Review

Candida tropicalis: its prevalence, pathogenicity and increasing resistance to fluconazole

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Candida tropicalis has been identified as the most prevalent pathogenic yeast species of the Candida-non-albicans group. Historically, Candida albicans has been the major species responsible for causing candidiasis in immunocompromised and immunocompetent patients. However, infections (candidiasis) due to C. tropicalis have increased dramatically on a global scale thus proclaiming this organism to be an emerging pathogenic yeast. The reasons for this organism’s dominance and its resistance to fluconazole have been difficult to elucidate. In addition, the mechanism of this organism’s pathogenicity and the consequent immune response remain to be clarified. This paper describes certain predisposing factors potentially responsible for these characteristics and presents a ‘root cause analysis’ to explain the increasing prevalence of C. tropicalis in developed and undeveloped countries, as well as the organism’s acquired drug resistance. Control measures against fluconazole resistance in clinical management have also been discussed.

Introduction

Fungi are widespread in the environment. Some are associated with animals and humans as commensals, but turn pathogenic or opportunistic after alteration of the host immune system (Krasner, 2002). Therapeutic applications of immunosuppressive drugs, the use of broad-spectrum antibiotics, and the varying clinical conditions and other predisposing factors are responsible for an increasing number of immunocompromised patients and consequent opportunistic infections globally. A weakened or impaired immune system provides favourable conditions for pathogenic and non-pathogenic micro-organisms. AIDS due to human immunodeficiency virus (HIV-I and HIV-II) is one of the major contributing factors for the increasing number of patients with fungal infections (Nissapatorn et al., 2003; Singh et al., 2003; Vasquez & Sobel, 1995). The extensive use of antifungals for prophylaxis in these patients became the leading cause of colonization of Candida-non-albicans (CNA) species and increasing resistance to antifungal drugs (Hsu et al., 2005; Perfect, 2004). In India, Candida tropicalis is the most common cause of nosocomial candidaemia. Epidemiological data from the Indian subcontinent showed that 67–90% of nosocomial candidaemia cases were due to CNA species of which C. tropicalis was the most dominant (Kothari & Sagar, 2009; Verma et al., 2003). This review demonstrates the increasing importance of CNA species, particularly C. tropicalis, in terms of (1) pathogenic potential, (2) ability to cause systemic life-threatening infections – candidiasis/candidaemia and (3) acquired fluconazole resistance and consequent mortality rate.

Clinical and laboratory diagnosis of candidiasis

The clinical features of candidiasis are dependent on the sites of infection. Oropharyngeal candidiasis, angular chelitis, balanoposthitis, oral thrush and vulvovaginal candidiasis are features of mucous membrane (mucocutaneous candidiasis) infection; interdigital candidiasis, paronychia and nappy rash are features of cutaneous candidiasis; and pulmonary candidiasis, disseminated candidiasis, gastrointestinal candidiasis and candidaemia are features of systemic candidiasis, involving internal body fluids and organs (Jacobs & Nall, 1990). Microscopic examination is the basic test for diagnosis of a fungal infection, by using a 10% potassium hydroxide wet mount prepared from skin scrapings or crushed autopsy
specimens and a simple wet mount preparation for body fluids such as blood, cerebrospinal fluid (CSF) or urine. Haematoxylin and eosin, periodic acid–Schiff and Gomori–Grocott methenamine silver stains are the preferred stains used for differential diagnosis of fungal infection in tissue sections taken from biopsy or autopsy specimens. Processed clinical samples are cultured on Sabouraud dextrose agar, which allows growth of any fungi and their isolation. Biochemical tests such as the rapid API 20 microtbe system are readily available for species identification of the isolated colonies (Buesching et al., 1979). There is an automated continuous-monitoring blood culture system available for critically ill patients. The rapid molecular and more specific techniques such as PCR offer genotyping and allow for browsing of any drug resistance by clinical isolates of Candida species (Krawczyk et al., 2009; Antonopoulou et al., 2009).

C. tropicalis and C. albicans infections in clinical settings

Patients with chronic mucocutaneous candidiasis are occasionally associated with other disseminated or systemic fungal infections such as C. neoformans, but never with any other species of Candida (Stein & Sugar, 1989). However, disseminated C. tropicalis infections have been reported in immunocompromised patients who have had chronic mucocutaneous candidiasis (Dixon et al., 2004).

Acute leukaemia (immunocompromised) patients with gastrointestinal infections are more prone to invasive candidiasis (Bodey, 1984; Myerowitz et al., 1977). Some rare cases of cancer and other underlying conditions associated with candidiasis are summarized in Table 1. In addition to the oral mucosa, the gastrointestinal tract seems to be a favourable site for penetration of Candida species through gastric mucosal layers and subsequent dissemination to immunocompromised patients (Stone et al., 1974). Autopsy studies in such patients have demonstrated culture-proven disseminated candidiasis due to C. albicans or C. tropicalis infection with the involvement of the gastrointestinal tract. The classical morphological features of Candida yeasts (budding yeast and pseudohyphal forms) in submucosal layers are usually preceded by a band of progressive necrotic tissue. These necrotic bands at the advancing mycelial margin have been observed with C. tropicalis but not with C. albicans (Walsh & Merz, 1986). Details of such studies are summarized in Table 2. C. tropicalis has progressively been observed to be the commonest cause of invasive candidiasis in neutropenic patients such as those with acute leukaemia or those who have undergone bone marrow transplantation (Sandford et al., 1980; Wingard et al., 1979). However, the mechanism of the mutual role of the microbes and associated host factors in creating opportunistic conditions for C. tropicalis to cause gastrointestinal colonization or infection and any consequent dissemination in such patients (Fromling et al., 1987) remains obscure.

Candida tropicalis is an emerging pathogen in neonatal intensive care units (ICUs) (Paya, 1993; Singh et al., 2003). Persistent candidiasis in such patients has been associated with haemodialysis, fungal colonization, exposure to broad-spectrum antibiotics, intensive care unit (ICU) hospitalization, acute hepatic failure and other surgical events. In addition, during several post-operative surgical procedures, bacterial and viral infections (cytomegalovirus and human herpesvirus 6) also occurred in such patients (Winston et al., 1999; Husain et al., 2003). C. albicans has been observed to be the most prevalent species associated with candidal pericarditis followed by C. glabrata and C. tropicalis. A 30–100% mortality rate in such patients has been reported to be exclusively due to CNA species (Paya, 1993; Fung, 2002). However, widespread use of fluconazole and the emerging trend of CNA species pose a major risk of colonization or infections in liver transplant patients. This scenario warns that the use of fluconazole should be focused more on high-risk patients (Husain et al., 2003).

A considerable risk of colonization by CNA species in the neonatal ICU may lead to the predominance of C. tropicalis as a subsequent cause of neonatal fungaemia (Roilides et al., 2003). Acquisition of C. tropicalis very likely occurs in the neonatal ICU by cross-contamination. There are several reports of nosocomial cross-infections due to C. albicans or Candida parapsilosis in the neonatal ICU.
Table 1. Comparative clinical features of *C. tropicalis* and *C. albicans* infections, underlying clinical conditions, treatment and outcome in cancer patients

| Group of patients | Year | No. of cases | No. of cases | Affected area | Underlying disease/clinical features* | Therapy | Outcome | No. of cases | Underlying disease/clinical features* | Therapy | Outcome |
|-------------------|------|--------------|--------------|--------------|--------------------------------------|---------|---------|--------------|--------------------------------------|---------|---------|
| Candida arthritis (Sim et al., 2005) | 2005 | 12 | 3 | Knee | ALL | AmB, FL, FL in combination with CSFG | Resolved | 1 | Knee | ALL | AmB, FL, FL in combination with CSFG | Resolved |
| | | | | | | | | | | | | | |
| | | | 2 | Knee | AML | AmB and micamazole | Resistant | 1 | Knee | ALL | AmB and 5-flucytosine | Resistant |
| | | | 1 | Knee | CML-BC | Ketoconazole | Resistant | 1 | Knee | ALL | AmB and 5-flucytosine | Resistant |
| | | | 1 | Knee | SLL | AmB, micamazole | Resistant | 1 | Knee | ALL | AmB and 5-flucytosine | Resistant |
| | | | | | | | | | | | | |
| Sporotrichosis (Faridkous et al., 2008) | 2008 | 4 | 1 | Vertebræ | (i) Sporotrichosis of L23 and L12 vertebrae; (ii) sigmoid colon | FL (L=, oral) | Resistant | 1 | Knee | ALL | AmB and 5-flucytosine | Resistant |
| | | | | | | | | | | | | |
| Oral candidiasis in children and adolescents with cancer (Castilao-Terron et al., 2007) | 2007 | 26 | 6 | Oral mucosa | (i) 5 cases with pseudomembranous and 1 case with erythematous candidiasis; (ii) 2 with ALL; 1 with medulloblastoma and 1 with grade 1 astrocytoma | NS | Resistant | 20 | Oral mucosa | (i) 14 cases with pseudomembranous and 6 cases with erythematous candidiasis; (ii) 13 with ALL; 1 with medulloblastoma; 1 with grade 1 astrocytoma; 2 with reticulum cell sarcoma and 1 with thalidomide sarcoma | NS | NS | NS |

*ALL, acute lymphoblastic leukaemia; AML, acute myeloid leukaemia; CLL, chronic lymphocytic leukaemia; CML-BC, chronic myeloid leukaemia in blastic crisis; SLL, small lymphocytic lymphoma.*
setting, C. tropicalis associated with candidiasis is not often encountered in neonates. However, adults and children with haematological malignancies have a higher mortality rate due to such an infection. The epidemiology of C. tropicalis in neonates is uncertain, but the probability for nosocomial spread must be carefully measured. Nosocomial transmission of a predominant genotype of C. tropicalis may occur among neonates most likely via cross-contamination. It is noteworthy that neonatal C. tropicalis isolates tested in some studies were susceptible to amphotericin B and flucytosine. A significant proportion of C. tropicalis isolates from neonates demonstrated reduced susceptibility to azoles compared to C. albicans (Rolildes et al., 2003). In addition to weakened immunity, high virulence and low azole susceptibility characteristics of C. tropicalis may be the leading cause of disseminated candidiasis in patients with haematological malignancies. Under such debilitating conditions, as well as infections caused by C. albicans alone, C. tropicalis infection could be augmenting the high mortality rates.

Pathogenicity of C. tropicalis

Increased virulence of C. tropicalis isolates was observed when given orally to compromised mice, which parallels clinical observations in immunocompromised patients. Some studies showed that C. tropicalis is even more invasive than C. albicans in the human intestine, particularly in oncology patients (Walsh & Merz, 1986; Wingard et al., 1979).

Secreted aspartyl proteinase 5 and 9 (SAP5 and SAP9) activity occurs in all Candida species, in the following order: C. albicans>C. tropicalis>Candida kefyr>Candida krusei. A few experimental studies have suggested that, following ingestion of yeast cells by phagocytic cells, SAP antigens are expressed by C. albicans and C. tropicalis, but not by C. parapsilosis (Borg & Rüchel, 1990; Rüchel, 1986; Rüchel et al., 1986). The aspartic proteinases secreted by C. tropicalis have also been demonstrated on the surface of the fungal cell walls before invading tissues during disseminated infections and invading macrophages after phagocytosis of yeast cells (Borg & Rüchel, 1990; Borg-von Zepelin et al., 1998; Rüchel et al., 1991).

Some CNA species that were previously thought to be SAP-negative were in fact proteolytic. The purified tropiae from C. tropicalis (a novel acid proteinase) demonstrated haemorrhagic activity and the ability to increase capillary permeability (Capobianco et al., 1992; Okumura et al., 2007). In order to examine these detrimental properties of tropiae in humans, comprehensive evaluation in a clinical setting (gastroenterology) needs to be focused on C. tropicalis-infected patients who are also suffering from ulcerative colitis or varying levels of gastrointestinal illnesses or complications.

Recent studies on three specific key virulence factors (proteinase, phospholipase and biofilm) suggest that the detection of hydrolytic enzymes and the ability of Candida yeasts to form biofilm may be useful indicators of possible haematogenous infection. Such findings may support clinicians in the management of patients who have a high risk of haematogenous Candida infection (Gokce et al., 2007).

Host defence

The oral cavity possesses physical barriers such as epithelial cells, saliva and salivary immunoglobulin (IgA), lysozyme, histidine-rich polypeptide, lactoferrin and lactoperoxidase for antagonistic action against Candida overgrowth (Jorge et al., 1993). Although there is a clear understanding of the dominant host defence mechanisms against infections caused by C. albicans, less is understood about those against infections caused by C. tropicalis which has proven almost always to be the concomitant agent in the development of mycotic infections (Wingard et al., 1979).

Invasive candidiasis due to C. tropicalis has been found more frequently in neutropenic patients receiving treatment for acute leukaemia or bone marrow transplants (Sandford et al., 1980; Wingard et al., 1979). This indicates that polymorphonuclear leukocytes are the first line of defence against C. tropicalis (Odds, 1988). However, the mutual role of microbial and other predisposing host factors which allow C. tropicalis to colonize the gastrointestinal tract remains uncertain (Fromlting et al., 1987). There have been an insufficient number of studies describing the fungal cell morphology and the histopathological manifestations associated with infections caused by C. tropicalis. In several cases, the histopathological manifestation has been described only in broad terms.
Epidermal keratinocytes play an important role in the cutaneous immune response through the production of cytokines and chemokines, including interferon (IFN)-γ-inducible protein 10 (IP-10). Recent investigations demonstrated that C. albicans and C. tropicalis impaired IFN-γ-induced IP-10 expression but C. glabrata did not. C. albicans and C. tropicalis produced marked levels of prostaglandins, while C. glabrata produced a very low level. The prostaglandin antagonist restores IFN-γ-induced IP-10 expression in C. albicans-infected normal human epidermal keratinocytes (NHEKs). These experimental findings suggest that prostaglandin E2 may be a major predisposing factor for diminishing IFN-γ-induced IP-10 expression in NHEKs (Shiraki et al., 2008).

Based on clinical observations and experimental studies on mucosal (chronic mucocutaneous and gastrointestinal) candidiasis, T-cell (CD4+ and CD8+) and cell-mediated immunity is the predominant host defense mechanism against C. albicans (Barnett et al., 1990; Cantorna & Balish, 1990; Kirkpatrick, 1989; Kirkpatrick et al., 1971). It is believed that vaginal candidiasis is affected by T-cell response. Experimental studies also suggest that T cells are important in the local T-cell response, such as in vaginal candidiasis caused by C. albicans. However, these findings do not correlate with decreased T-cell (CD4+) counts in HIV-infected women with vaginal candidiasis (White, 1996; Rhoads et al., 1987; Imam et al., 1990; Clark et al., 1995). As far as the B-cell-mediated immune response to candidiasis is concerned, B-cell deficiency does not support susceptibility to C. albicans infection. Interestingly, CNA species, particularly C. tropicalis, and systemic candidiasis are becoming more prevalent in oral and gastrointestinal candidiasis (Wingard et al., 1979, 1980; Sandford et al., 1980; Fromtling et al., 1987; Prasad et al., 1999; Nucci & Colombo, 2007).

Clinical and experimental observations suggest that morbidity and mortality rates are higher due to C. tropicalis infection than to C. albicans infection (Wingard et al., 1979; Fromtling et al., 1987). These findings support the hypothesis that there must be some additional C. tropicalis secretory products that are probably more pronounced in a T-cell-deficient host. Such secretory products from C. tropicalis could be intensely cytotoxic or there could be synergistic interactions with the host cells that culminate in the deaths of immunocompromised patients. There are two basic queries that need to be addressed by clinical and experimental studies: why is C. tropicalis becoming an emerging pathogen and why is it causing higher mortality rates than C. albicans?

From the group of CNA species, C. tropicalis is becoming an emerging pathogen globally. The major contributory factors in the emergence of C. tropicalis include the following: (1) increasing use of an antifungal regimen, (2) the increasing number of immunocompromised patients, (3) long-term use of catheters, (4) use of broad-spectrum antibiotics and (5) complexity in treating underlying subclinical conditions coupled with antifungal drug intolerance and resultant recurrent infections and nosocomial outbreaks. In addition, drug resistance in immunocompromised patients that survive longer has increased alongside the resultant mortality.

Poor cellular transportation of antifungal agents and inadequate immune response are the major contributory factors that allow yeasts to colonize extensively in immunocompromised patients such as AIDS sufferers. As a result, antifungal drug intolerance and toxicity has become the leading cause of increasing morbidity and mortality in patients infected with C. tropicalis. To investigate a more specific root cause, histochemical or biochemical (toxicity) studies on autopsy specimens recovered from immunocompromised or HIV/AIDS patients concomitantly infected with C. tropicalis may be more conclusive than experimental studies.

C. tropicalis and fluconazole resistance

C. albicans is the cause of a wide spectrum of infections such as superficial, cutaneous, subcutaneous and systemic candidiasis in immunocompromised patients. Infections caused by non-albicans species of Candida such as C. tropicalis, C. parapsilosis, C. krusei, Candida lusitaniae, Candida inconspicua, Candida lipolytica and Candida norvegensis are numerically dominant over those caused by C. albicans (Weinberger et al., 1997; Ng et al., 1998). C. tropicalis alone or in association with C. parapsilosis is the second most prevalent Candida species after C. albicans (Ellis, 2002; Kao et al., 1999; Kontoyiannis et al., 2001). In a large surveillance study conducted by Pfaffer et al. (2009), C. tropicalis showed a moderate level of fluconazole resistance. This indicates that there may be a risk of fluconazole resistance through upregulation of efflux transporters upon exposure to increasing concentrations of the drug (Barchiesi et al., 2006). There are several factors probably responsible for the development of drug resistance in various clinical conditions. It is possible that higher MICs in strains from patients who have received antifungal regimens in the past in either a consistent or inconsistent manner or widespread use of fluconazole within community care facilities might have facilitated resistance to fluconazole (Joseph-Horne & Hollomon, 1997). The epidemiology appears complex and varies among the different patient care units.

Resistance to fluconazole in clinical isolates of C. tropicalis has increased (Tortorano et al., 2003; Yang et al., 2004; Myoken et al., 2004). There are several reports on azole resistance, specifically in C. albicans and C. tropicalis (Brun et al., 2004; Yang et al., 2004; Vermijsky & Edlin, 2004). The precise mechanisms responsible for drug resistance in Candida species have been described by Sanglard & Odds (2002). Acquired resistance to azole in C. tropicalis could be due to overexpression of C1ERG11 gene associated missense mutation.

There is a significant correlation between phospholipase activity of clinical isolates of C. albicans recovered from
muco-cutaneous lesions with infectivity in albino mice (Kothavade & Panthaki, 1998). However, Candida species exposed to antymycotic agents have shown a significant reduction of their phospholipase activity. Nystatin and amphotericin B, but not fluconazole, significantly reduce the phospholipase activity of both C. albicans and C. tropicalis species (Anil & Samaranyake, 2003). In HIV-infected patients, HIV-1 interacts with different clinically important Candida species and this could be affecting the clinical efficacy of fluconazole or other antifungal agents (Gruber et al., 2003). The basic query here is: does fluconazole remain fungistic because of its poor antiphospholipase activity? The exact mechanism that fluconazole has against phospholipase activity is not clearly understood, and hence additional clinico-mycological observations are needed for a more definitive conclusion.

**Measures for controlling fluconazole resistance in clinical management**

The increasing use of fluconazole globally in various clinical conditions (candidiasis) is a major cause of CNA dominance over C. albicans. (1) Therapeutic application of fluconazole should be limited to selected high-risk patients to minimize the risk of emergence of azole-resistant strains of Candida. (2) Patients with recurrent candidiasis, but recently treated with fluconazole, should not be treated again with the same drug as counteractive treatment for a presumed or proven incidence of systemic candidiasis. (3) To control nosocomial outbreaks of drug-resistant strains of C. tropicalis, rapid detection followed by a drug susceptibility test needs to be performed on the clinical isolates. (4) Use of various antifungal agents and their interactions with other drugs for treating subclinical or underlying conditions needs to be carefully thought out prior to their application in the clinical management of high-risk patients. (5) The best way to improve antifungal drug therapy is to improve immunity of the host. In many cases, this is not possible, but there are clinical scenarios in which improving immune responses may improve clinical prognosis. For example, granulocyte colony-stimulating factor, a cytokine, in combination with fluconazole may be useful in the management of fungal diseases. (6) The removal of fungus-contaminated foreign objects or the surgical removal of abscesses can reduce the fungal burden and allow the host and antifungal drugs to clear the infection even with strains that are resistant to standard antifungal therapy. (11) In surgical patients, new antifungal agents such as azoles (voriconazole) and echinocandins are less-toxic therapeutic options for prevention and optimized therapy for Candida infections. (12) In invasive candidiasis (paediatric intensive care patients), quick removal of lines (e.g. parenteral nutrition, arterial lines, central venous catheter lines) and instigation of treatment with novel antifungal agents such as second-generation triazole and echinocandins may be preferred in clinical management of hospitalized patients. (13) Increased awareness of risk factors for CNA species can provide guidance for appropriate choices of antifungal therapy (Davis et al., 2007).

**Conclusions**

Use of fluconazole should not be continued in patients with recurrent Candida infections. Rapid species identification from clinical specimens and standard drug susceptibility testing would be an effective approach for controlling nosocomial outbreaks caused by C. tropicalis or CNA species in different clinical settings. Consistent application of standard techniques, guidelines for the use of antifungal agents and control measures for predisposing factors or risk factors may potentially reduce the risk of drug-resistant life-threatening infections. However, application of standardized technology and its consistent use in diagnostics and research still remains a major global challenge.

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