventive technology to the home as home care in cancer therapy increases, investigation of the relationship between food contamination and mycoses, and application of research findings to practical interventions to improve the state of the science in preventing invasive fungal infections.

Table 6. Summary of Research Publications on Dietary Considerations for Neutropenic Patients

Citation	Design	Methods	Findings	Recommendations
McKee, 1995	Review of research studies	Reviewed 25 studies investigating fungal contamination of spices and herbs	*Aspergillus* species (spp.), *Rhizopus* spp., and *Fusarium* spp. commonly were detected in the spices and herbs analyzed, particularly black pepper.	Evaluate use of spices and herbs in light of widespread fungal contamination.
Todd et al., 1999	Descriptive survey	Telephone survey results of 21 hospitals' use of diets for neutropenic patients plus two position statements	43% used some form of low-bacteria diet (LBD) for neutropenic, non-bone marrow transplant (BMT) recipients; 86% used LBD for BMT recipients. Safe food handling also is important to reduce infection. No randomized, controlled trials were available.	Weigh the theoretical advantage of lower risk of food-borne illness with the practical disadvantage of limiting food choices for at-risk patients.
Bouakline et al., 2000	Research study of fungal contamination of foods	Isolation and identification of fungal contamination of 36 foods served to neutropenic patients in hematology units in a Paris, France, hospital	Greatest contamination was *Aspergillus* spp. and Mucorales in pepper, tea, and dried soups; yeasts in soft cheese; and *Aspergillus* spp. in pubescent fruits (e.g., apricot, peach, kiwi).	Eliminate pepper, soft cheeses, and pubescent fruits from diet. Prepare tea and dried soup and clean fruit and food packages in patient's absence prior to serving. Test kitchens for contamination.
Smith & Besser, 2000	Descriptive survey	156 institutions of Association of Community Cancer Centers returned mail surveys (39% response rate) on dietary restrictions for neutropenic patients.	78% suggested restricted diets for neutropenic patients; 83% suggested restricted diets only during neutropenia. Most common restrictions were fresh vegetables (95%), fresh fruits and juices (92%), raw eggs (74%), beer (40%), and wine (39%).	In light of diverse practices and lack of evidence on diet's effect on infections in neutropenia, research on dietary factors contributing to these infections is needed. Umbrella organizations can foster prospective and retrospective research.

Downloaded on 07-05-2024. Single-user license only. Copyright 2024 by the Oncology Nursing Society. For permission to post online, reprint, adapt, or reuse, please email pubpermissions@ons.org. ONS reserves all rights.

Table 7. Recommendations to Reduce Exposure to Fungal Pathogens Through Dietary Measures

Activity	Actions	Selected References
Education	Educate patients, caregivers, and healthcare workers about recommendations to reduce fungal exposure through dietary measures.	Centers for Disease Control and Prevention (CDC) et al., 2000
Research	Develop research programs on dietary factors contributing to fungal infections in neutropenia in light of diverse practices reported and lack of evidence on effect of diet on mycoses. Umbrella organizations can foster prospective and retrospective research.	Bouakline et al, 2000; Gangneux et al., 2002; Smith & Besser, 2000; Todd et al., 1999
Dietary restrictions	Consider the following dietary modifications for at-risk patients. • Use a low-microbial diet. The advantage of potentially reducing the risk of food-borne infection versus the disadvantage of restricting food choices must be weighed. • Eliminate spices, particularly ground black pepper, herbs, soft cheeses, and pubescent fruits, including kiwis, peaches, and apricots, from diet because of fungal contamination not amenable to disinfection.	Bouakline et al.; Burgess, 1981; CDC et al.; Denning, 1998; Gangneux et al.; Manuel & Kibbler, 1998; McKee, 1995; Philpott-Howard, 1996; Ribes et al., 2000; Smith & Besser; Todd et al.
Food and beverage preparation and storage	Consider the following measures in the preparation and storage of food and beverages. • Prior to serving, add water to tea and dried soup in an area removed from the patient to avoid exposure to possible aerosols containing pathogenic spores. • Disinfect food wrappings and glabrous fruits, including apples, with soap and water followed by a rinse with 70% ethanol. • Refrigerate leftover food within two hours of cooking. • Discard leftover food kept at room temperature for more than two hours. • Reheat leftover food, heat partially cooked food to more than 165°F, and boil leftover soups, sauces, and gravies before serving.	Bouakline et al.; CDC et al.; Gangneux et al.
Drinking water restrictions	Consider sterile water for drinking because of contamination of some water systems with pathogenic fungi.	Anaissie et al., 2001, 2003; Anaissie, Stratton, Dignani, Summerbell, et al., 2002

Note. Adherence to these guidelines is recommended before, during, and for at least three months following immunosuppressive therapy as well as during periods of immunosuppression (e.g., graft-versus-host disease, systemic steroid use, relapses of malignancy) (CDC et al., 2000; Smith & Besser, 2000) to reduce potential exposure to fungal pathogens.

In summary, research on preventing systemic mycoses in neutropenia suggests approaches to decrease exposure to contamination through modification of the patient environment, activities, and possibly diet in the institutional and home settings. Expanded recommendations to prevent infections for ambulatory patients, emphasis on the role of nurses in education of patients, and further research in preventive measures will all serve to improve the outcomes for at-risk, neutropenic patients.

The authors thank Lenore R. Wilkas, MLS, in the School of Nursing at the University of Pennsylvania in Philadelphia, for her many helpful suggestions on the literature search for this article and Zofia Pokacka, DSc (Agr), in the Mycology Department at the Plant Protection Institute in Poznan, Poland, for productive discussions on fungal ecology.

Author Contact: Constance M. Smith, PhD, RN, can be reached at smithC2@nursing.upenn.edu, with copy to editor at rose_mary@earthlink.net.

References

Alberti, C., Bouakline, A., Ribaud, P., Lacroix, C., Rousselot, P., Leblanc, T., et al. (2001). Relationship between environmental fungal contamination and the incidence of invasive aspergillosis in haematology patients. *Journal of Hospital Infection, 48,* 198–206.

Anaissie, E.J., Kuchar, R.T., Rex, J.H., Francesconi, A., Kasai, M., Muller, F.M., et al. (2001). Fusariosis associated with pathogenic *Fusarium* species colonization of a hospital water system: A new paradigm for the epidemiology of opportunistic mold infections. *Clinical Infectious Diseases, 33,* 1871–1878.

Anaissie, E.J., Stratton, S.L., Dignani, M.C., Lee, C.K., Mahfouz, T.H., Rex, J.H., et al. (2002). Cleaning patient shower facilities: A novel approach to reducing patient exposure to aerosolized *Aspergillus* species and other opportunistic molds. *Clinical Infectious Diseases, 35,* E86–E88.

Anaissie, E.J., Stratton, S.L., Dignani, M.C., Lee, C.K., Summerbell, R.C., Rex, J.H., et al. (2003). Pathogenic molds (including *Aspergillus* species) in hospital water distribution systems: A 3-year prospective study and clinical implications for patients with hematologic malignancies. *Blood, 101,* 2542–2546.

Anaissie, E.J., Stratton, S.L., Dignani, M.C., Summerbell, R.C., Rex, J.H., Monson, T.P., et al. (2002). Pathogenic *Aspergillus* species recovered from a hospital water system: A 3-year prospective study. *Clinical Infectious Diseases, 34,* 780–789.

Angulo, F.J., Glaser, C.A., Juranek, D.D., Lappin, M.R., & Regnery, R.L. (1994). Caring for pets of immunocompromised persons. *Journal of the American Veterinary Medical Association, 205,* 1711–1718.

Bart-Delabesse, E., Cordonnier, C., & Bretagne, S. (1999). Usefulness of genotyping with microsatellite markers to investigate hospital-acquired invasive aspergillosis. *Journal of Hospital Infection, 42,* 321–327.

Bodey, G.P. (1997). Fungal infection in neutropenic patients: Past achievements and future problems. In J.A. Klastersky (Ed.), *Febrile neutropenia* (pp. 89–98). New York: Springer.

Bouakline, A., Lacroix, C., Roux, N., Gangneux, J.P., & Derouin, F. (2000). Fungal contamination of food in hematology units. *Journal of Clinical Microbiology, 38,* 4272–4273.

Boutati, E.I., & Anaissie, E.J. (1997). *Fusarium*, a significant emerging pathogen in patients with hematologic malignancy: Ten years' experience at a cancer center and implications for management. *Blood, 90,* 999–1008.

Bow, E.J. (1998). Invasive fungal infections in patients receiving intensive cytotoxic therapy for cancer. *British Journal of Haematology, 101*(Suppl. 1), S1–S4.

Burgess, L.W. (1981). General ecology of the Fusaria. In P.E. Nelson,

Downloaded on 07-05-2024. Single-user license only. Copyright 2024 by the Oncology Nursing Society. For permission to post online, reprint, adapt, or reuse, please email pubpermissions@ons.org. ONS reserves all rights.

T.A. Toussoun, & R.J. Cook (Eds.), *Fusarium: Diseases, biology, and taxonomy* (pp. 225–235). University Park, PA: Pennsylvania State University Press.

Burwen, D.R., Lasker, B.A., Rao, N., Durry, E., Padhye, A.A., & Jarvis, W.R. (2001). Invasive aspergillosis outbreak on a hematology-oncology ward. *Infection Control and Hospital Epidemiology, 22,* 45–48.

Centers for Disease Control and Prevention, Infectious Disease Society of America, and American Society of Blood and Marrow Transplantation. (2000). Guidelines for preventing opportunistic infections among hematopoietic stem cell transplant recipients: Recommendations of CDC. *Morbidity and Mortality Weekly Report, 49*(No. RR-10), 1–128. Retrieved June 12, 2004, from http://www.cdc.gov/mmwr/preview/mmwrhtml/rr4910a1.htm

Coopersmith, C.M., Rebmann, T.L., Zack, J.E., Ward, M.R., Corcoran, R.M., Schallom, M.E., et al. (2002). Effect of an education program on decreasing catheter-related bloodstream infections in the surgical intensive care unit. *Critical Care Medicine, 30,* 59–64.

Denning, D.W. (1998). Invasive aspergillosis. *Clinical Infectious Diseases, 26,* 781–805.

Faure, O., Fricker-Hidalgo, H., Lebeau, B., Mallaret, M.R., Ambroise-Thomas, P., & Grillot, R. (2002). Eight-year surveillance of environmental fungal contamination in hospital operating rooms and haematological units. *Journal of Hospital Infection, 50,* 155–160.

Feld, R. (1997). Quality of life in patients with febrile neutropenia. In J.A. Klastersky (Ed.), *Febrile neutropenia* (pp. 117–123). New York: Springer.

Fidel, P.L., Jr., Vazquez, J.A., & Sobel, J.D. (1999). *Candida glabrata*: Review of epidemiology, pathogenesis, and clinical disease with comparison to *C. albicans*. *Clinical Microbiology Reviews, 12,* 80–96.

Fleming, R.V., Walsh, T.J., & Anaissie, E.J. (2002). Emerging and less common fungal pathogens. *Infectious Disease Clinics of North America, 16,* 915–933.

Fridkin, S.K., & Jarvis, W.R. (1996). Epidemiology of nosocomial fungal infections. *Clinical Microbiology Reviews, 9,* 499–511.

Gangneux, J.P., Bretagne, S., Cordonnier, C., Datry, A., Derouin, F., Grillot, R., et al. (2002). Prevention of nosocomial fungal infection: The French approach. *Clinical Infectious Diseases, 35,* 343–346.

Gerson, S.L., Parker, P., Jacobs, M.R., Creger, R., & Lazarus, H.M. (1994). Aspergillosis due to carpet contamination. *Infection Control and Hospital Epidemiology, 15,* 221–223.

Gudlaugsson, O., Gillespie, S., Lee, K., Vande Berg, J., Hu, J., Messer, S., et al. (2003). Attributable mortality of nosocomial candidemia, revisited. *Clinical Infectious Diseases, 37,* 1172–1177.

Guiot, H.F., Fibbe, W.E., & van't Wout, J.W. (1994). Risk factors for fungal infection in patients with malignant hematologic disorders: Implications for empirical therapy and prophylaxis. *Clinical Infectious Diseases, 18,* 525–532.

Hahn, T., Cummings, M., Michalek, A.M., Lipman, B.J., Segal, B.H., & McCarthy, P.L., Jr. (2002). Efficacy of high-efficiency particulate air filtration in preventing aspergillosis in immunocompromised patients with hematologic malignancies. *Infection Control and Hospital Epidemiology, 23,* 525–531.

Herrmann, R.P., Trent, M., Cooney, J., & Cannell, P.K. (1999). Infections in patients managed at home during autologous stem cell transplantation for lymphoma and multiple myeloma. *Bone Marrow Transplantation, 24,* 1213–1217.

Hobson, R.P. (2003). The global epidemiology of invasive *Candida* infections—Is the tide turning? *Journal of Hospital Infection, 55,* 159–168.

Humphreys, H. (2004). Positive-pressure isolation and the prevention of invasive aspergillosis. What is the evidence? *Journal of Hospital Infection, 56,* 93–100.

Jantunen, E., Ruutu, P., Niskanen, L., Volin, L., Parkkali, T., Koukila-Kahkola, P., et al. (1997). Incidence and risk factors for invasive fungal infections in allogeneic BMT recipients. *Bone Marrow Transplantation, 19,* 801–808.

Johnson, E., Gilmore, M., Newman, J., & Stephens, M. (2000). Preventing fungal infections in immunocompromised patients. *British Journal of Nursing, 9,* 1154, 1156, 1158–1164.

Kuderer, N.M., Cosler, L., Crawford, J., Dale, D.C., & Lyman, G.H. (2002). Cost and mortality associated with febrile neutropenia in adult cancer patients [Abstract 998]. *Proceedings of the American Society of Clinical Oncology, 21,* 250a.

Lass-Florl, C., Rath, P., Niederwieser, D., Kofler, G., Wurzner, R., Krezy, A., et al. (2000). *Aspergillus terreus* infections in haematological malignancies: Molecular epidemiology suggests association with in-hospital plants. *Journal of Hospital Infection, 46,* 31–35.

Lass-Florl, C., Salzer, G.M., Schmid, T., Rabl, W., Ulmer, H., & Dierichi, M. (1999). Pulmonary *Aspergillus* colonization in humans and its impact on management of critically ill patients. *British Journal of Haematology, 104,* 745–747.

Latge, J.P. (1999). *Aspergillus fumigatus* and aspergillosis. *Clinical Microbiology Reviews, 12,* 310–350.

Loudon, K.W., Coke, A.P., Burnie, J.P., Shaw, A.J., Oppenheim, B.A., & Morris, C.Q. (1996). Kitchens as a source of *Aspergillus niger* infection. *Journal of Hospital Infection, 32,* 191–198.

Lueg, E.A., Ballagh, R.H., & Forte, V. (1996). Analysis of the recent cluster of invasive fungal sinusitis at the Toronto Hospital for Sick Children. *Journal of Otolaryngology, 25,* 366–370.

Lyman, G.H., & Kuderer, N.M. (1997). Incorporation of quality-of-life considerations into decision models for the use of colony-stimulating factors in chemotherapy patients at risk for febrile neutropenia. In J. A. Klastersky (Ed.), *Febrile neutropenia* (pp. 17–22). New York: Springer.

Manuel, R.J., & Kibbler, C.C. (1998). The epidemiology and prevention of invasive aspergillosis. *Journal of Hospital Infection, 39,* 95–109.

Marr, K.A., Carter, R.A., Boeckh, M., Martin, P., & Corey, L. (2002). Invasive aspergillosis in allogeneic stem cell transplant recipients: Changes in epidemiology and risk factors. *Blood, 100,* 4358–4366.

Marr, K.A., Carter, R.A., Crippa, F., Wald, A., & Corey, L. (2002). Epidemiology and outcome of mould infections in hematopoietic stem cell transplant recipients. *Clinical Infectious Diseases, 34,* 909–917.

Martino, P., Girmenia, C., Venditti, M., Micozzi, A., Santilli, S., Burgio, V.L., et al. (1989). *Candida* colonization and systemic infection in neutropenic patients: A retrospective study. *Cancer, 64,* 2030–2034.

McKee, L.H. (1995). Microbial contamination of spices and herbs: A review. *Lebensmittel-Wissenschaft und Technologie, 28,* 1–11.

Meunier, F. (1987). Prevention of mycoses in immunocompromised patients. *Reviews of Infectious Diseases, 9,* 408–416.

Morris, G., Kokki, M.H., Anderson, K., & Richardson, M.D. (2000). Sampling of *Aspergillus* spores in air. *Journal of Hospital Infection, 44,* 81–92.

Nelson, P.E., Dignani, M.C., & Anaissie, E.J. (1994). Taxonomy, biology, and clinical aspects of *Fusarium* species. *Clinical Microbiology Reviews, 7,* 479–504.

Nucci, M., & Anaissie, E. (2002). Cutaneous infection by *Fusarium* species in healthy and immunocompromised hosts: Implications for diagnosis and management. *Clinical Infectious Diseases, 35,* 909–920.

Nucci, M., Marr, K.A., Queiroz-Telles, F., Martins, C.A., Trabasso, P., Costa, S., et al. (2004). *Fusarium* infection in hematopoietic stem cell transplant recipients. *Clinical Infectious Diseases, 38,* 1237–1242.

Orth, B., Frei, R., Itin, P.H., Rinaldi, M.G., Speck, B., Gratwohl, A., et al. (1996). Outbreak of invasive mycoses caused by *Paecilomyces lilacinus* from a contaminated skin lotion. *Annals of Internal Medicine, 125,* 799–806.

Pagano, L., Antinori, A., Ammassari, A., Mele, L., Nosari, A., Melillo, L., et al. (1999). Retrospective study of candidemia in patients with hematological malignancies. Clinical features, risk factors and outcome of 76 episodes. *European Journal of Haematology, 63,* 77–85.

Patterson, J.E., Zidouh, A., Miniter, P., Andriole, V.T., & Patterson, T.F. (1997). Hospital epidemiologic surveillance for invasive aspergillosis: Patient demographics and the utility of antigen detection. *Infection Control and Hospital Epidemiology, 18,* 104–108.

Pfaller, M.A. (1996). Nosocomial candidiasis: Emerging species, reservoirs, and modes of transmission. *Clinical Infectious Diseases, 22*(Suppl. 2), S89–S94.

Philpott-Howard, J. (1996). Prevention of fungal infections in hematology patients. *Infection Control and Hospital Epidemiology, 17,* 545–551.

Pittet, D., Mourouga, P., & Perneger, T.V. (1999). Compliance with handwashing in a teaching hospital. *Annals of Internal Medicine, 130,* 126–130.

Price, E.H., Jones, R., Groombridge, S., & Hoffman, P.N. (2002). Risk to

Downloaded on 07-05-2024. Single-user license only. Copyright 2024 by the Oncology Nursing Society. For permission to post online, reprint, adapt, or reuse, please email pubpermissions@ons.org. ONS reserves all rights.

immune suppressed patients from *Aspergillus* spp. growing in fridge condensate trays. *Journal of Hospital Infection, 52,* 72.

Raad, I., Hanna, H., Osting, C., Hachem, R., Umphrey J., Tarrand, J., et al. (2002). Masking of neutropenic patients on transport from hospital rooms is associated with a decrease in nosocomial aspergillosis during construction. *Infection Control and Hospital Epidemiology, 23,* 41–43.

Raad, I., Tarrand, J., Hanna, H., Albitar, M., Janssen, E., Boktour, M., et al. (2002). Epidemiology, molecular mycology, and environmental sources of *Fusarium* infection in patients with cancer. *Infection Control and Hospital Epidemiology, 23,* 532–537.

Reagan, D.R., Pfaller, M.A., Hollis, R.J., & Wenzel, R.P. (1990). Characterization of the sequence of colonization and nosocomial candidemia using DNA fingerprinting and a DNA probe. *Journal of Clinical Microbiology, 28,* 2733–2738.

Rhame, F.S. (1991). Prevention of nosocomial aspergillosis. *Journal of Hospital Infection, 18*(Suppl. A), 466–472.

Ribes, J.A., Vanover-Sams, C.L., & Baker, D.J. (2000). Zygomycetes in human disease. *Clinical Microbiology Reviews, 13,* 236–301.

Richard-Smith, A., & Buh, S. (1995). Reducing central line catheter infections in bone marrow transplant patients. *Nursing Clinics of North America, 30,* 45–52.

Risi, G.F., & Tomascak, V. (1998). Prevention of infection in the immunocompromised host. *American Journal of Infection Control, 26,* 594–606.

Rotstein, C., Bow, E.J., Laverdiere, M., Carr, D., Moghaddam, N., & Ioannou, S. (1996). A multicentre, randomized, placebo-controlled trial of fluconazole prophylaxis for fungal infection in neutropenic cancer patients [Abstract 1694]. *Blood, 88*(Suppl. 1), S426a.

Segal, B.H., Bow, E.J., & Menichetti, F. (2002). Fungal infections in non-transplant patients with hematologic malignancies. *Infectious Disease Clinics of North America, 16,* 935–964.

Shinjo, K., Takeshita, A., Yanagi, M., Yokota, K., Hirano, K., Suzuki, M., et al. (2002). Efficacy of the Shinki bioclean room for preventing infection in neutropenic patients. *Journal of Advanced Nursing, 37,* 227–233.

Smith, L.H., & Besser, S.G. (2000). Dietary restrictions for patients with neutropenia: A survey of institutional practices. *Oncology Nursing Forum, 27,* 515–520.

Sporik, R.B., Arruda, L.K., Woodfolk, J., Chapman, M.D., & Platts-Mills, T.A.E. (1993). Environmental exposure to *Aspergillus fumigatus* allergen (*Asp f* I). *Clinical and Experimental Allergy, 23,* 326–331.

Stoiser, B., Kofler, J., Staudinger, T., Georgopoulos, A., Lugauer, S., Guggenbichler, J.P., et al. (2002). Contamination of central venous catheters in immunocompromised patients: A comparison between two different types of central venous catheters. *Journal of Hospital Infection, 50,* 202–206.

Strausbaugh, L.J., Sewell, D.L., Ward, T.T., Pfaller, M.A., Heitzman, T., & Tjoelker, R. (1994). High frequency of yeast carriage on hands of hospital personnel. *Journal of Clinical Microbiology, 32,* 2299–2300.

Symoens, F., Burnod, J., Lebeau, B., Viviani, M.A., Piens, M.A., Tortorano, A.M., et al. (2002). Hospital-acquired *Aspergillus fumigatus* infection: Can molecular typing methods identify an environmental source? *Journal of Hospital Infection, 52,* 60–67.

Thio, C.L., Smith, D., Merz, W.G., Streifel, A.J., Bova, G., Gay, L., et al. (2000). Refinements of environmental assessment during an outbreak investigation of invasive aspergillosis in a leukemia and bone marrow transplant unit. *Infection Control and Hospital Epidemiology, 21,* 18–23.

Todd, J., Schmidt, M., Christain, J., & Williams, R. (1999). The low-bacteria diet for immunocompromised patients: Reasonable prudence or clinical superstition? *Cancer Practice, 7,* 205–207.

Trustees of the University of Pennsylvania. (2001). *What you should know about low blood counts* [Brochure]. Philadelphia: Author.

Vazquez, J.A., Dembry, L.M., Sanchez, V., Vazquez, M.A., Sobel, J.D., Dmuchowski, C., et al. (1998). Nosocomial *Candida glabrata* colonization: An epidemiologic study. *Journal of Clinical Microbiology, 36,* 421–426.

Vazquez, J.A., Sanchez, V., Dmuchowski, C., Dembry, L.M., Sobel, J.D., & Zervos, M.J. (1993). Nosocomial acquisition of *Candida albicans*: An epidemiologic study. *Journal of Infectious Diseases, 168,* 195–201.

Wald, A., Leisenring, W., van Burik, J., & Bowden, R.A. (1997). Epidemiology of *Aspergillus* infections in a large cohort of patients undergoing bone marrow transplantation. *Journal of Infectious Diseases, 175,* 1459–1466.

Warnock, D.W. (1998). Fungal infections in neutropenia: Current problems and chemotherapeutic control. *Journal of Antimicrobial Chemotherapy, 41*(Suppl. D), 95–105.

Withington, S., Chambers, S.T., Beard, M.E., Inder, A., Allen, J.R., Ikram, R.B., et al. (1998). Invasive aspergillosis in severely neutropenic patients over 18 years: Impact of intranasal amphotericin B and HEPA filtration. *Journal of Hospital Infection, 38,* 11–18.

Downloaded on 07-05-2024. Single-user license only. Copyright 2024 by the Oncology Nursing Society. For permission to post online, reprint, adapt, or reuse, please email pubpermissions@ons.org. ONS reserves all rights.