



## Antifungals, Oral Therapeutic Class Review (TCR)

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## FDA-APPROVED INDICATIONS

Drug	Manufacturer	FDA-Approved Indication(s) for oral use
clotrimazole lozenge (troche) <sup>1</sup>	generic	<ul style="list-style-type: none"> <li>Treatment of oropharyngeal candidiasis</li> <li>To prophylactically reduce the incidence of oropharyngeal candidiasis in patients immunocompromised by conditions that include chemotherapy, radiotherapy, or steroid therapy utilized in the treatment of leukemia, solid tumors, or renal transplantation</li> </ul>
fluconazole (Diflucan <sup>®</sup> ) <sup>2</sup>	generic, Pfizer	<ul style="list-style-type: none"> <li>Treatment of oropharyngeal, esophageal, and vaginal candidiasis</li> <li>Treatment of <i>Candida</i> urinary tract infections, peritonitis, candida systemic infections including candidemia, disseminated candidiasis, and pneumonia</li> <li>Cryptococcal meningitis</li> <li>Prevention of candidiasis in patients undergoing bone marrow transplantation receiving cytotoxic chemotherapy and/or radiation</li> </ul>
flucytosine (Ancobon <sup>®</sup> ) <sup>3</sup>	generic, Valeant	<ul style="list-style-type: none"> <li>Used in combination with amphotericin B for the treatment of serious infections caused by susceptible strains of <i>Candida</i> or <i>Cryptococcus</i></li> </ul>
griseofulvin suspension <sup>4</sup>	generic	<ul style="list-style-type: none"> <li>Ringworm infections of the body, skin, hair, and nails, namely tinea corporis, tinea pedis, tinea cruris, tinea barbae, tinea capitis, and tinea unguium (onychomycosis)</li> </ul>
griseofulvin, microsize <sup>5</sup>	generic	
griseofulvin, ultramicrosize <sup>6</sup>	generic	
isavuconazonium (Cresemba) <sup>7</sup>	Astellas	<ul style="list-style-type: none"> <li>Azole antifungal for use in the treatment of invasive aspergillosis, and invasive mucormycosis in patients 18 years and older</li> </ul>
itraconazole (Onmel <sup>™</sup> ) <sup>8</sup>	Merz	<ul style="list-style-type: none"> <li>Treatment of onychomycosis of the toenail caused by <i>Trichophyton rubrum</i>, or <i>T. mentagrophytes</i></li> </ul>
itraconazole (Sporanox <sup>®</sup> ) <sup>9</sup>	generic, Janssen	<ul style="list-style-type: none"> <li>Onychomycosis of the fingernail and/or toenail due to dermatophytes (tinea unguium) in non-immunocompromised patients</li> <li>Treatment in immunocompromised and non-immunocompromised patients with pulmonary and extrapulmonary blastomycosis, histoplasmosis; or patients with aspergillosis intolerant of amphotericin B; or aspergillosis refractory to amphotericin B</li> </ul>
itraconazole (Tolsura <sup>™</sup> ) <sup>10</sup>	Mayne	<ul style="list-style-type: none"> <li>Treatment in immunocompromised and non-immunocompromised patients with pulmonary and extrapulmonary blastomycosis; histoplasmosis, including chronic cavitary pulmonary disease and disseminated, non-meningeal histoplasmosis; or aspergillosis, if the patient is intolerant of or refractory to amphotericin B</li> </ul>
ketoconazole <sup>11</sup>	generic	<ul style="list-style-type: none"> <li>Blastomycosis, coccidioidomycosis, histoplasmosis, chromomycosis, paracoccidioidomycosis, only in patients who are intolerant to, or who have failed, other agents<sup>†</sup></li> </ul>
miconazole (Oravig <sup>™</sup> ) <sup>12</sup>	Midatech	<ul style="list-style-type: none"> <li>Local treatment of oropharyngeal candidiasis in adults</li> </ul>
nystatin <sup>13</sup>	generic	<ul style="list-style-type: none"> <li>Gastrointestinal and oral candidiasis caused by <i>Candida albicans</i></li> </ul>

## FDA-Approved Indications (continued)

Drug	Manufacturer	FDA-Approved Indication(s) for oral use
posaconazole (Noxafil®) <sup>14</sup>	Merck	<ul style="list-style-type: none"> <li>▪ Delayed-release tablet and oral suspension: Prophylaxis of invasive <i>Aspergillus</i> and <i>Candida</i> infections in patients 13 years and older who are at high risk of developing these infections due to being severely immunocompromised (e.g., hematopoietic stem cell transplant recipient with graft versus host disease [GVHD] or those with hematologic malignancies with prolonged neutropenia from chemotherapy)</li> <li>▪ Oral suspension: Treatment of oropharyngeal candidiasis, including oropharyngeal candidiasis refractory to itraconazole and/or fluconazole</li> </ul>
terbinafine <sup>15</sup>	generic	<ul style="list-style-type: none"> <li>▪ Onychomycosis of the toenail or fingernail due to dermatophytes (tinea unguium)</li> </ul>
voriconazole (Vfend®) <sup>16</sup>	generic, Pfizer	<p>Treatment of the following infections in those 2 years of age and older:</p> <ul style="list-style-type: none"> <li>▪ Invasive aspergillosis</li> <li>▪ Serious fungal infections caused by <i>Scedosporium apiospermum</i> and <i>Fusarium</i> species including <i>Fusarium solani</i>, in patients intolerant of, or refractory to, other therapy</li> <li>▪ Esophageal candidiasis</li> <li>▪ Candidemia in non-neutropenics and other deep tissue <i>Candida</i> infections</li> </ul>

\* Tolsura (itraconazole) is not indicated for the treatment of onychomycosis and is not interchangeable or substitutable with other itraconazole products.

† Ketoconazole is no longer to be used as first-line therapy for any fungal infection and should be reserved for only those cases where alternative therapies are unavailable or not tolerated. Please revisit the indications section of the package insert for details. Previously, ketoconazole was indicated for candidiasis, chronic mucocutaneous candidiasis, oral thrush, candiduria, and severe recalcitrant cutaneous dermatophyte infections not responding to topical or oral griseofulvin therapy. These indications were removed due to the risk of hepatic toxicity.<sup>17</sup>

## OVERVIEW

The antifungal agents have different spectrums of activity and are FDA-approved to treat a variety of infections. Few trials have been performed to compare safety and efficacy profiles of the drugs. In addition, many of the agents carry boxed warnings related to adverse events and/or drug interactions.

According to the Infectious Diseases Society of America (IDSA) 2016 candidiasis guidelines, treatment of oropharyngeal candidiasis in adults include clotrimazole troches, miconazole mucoadhesive buccal tablet (Oravig), or nystatin for 7 to 14 days for mild disease; for moderate to severe disease, fluconazole (Diflucan) is recommended daily for 7 to 14 days.<sup>18</sup> For fluconazole-refractory disease, itraconazole solution or posaconazole suspension (Noxafil) may be used for up to 28 days. In other refractory cases, voriconazole (Vfend) or amphotericin B oral suspension may be administered. Chronic suppressive therapy for patients with human immunodeficiency virus (HIV) is not always necessary. If suppressive therapy is required, fluconazole is recommended.

Since highly active antiretroviral therapy (HAART) for the treatment of HIV for infants and children is widely available and utilized in the United States, routine primary prophylaxis of mucosal candidiasis is not indicated.<sup>19</sup> Uncomplicated infections can be effectively treated with topical therapy such as clotrimazole troches or nystatin; however, troches should not be used in infants. Systemic therapy with oral fluconazole may be considered for the initial treatment of oropharyngeal candidiasis. Fluconazole is more effective than nystatin in infants. Itraconazole and posaconazole have equivalent efficacy to fluconazole for oropharyngeal candidiasis, and are considered alternatives to fluconazole, particularly in cases that are azole-refractory.

IDSA states that systemic therapy is always required for esophageal candidiasis in adults: fluconazole, oral or IV, is considered first line.<sup>20</sup> Posaconazole, itraconazole, or voriconazole may be used in patients with fluconazole-refractory infections. Fluconazole is preferred for children for the management of esophageal candidiasis, but IV agents (e.g., fluconazole, amphotericin B, or an echinocandin) may be used in those unable to tolerate oral therapy. Itraconazole, voriconazole, amphotericin B, or an echinocandin may be used in fluconazole-refractory children.<sup>21</sup>

For the treatment of candidemia, IDSA recommends an echinocandin as initial therapy in neutropenic and nonneutropenic patients.<sup>22</sup> Fluconazole (IV or oral) is an alternative initial therapy in select patients. Amphotericin lipid formulation is reasonable if intolerance, limited availability, or resistance to other agents is present. Voriconazole offers little benefit over fluconazole, but is recommended as step-down therapy from fluconazole in select patients. The minimum duration of therapy for candidemia is 2 weeks post resolution of symptoms and documented clearance of *Candida* from the bloodstream.

Onychomycosis is a fungal infection of the nail bed (skin beneath the nail plate) with secondary involvement of the nail plate (visible part of the nail on fingers and toes).<sup>23</sup> Dermatophytes, yeasts, and molds are the primary pathogens associated with onychomycosis. More common in toenails than fingernails, the disease often causes the end of the nail to separate from the nail bed. The most common clinical presentations are distal and lateral subungual onychomycosis (which usually affects the great or first toe) and white superficial onychomycosis (which generally involves the third or fourth toes).<sup>24</sup> Additionally, debris (white, green, yellow, or black) may build up under the nail plate and discolor the nail bed. Onychomycosis is often chronic, difficult to eradicate, has a tendency to recur, and is found more frequently in the elderly. Treatment of onychomycosis depends on the clinical type of the onychomycosis, the number of affected nails, and the severity of nail involvement. While white superficial and distal lateral onychomycosis may be treated with topical antifungal agents, proximal subungual and distal lateral subungual cases require systemic treatment, including griseofulvin, itraconazole, and terbinafine.

Opportunistic fungal infections are particularly likely to occur in patients during corticosteroid, immunosuppressant, or antimetabolite therapy, or in patients with Acquired Immunodeficiency Syndrome (AIDS), azotemia, diabetes mellitus, bronchiectasis, emphysema, tuberculosis, lymphoma, leukemia, or burns.<sup>25</sup> Histoplasmosis, coccidioidomycosis, cryptococcosis, blastomycosis, paracoccidioidomycosis, and sporotrichosis are systemic mycoses which can cause disease in both healthy and immunocompromised individuals. In contrast, mycoses caused by opportunistic fungi such as *Candida albicans*, *Aspergillus spp*, *Trichosporon*, *Torulopsis (Candida) glabrata*, *Fusarium*, *Alternaria*, and *Mucor* are generally found only in an immunocompromised host.

The IDSA guidelines for the management of aspergillosis 2016 also recommends voriconazole as the initial treatment option for invasive and extrapulmonary aspergillosis infections.<sup>26</sup> Other azole antifungals approved for aspergillosis may be considered as alternatives in salvage therapy. Posaconazole or voriconazole are options for prophylaxis of invasive aspergillosis.

## PHARMACOLOGY<sup>27,28,29,30,31,32,33,34,35,36,37,38,39</sup>

Drug	Mechanism of Action
clotrimazole	Inhibits the action of fungal ergosterol synthesis; interacts with the cytochrome P450 enzyme 14-alpha demethylase; inhibits growth of pathogenic yeasts by altering cell membrane permeability
fluconazole (Diflucan)	Highly selective inhibitor of fungal cytochrome P450 sterol C-14 alpha-demethylase, which results in fungistatic activity Fungal isolates with reduced susceptibility to other azoles may also show reduced susceptibility to fluconazole; the frequency of occurrence is unknown.
flucytosine (Ancobon)	Enters the fungal cell and is metabolized to 5-fluorouracil, which is extensively incorporated into fungal RNA and inhibits synthesis of both DNA, RNA, and protein synthesis; the result is unbalanced growth and death of the fungal organism
griseofulvin	Fungistatic amounts are deposited in the keratin precursor cell; the new keratin becomes resistant to fungal invasion
isavuconazonium (Cresemba)	Isavuconazonium sulfate is a prodrug of isavuconazole, which inhibits the synthesis of ergosterol within the fungal cell membrane via inhibition of the enzyme lanosterol 14-alpha-demethylase, which in turn is responsible for the conversion of lanosterol to ergosterol; this results in a weakening of the cell membrane function and structure
itraconazole (Omnel, Sporanox, Tolsura)	Inhibits the cytochrome P450-dependent synthesis of ergosterol, a vital component of the fungal cell membrane, resulting in increased cellular permeability and therefore leakage of cellular contents
ketoconazole	Impairs the synthesis of ergosterol, a vital component of fungal cell membranes
miconazole (Oravig)	Inhibits cytochrome P450-dependent 14- $\alpha$ demethylase in the biosynthetic pathway of ergosterol, an essential component of the fungal cell membrane
nystatin	Binds to sterols in the fungal cell membranes which leads to fungistatic activity
posaconazole (Noxafil)	Inhibits cytochrome P450-dependent 14- $\alpha$ demethylase in the biosynthetic pathway of ergosterol which weakens the structure and function of the fungal cell membrane
terbinafine	Inhibits squalene epoxidase, a key enzyme in fungal sterol biosynthesis; resulting in cell death due to increased cell membrane permeability; fungicidal <i>in vitro</i> depending on organism and concentration
voriconazole (Vfend)	Inhibits ergosterol synthesis by interacting with the 14-alpha-lanosterol demethylation step, a cytochrome P450 enzyme

## PHARMACOKINETICS<sup>40,41,42,43,44,45,46,47,48,49,50,51,52</sup>

Drug	Bioavailability (%)	Half-life (hr)	Metabolism	Excretion (%)	CYP 450 Enzyme Inhibition
clotrimazole	negligible absorption	--	The small amount that is absorbed is metabolized by the liver	Bile	--
fluconazole (Diflucan)	> 90	20-50	--	Renal: 91	2C9, 3A4
flucytosine (Ancobon)	78-89	2.4-4.8	Small amount of flucytosine is deaminated (probably by gut bacteria) to 5-fluorouracil and reabsorbed	Renal: 90 Fecal: < 10	--
griseofulvin	varies with formulation; absorption increases with a high-fat meal	9-24	No active metabolites	Renal , fecal and perspiration excretion	--
isavuconazonium (Cresemba)	98	130	Rapidly hydrolyzed into active drug	Renal: 45.6 Fecal: 46.1	3A4, 3A5
itraconazole (Onmel)	63 absorption increases with a high-fat meal	37	Several metabolites; hydroxy-itraconazole is the major active one	Renal: 35 Fecal: 54	3A4
itraconazole (Sporanox)	55	64			
itraconazole (Tolsura)	nr	34 to 42 (fed conditions)			
ketoconazole	-- (requires acidic pH)	8	Several inactive metabolites	Renal: 13 Bile: 87 (Fecal: 57)	3A4
miconazole (Oravig)	--	24	No active metabolites	Renal: < 1	2C9, 3A4
nystatin	poorly absorbed	--	--	Predominantly feces	--
posaconazole (Noxafil)	-- (suspension: varies based on fed or fasting state) 54 (tablet)	20-66 (suspension) 26-31 (tablet)	No active metabolites	Renal: 13 Fecal: 71	3A4
terbinafine	40	200-400	No active metabolites	Renal: 70	2D6
voriconazole (Vfend)	96	dose dependent	N-oxide metabolite is inactive; several other inactive metabolites	Renal: 80-83	2C19, 2C9,3A4

## CONTRAINDICATIONS/WARNINGS<sup>53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70</sup>

### **clotrimazole**

Clotrimazole is not indicated for systemic mycoses including systemic candidiasis.

### **fluconazole (Diflucan)**

Fluconazole is contraindicated in patients with hypersensitivity to fluconazole or any of its excipients. There is no information regarding cross-hypersensitivity among fluconazole and other azole antifungal agents. Caution should be used in prescribing fluconazole to patients with hypersensitivity to other azoles.

Fluconazole is associated with QT prolongation and is a moderate CYP3A4 inhibitor. Therefore, fluconazole is contraindicated with concurrent administration of drugs that prolong the QT interval and are metabolized via CYP3A4. Avoid concomitant administration of fluconazole with quinidine, pimozide, or erythromycin. In addition, concomitant use of fluconazole and voriconazole, a substrate for both CYP2C9 and CYP3A4, should be avoided due the risk of increased exposure of voriconazole.

Fluconazole is known to be a strong inhibitor of CYP2C19 as well. Adverse drug events have been reported with concomitant use of agents utilizing this pathway. Additional postmarketing experience has led to reports of adrenal insufficiency, drug reaction with eosinophilia and systemic symptoms syndrome (DRESS), and fixed drug eruptions occurring with fluconazole use.

Fluconazole has been associated with rare reports of anaphylaxis, serious hepatic toxicity, and exfoliative skin disorders including Stevens-Johnson syndrome and toxic epidural necrosis during treatment. Discontinuation of the drug is recommended if skin reactions occur.

Fluconazole has been associated with rare cases of serious hepatic toxicity, including fatalities, primarily in patients with serious underlying medical conditions. There has been no obvious relationship to total daily dose, duration of therapy, or sex and age of the patients in the known cases of fluconazole-associated hepatotoxicity. Fluconazole hepatotoxicity has usually, but not always, been reversible upon discontinuation. Patients with abnormal liver function tests during fluconazole therapy should be monitored for more severe hepatic injury. Discontinue fluconazole therapy if clinical signs and symptoms of liver disease develop during therapy.

### **flucytosine (Ancobon)**

Flucytosine is excreted primarily by the kidneys, and renal impairment leads to accumulation of drug. There is a boxed warning associated with flucytosine to use extreme caution in patients with impaired renal function. Monitoring of renal, hepatic, and hematologic status is stressed to prevent progressive accumulation of active drug. In addition, extreme caution in patients with bone marrow depression should be exercised. Frequent monitoring of hepatic function and of the hematopoietic system is indicated during therapy.

### **griseofulvin**

Griseofulvin is contraindicated in patients with porphyria, hepatocellular failure, and in patients with a history of hypersensitivity to griseofulvin.

Griseofulvin should not be prescribed to pregnant patients. If a patient becomes pregnant while taking this drug, the patient should be apprised of the potential hazard to the fetus. Since griseofulvin has

demonstrated harmful effects *in vitro* on the genotype in bacteria, plants, and fungi, males should wait at least 6 months after completing griseofulvin therapy before fathering a child. Concomitant use of griseofulvin and oral contraceptives has been reported to reduce the efficacy of the oral contraceptive and cause breakthrough bleeding. Patients who experience breakthrough bleeding while receiving these drugs together should notify their prescribers. An alternate or additional form of contraception should be used during concomitant treatment and should be continued for 1 month after griseofulvin discontinuation. Additionally, patients taking non-oral combination contraceptives, estrogens, or progestins for hormone replacement therapy may also experience reduced clinical efficacy; dosage adjustments may be necessary.

Griseofulvin is produced by a species of *Penicillium*; patients with penicillin hypersensitivity theoretically could exhibit a cross-sensitivity to griseofulvin. However, patients with penicillin hypersensitivity have been treated with griseofulvin without adverse effects. Similar warnings may apply to patients with cephalosporin hypersensitivity or carbapenem hypersensitivity because of the structural similarity of cephalosporins and carbapenems to penicillin.

Lupus erythematosus or lupus-like syndromes have been reported in patients receiving griseofulvin, as well as exacerbating the condition of those with systemic lupus erythematosus (SLE) or lupus-like syndrome.

Photosensitivity skin reactions have been associated with griseofulvin therapy. Patients should be warned to avoid exposure to intense natural or artificial sunlight. Severe skin reactions, (e.g., Stevens-Johnson syndrome, toxic epidermal necrolysis, and erythema multiforme), have been reported with griseofulvin use. These reactions may be serious and may result in hospitalization or death. If severe skin reactions occur, griseofulvin should be discontinued.

Elevated liver function tests and jaundice have been reported with griseofulvin use. These reactions may be serious and may result in hospitalization or death. Patients should be monitored for hepatic adverse events and discontinuation of griseofulvin considered, if warranted.

### **isavuconazonium (Cresemba)**

Isavuconazonium is contraindicated in patients with hypersensitivity to isavuconazole. Do not use in the presence of strong CYP3A4 inhibitors or strong CYP3A4 inducers. Either can significantly increase or decrease plasma concentrations of isavuconazole.

Isavuconazole is known to shorten the QTc interval, therefore it is contraindicated in those adults with familial short QT syndrome.

Warnings for hepatic adverse drug reactions include; increases in alanine aminotransferase (ALT) and aspartate aminotransferase (AST) that are generally reversible and do not require discontinuation. More severe hepatic reactions such as hepatitis, cholestasis, or liver failure including death have been reported in those patients with underlying medical conditions. Evaluate hepatic laboratory tests at baseline and during therapy. Discontinue drug if liver disease develops.

Fetal harm may occur when isavuconazonium is administered to pregnant females. Use in pregnancy only when the potential benefit outweighs risk to the fetus.

## itraconazole (Onmel, Sporanox, Tolsura)

Itraconazole should not be administered to women considering pregnancy or who are pregnant. Concomitant use with drugs metabolized by CYP 3A4 (e.g., simvastatin, lovastatin) are contraindicated with itraconazole. Itraconazole should not be administered with ergot alkaloids such as dihydroergotamine, ergometrine (ergonovine), ergotamine, and methylergometrine (methylergonovine). Additionally, co-administration with pimozide, quinidine, oral midazolam, cisapride, triazolam, lev-acetylmethadol (levomethadyl), and dofetilide are contraindicated as concomitant use may result in elevated plasma concentrations of those drugs leading to potentially serious adverse events. See Drug Interaction section for additional drug-drug contraindications.

Itraconazole is contraindicated in patients with ventricular dysfunction as evidenced by congestive heart failure (CHF) or a history of CHF. A boxed warning associated with itraconazole stresses that itraconazole should not be used for onychomycosis in patients with evidence of ventricular dysfunction or CHF due to the risk of pulmonary edema and/or CHF. Negative inotropic effects have been observed with intravenous itraconazole. Serious cardiovascular events, including QTc prolongation, torsades de pointes, ventricular tachycardia, cardiac arrest, and/or sudden death have occurred when itraconazole is co-administered with inhibitors of CYP450 3A4 isoenzyme. Such patients should be monitored for signs and symptoms of CHF during treatment. If signs or symptoms of CHF appear during administration of itraconazole, discontinue administration.

A boxed warning regarding drug interactions is now included in the label. There is a list of drugs contraindicated in the presence of itraconazole (see Drug Interactions section). Coadministration of any of these drugs with itraconazole can cause elevations of plasma concentrations thereby increasing or prolonging both the pharmacologic effects and/or the adverse reactions to the drugs. Do not use itraconazole in the presence of CYP3A4 substrates. For example; calcium channel blockers can have negative inotropic effects which may be additive to those of itraconazole. In addition, itraconazole can inhibit the metabolism of calcium channel blockers. Therefore, caution should be used when coadministering itraconazole and calcium channel blockers due to an increased risk of CHF. Concomitant administration of itraconazole and nisoldipine is contraindicated, as is coadministration of itraconazole with ivabradine.

Transient or permanent hearing loss has been reported in patients receiving treatment with itraconazole. Several of these reports included concurrent administration of quinidine which is contraindicated. The hearing loss usually resolves when treatment is stopped but can persist in some patients.

Itraconazole capsules and oral solution should not be used interchangeably as the drug exposure is greater with the oral solution than with the capsules when the same dose of drug is administered. Only the oral solution has demonstrated efficacy for oral and/or esophageal candidiasis. **Itraconazole 65 mg capsule (Tolsura) is not interchangeable or substitutable with other itraconazole products.**

Serious hepatotoxicity, including liver failure and death, has been associated with itraconazole. Some patients did not have an underlying medical condition or pre-existing liver disease. Hepatotoxicity may develop as early as the first week of treatment. If signs or symptoms develop that are consistent with liver disease, itraconazole therapy should be discontinued and liver function testing performed.

Due to large pharmacokinetic variability in cystic fibrosis patients, consider switching to alternative antifungal therapy when the patient does not respond to itraconazole.

The itraconazole prescribing information recommends laboratory testing to confirm onychomycosis diagnosis.

## **ketoconazole**

Ketoconazole should not be administered with terfenadine, astemizole, cisapride, or triazolam as concurrent administration has resulted in cardiovascular adverse events.

Ketoconazole tablets should only be used when other effective antifungal therapy is not available or not tolerated. QT prolongation can occur if certain drugs are coadministered with ketoconazole (see interactions chart). The QT prolongation has resulted in life-threatening ventricular dysrhythmias such as torsades de pointes.

A boxed warning states that ketoconazole has been linked to hepatic toxicities and fatalities. Use in patients with hepatic disease is contraindicated. The presence of viral hepatitis and liver function tests should be assessed prior to therapy, and monitoring of hepatic function is recommended weekly during therapy.<sup>71</sup>

Adrenal insufficiency has also been reported due to the inhibition of production of adrenal corticosteroids at doses exceeding 400 mg daily. Monitor adrenal function in those patients with existing adrenal concerns while they are utilizing oral ketoconazole therapy.

A medication guide outlining the risks associated with oral ketoconazole use has been approved for distribution by the FDA.

## **miconazole (Oravig)**

Miconazole is contraindicated in patients with known hypersensitivity (e.g., anaphylaxis) to miconazole, milk protein concentrate, or any other component of the product.

Allergic reactions, including anaphylactic reactions and hypersensitivity, have been reported with the administration of miconazole products. Discontinue miconazole immediately at the first sign of hypersensitivity.

## **nystatin**

Nystatin suspension contains significant amounts of sucrose; it should be used cautiously in patients with diabetes mellitus.

## **posaconazole (Noxafil)**

Posaconazole is contraindicated in patients with known hypersensitivity (e.g., anaphylaxis) to posaconazole, any other component of the product, or hypersensitivity to any other azole antifungal. Posaconazole is contraindicated in coadministration with sirolimus (sirolimus toxicity) and ergot alkaloids (ergotism). Posaconazole is also contraindicated in coadministration with the CYP3A4 substrates, pimozide, halofantrine, or quinidine, since this may result in increased plasma concentrations of these agents leading to QTc prolongation and rare occurrences of torsades de pointes. Posaconazole is contraindicated with HMG-CoA reductase inhibitors primarily metabolized through CYP3A4 due to risk of rhabdomyolysis.

Electrolyte disturbances are known to occur with use of posaconazole, monitor and correct levels of magnesium, potassium, and calcium before and during therapy. Pseudoaldosteronism and pancreatitis also have been reported.

Infrequent cases of hepatic reactions such as mild to moderate elevations in alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase, total bilirubin, and/or clinical hepatitis have been reported with posaconazole. Liver enzyme elevations were generally reversible upon discontinuation or, in some cases, normalized without drug interruption, and rarely require drug discontinuation. More serious hepatic reactions including cholestasis or hepatic failure (including fatalities), have been reported in patients with serious underlying medical conditions, such as hematologic malignancy, during treatment with posaconazole. Posaconazole 800 mg daily has been associated with the more severe hepatic reactions. Liver function tests should be evaluated at therapy initiation and during the course of posaconazole therapy. If abnormal liver function tests occur during posaconazole therapy, monitor for the development of more severe hepatic injury. Posaconazole should be discontinued if worsening of liver function tests continues.

Elevated cyclosporine levels resulting in rare serious adverse events, including nephrotoxicity, leukoencephalopathy, and death, were reported in clinical efficacy trials for posaconazole. Dose reduction and more frequent monitoring of cyclosporine and tacrolimus should be performed when posaconazole therapy is initiated.

Posaconazole significantly increases the maximum concentration (C<sub>max</sub>) and area under the curve (AUC) of tacrolimus. Reduce tacrolimus dose by approximately one-third of the original dose on initiation of posaconazole treatment. Frequent monitoring of tacrolimus trough concentrations should be performed during and at discontinuation of posaconazole treatment.

Posaconazole should be administered with caution to patients with potentially proarrhythmic conditions and should not be administered with drugs that are known to prolong the QTc interval and are metabolized through CYP3A4. Rigorous attempts to correct potassium, magnesium, and calcium should be made before starting posaconazole.

Posaconazole has been known to prolong the sedative/hypnotic effects of midazolam, the serum concentration of midazolam may be increased 5-fold. Monitor those patients taking concomitant midazolam. In the event signs or symptoms of prolonged hypnosis/sedation signs are noted, have benzodiazepine receptor antagonists available for administration.

Use of posaconazole with vincristine has been associated with not only neurotoxicity, but other serious adverse reactions such as seizures, syndrome of inappropriate antidiuretic hormone secretion, peripheral neuropathy, and paralytic ileus. It is advised that use of azole antifungals, including posaconazole, be reserved for those patients receiving a vinca alkaloid who have no alternative antifungal treatment option.

## **terbinafine**

Terbinafine is contraindicated in patients with a history of allergic reaction to oral terbinafine because of the risk of anaphylaxis.

Severe hepatic injury, including liver failure, with some leading to death or liver transplantation, has occurred with the use of oral terbinafine. Assessment of serum transaminases are advised before

initiation of treatment with terbinafine. Terbinafine should be discontinued if biochemical or clinical evidence of liver injury occurs.

Severe neutropenia has been reported, if neutrophil count is  $\leq 1,000$  cells/mm<sup>3</sup>, discontinue drug. Stevens-Johnson syndrome, and toxic epidermal necrolysis have been reported with terbinafine use as has erythema multiforme, exfoliative dermatitis, and bullous dermatitis. If a progressive skin rash occurs, treatment with terbinafine should be discontinued. DRESS also has been reported. Depressive symptoms have been reported with terbinafine, physicians should be alerted to the development of depressive symptoms.

Taste disturbance, including taste loss, has been reported with the use of terbinafine. Taste disturbances can be severe enough to result in decreased food intake, weight loss, and depressive symptoms. Resolution of taste disturbance may resolve within several weeks after discontinuation of treatment, but may be prolonged (greater than 1 year), or permanent. If symptoms of a taste disturbance occur, discontinue terbinafine.

In addition, smell disturbance and loss of smell has been reported. The changes may resolve after discontinuation of treatment but may be prolonged and possibly permanent. If symptoms of a smell disturbance occur, discontinue use.

There is also a risk of thrombotic microangiopathy (TMA) associated with use of terbinafine. Some cases have been fatal. Discontinue terbinafine if symptoms consistent with TMA occur. Unexplained thrombocytopenia and anemia should lead to consideration of a TMA diagnosis.

The prescribing information recommends laboratory testing to confirm onychomycosis diagnosis. Terbinafine should not be used in patients with pre-existing liver disease, and rare cases of liver failure have occurred during use.

## **voriconazole (Vfend)**

**Due to the risk of arrhythmias and QT prolongation, correct potassium, calcium, and magnesium levels prior to use.**

Coadministration of voriconazole is contraindicated with CYP3A4 substrates including terfenadine, astemizole, cisapride, pimozide, quinidine, rifabutin, sirolimus, or ergot alkaloids because increased plasma concentrations of these drugs can lead to QTc prolongation and rare occurrences of torsades de pointes. Voriconazole use with efavirenz 400 mg every 24 hours or higher is contraindicated. Voriconazole should not be given concurrently with sirolimus (increased sirolimus concentrations and decreased voriconazole concentration), rifampin, carbamazepine, and long-acting barbiturates (decreased voriconazole concentrations), high-dose ritonavir 400 mg every 12 hours (decreased voriconazole concentrations), ergotamines, and St. John's wort. Additionally, voriconazole should not be given with rifabutin as voriconazole concentrations are decreased, and rifabutin concentrations are increased. Ergot alkaloids should not be used with voriconazole.

Concurrent administration of oral voriconazole and oral fluconazole has shown to result in an increase in C<sub>max</sub> and AUC of voriconazole by an average of 57% and 79%, respectively. Reduced dosing and/or frequency of voriconazole and fluconazole did not eliminate or decrease this effect. Concomitant administration of voriconazole and fluconazole at any dose is not recommended. Close monitoring for adverse events related to voriconazole is recommended if voriconazole is used sequentially after fluconazole, especially within 24 hours of the last dose of fluconazole.

Voriconazole prescribing information should be consulted for a detailed description of drug interactions and required dosage modifications prior to initiating therapy.

Visual disturbances (including optic neuritis and papilledema) associated with therapy have been reported. Monitor visual function if therapy continues beyond 28 days.

Electrolyte disturbances including hypokalemia, hypomagnesemia, and hypocalcemia should be corrected prior to initiation of therapy with voriconazole as electrolyte disturbances increase the risk of cardiac arrhythmias.

As with other azole antifungals, hypersensitivity to voriconazole or any of the excipients contraindicates its use. There is no information regarding cross-sensitivity among voriconazole and other azole antifungal agents.

Voriconazole is associated with rare cases of serious hepatic reactions including clinical hepatitis, cholestasis, and fulminant hepatic failure with fatalities. Evaluate liver enzymes at the start of and during therapy. Severe hepatic reactions have occurred in patients with serious underlying medical conditions, predominantly hematological malignancy. Hepatic reactions such as hepatitis and jaundice have occurred in patients with no identifiable risk factors. Liver dysfunction was reversible after discontinuation of voriconazole in most cases. Liver function tests should be performed prior to voriconazole therapy and during therapy to monitor for hepatic injury.

Voriconazole tablets contain lactose and should not be given to patients with rare hereditary problems of galactose intolerance, Lapp lactase deficiency, or glucose-galactose malabsorption.

Embryo-fetal toxicity can occur; do not administer to pregnant women unless the benefit to the mother outweighs the risk to the fetus. Advise those of reproductive potential to use effective contraception during treatment.

Discontinue voriconazole use for exfoliative cutaneous reactions. Avoid sunlight due to risk of photosensitivity and use protective measures if sun exposure is unavoidable, such as high sun protection factor sunscreen and protective clothing. Refer the patient to a dermatologist if phototoxicity-related lesions occur since squamous cell carcinoma and melanoma cases have been reported with long-term voriconazole use. The frequency of phototoxicity reactions is higher in pediatric patients. Stringent photoprotection measures are warranted in children and dermatologic follow-up is recommended even after discontinuation of voriconazole therapy.

Skeletal events such as fluorosis and periostitis have occurred with long-term voriconazole therapy. Discontinue use if these events occur.

## DRUG INTERACTIONS<sup>72,73,74,75,76,77,78,79,80,81,82,83,84,85,86</sup>

Numerous drug interactions are associated with antifungal agents. See the Drug Interactions Table.

Due to low systemic absorption, drug interactions with clotrimazole and nystatin are limited.

Clotrimazole is an inhibitor of hepatic cytochrome P450 (CYP) 3A4, and tacrolimus is metabolized by CYP3A4.<sup>87,88</sup> Administration of clotrimazole troches to renal transplant patients receiving tacrolimus caused clinically significant increases in the relative oral bioavailability, time to maximum concentration (T<sub>max</sub>), and trough concentrations of tacrolimus.<sup>89,90</sup> Tacrolimus blood concentrations should be monitored closely whenever clotrimazole therapy is initiated or discontinued. Close

monitoring can minimize toxicity due to increased tacrolimus levels or prevent an acute rejection episode due to subtherapeutic tacrolimus levels.

Fluconazole (Diflucan) is a strong inhibitor of 2C19 and a moderate inhibitor of 3A4 and 2C9. The enzyme inhibiting effect persists up to 5 days after discontinuation of fluconazole. Clinically significant drug interactions have occurred with patients on combinations of drugs that utilize these enzyme systems; monitor patients on combinations of agents which use these pathways.

Isavuconazonium follows other azole antifungals in that use with strong CYP3A4 inhibitors or inducers is contraindicated as concomitant use can significantly increase/decrease isavuconazole concentrations.

Flucytosine (Ancobon) can cause significant hematologic toxicity. It should be used cautiously with all antineoplastic agents, especially those that cause bone marrow depression. Cytarabine can competitively inhibit flucytosine, antagonizing its antifungal activity. Other bone marrow depressants include carbamazepine, clozapine, phenothiazines, zidovudine, and other blood dyscrasia-causing medications.

Posaconazole (Noxafil) is primarily metabolized via UDP glucuronidation (phase 2 enzymes) and is a substrate for p-glycoprotein (P-gp) efflux. Therefore, inhibitors or inducers of these clearance pathways may affect posaconazole plasma concentrations. The UDP inducers include efavirenz, rifabutin, and phenytoin. The UDP inducers reduce C<sub>max</sub> and area under the curve (AUC) of posaconazole thus reducing bioavailability. Avoid concurrent use with efavirenz, phenytoin, rifabutin, or cimetidine unless the benefit outweighs the risks. Frequent monitoring of adverse effects and toxicity of ritonavir and atazanavir should be performed during coadministration with posaconazole.

In patients taking both posaconazole and digoxin, increased plasma concentrations of digoxin have been noted. Monitor digoxin plasma concentrations of patients taking both agents concomitantly.

While some medications that are metabolized through the CYP3A4 system have specific contraindications, any medication that is metabolized through this pathway and is taken concurrently with posaconazole should be monitored for adverse effects and toxicity. Dose adjustment may need to be considered.

Patients should be monitored for breakthrough fungal infections while on posaconazole when concurrently taking esomeprazole or cimetidine (due to an increase in gastric pH), as well as metoclopramide (due to an increase in gastrointestinal motility). Esomeprazole and metoclopramide have each shown to reduce C<sub>max</sub> and AUC of posaconazole. Avoid concurrent administration of posaconazole oral suspension with esomeprazole unless the benefit outweighs the risks. Other PPIs have not been studied in combination with posaconazole. The drug interactions with esomeprazole and metoclopramide do not apply to posaconazole delayed-release tablets. There are no drug interactions or dosage adjustments needed when posaconazole delayed-release tablets are concomitantly used with antacids, H<sub>2</sub>-receptor antagonists, and proton pump inhibitors. Sporanox is known to interact with contraceptives as well; monitor for adverse effects in patients concomitantly using contraceptives.

Concomitant administration of digoxin and itraconazole has led to increased plasma concentrations of digoxin. Fentanyl plasma concentrations could be increased or exposure prolonged by concomitant use of itraconazole and may cause potentially fatal respiratory depression.

Itraconazole, a potent cytochrome P450 3A4 isoenzyme system (CYP3A4) inhibitor, may increase plasma concentrations of drugs metabolized by this pathway. Serious cardiovascular events, including QT prolongation, torsades de pointes, ventricular tachycardia, cardiac arrest, and/or sudden death have occurred in patients using cisapride, pimozide, methadone, lev-acetylmethadol (levomethadyl), or quinidine, concomitantly with itraconazole and/or other CYP3A4 inhibitors. Coadministration of cisapride, oral midazolam, nisoldipine, felodipine, pimozide, quinidine, dofetilide, triazolam, lev-acetylmethadol (levomethadyl), lovastatin, simvastatin, ergot alkaloids such as dihydroergotamine, ergometrine (ergonovine), ergotamine and methylergometrine (methylergonovine), or methadone with itraconazole capsules or oral solution is contraindicated. See package insert for the full listing of drug interactions.

Ketoconazole is a strong inhibitor of the CYP3A4 system. Due to this, use of this agent is contraindicated with certain other drugs that are metabolized by CYP3A4.

Concomitant administration of miconazole (Oravig) and warfarin has resulted in enhancement of anticoagulant effect. Cases of bleeding and bruising following the concomitant use of warfarin and topical, intravaginal, or oral miconazole were reported. Closely monitor prothrombin time, International Normalized Ratio (INR), or other suitable anticoagulation tests if miconazole is administered concomitantly with warfarin. Also monitor for evidence of bleeding.

Although the systemic absorption of miconazole following miconazole (Oravig) buccal administration is minimal and plasma concentrations of miconazole are substantially lower than when given intravenously, the potential for interaction with drugs metabolized through CYP2C9 and CYP3A4, such as oral hypoglycemics, phenytoin, or ergot alkaloids, cannot be ruled out.

Voriconazole requires dose adjustment in the presence of CYP3A4, CYP2C9, and CYP2C19 inhibitors and inducers. Monitor for adverse reactions or lack of response. Increase the dose when concurrent use of phenytoin or efavirenz occurs.

Below is a list of common substrates for CYP 450 enzymes affected by oral antifungal agents:

- **Selected substrates for the 2C9 system:** diazepam, phenytoin, S-warfarin
- **Selected substrates for the 2C19 system:** phenytoin, thioridazine
- **Selected substrates for the 2D6 system:** carvedilol, clozapine, cyclobenzaprine, donepezil, flecainide, fluphenazine, fluoxetine, galantamine, haloperidol, hydrocodone, maprotiline, meperidine, methadone, methamphetamine, metoprolol, mexiletine, morphine, paroxetine, perphenazine, propafenone, propranolol, risperidone, thioridazine, timolol, tramadol, trazodone, and venlafaxine
- **Selected substrates for the 3A4 system:** triazolam, alprazolam, diazepam, atorvastatin, lovastatin, simvastatin, cyclosporine, tacrolimus, buspirone and pimozide

## Drug Interactions Table

Consult package inserts for additional details.

Drug	CYP 450 enzyme inhibition	Contraindications	Dose adjustments needed	Monitoring of other drug effects
fluconazole (Diflucan)	2C9, 2C19, 3A4	erythromycin pimozide quinidine verapamil voriconazole - Avoid concurrent use	renal impairment rifampin celecoxib tacrolimus midazolam triazolam	cyclosporine fluconazole warfarin phenytoin sulfonylureas theophylline
flucytosine (Ancobon)	--	--	renal impairment; drugs which reduce GFR	anti-neoplastic agents bone marrow suppressants
griseofulvin	--	--	barbiturates	warfarin cyclosporine tretinoin, ATRA sunitinib nilotinib
isavuconazonium (Cresemba)	3A4	Strong CYP3A4 inducers and inhibitors	Concurrent use is contraindicated	See package insert for details

**Drug Interactions Table (continued)**

Drug	CYP 450 enzyme inhibition	Contraindications	Dose adjustments needed	Monitoring of other drug effects
itraconazole (Onmel Sporanox, Tolsura)	3A4	<p>avanafil cisapride disopyramide dofetilide dronedarone eplerenone ergot alkaloids felodipine irinotecan isavuconazole ivabradine levomethadyl lomitapide lovastatin lurasidone methadone midazolam (oral) naloxegol nisoldipine pimozide quinidine ranolazine simvastatin telithromycin ticagrelor triazolam</p> <p>For patients with renal or hepatic impairment: colchicine fesoterodine solifenacin</p> <p>For poor or intermediate CYP2D6 metabolizers or patients who are taking strong or moderate CYP2D6 inhibitors: eliglustat</p>	Decreases elimination of drugs metabolized by CYP3A4; dosing modification is required; See package insert for complete detailed drug list	See package insert for full details

**Drug Interactions Table (continued)**

Drug	CYP 450 enzyme inhibition	Contraindications	Dose adjustments needed	Monitoring of other drug effects
ketoconazole	3A4	alprazolam cisapride dofetilide eplerenone ergot alkaloids HMG-CoA reductase inhibitors isoniazid midazolam nisoldipine pimozide quinidine rifampin triazolam	cyclosporine methylprednisolone tacrolimus See package insert for detailed drug list	digoxin phenytoin sulfonylureas warfarin See package insert for full details
miconazole (Oravig)	2C9, 3A4	--	--	ergot alkaloids oral hypoglycemic phenytoin warfarin
posaconazole (Noxafil)	3A4	cimetidine* efavirenz* ergot alkaloids esomeprazole (suspension)* halofantrine HMG-CoA reductase inhibitors phenytoin* pimozide quinidine rifabutin* sirolimus	vinca alkaloids calcium channel blockers (3A4 inhibitors) cyclosporine tacrolimus midazolam phenytoin	atazanavir cyclosporine digoxin metoclopramide midazolam ritonavir tacrolimus
terbinafine	2D6	thioridazine	TCAs SSRIs beta-blockers monoamine oxidase inhibitors–type b rifampin	caffeine cimetidine cyclosporine fluconazole theophylline warfarin
voriconazole (Vfend)	2C19, 2C9, 3A4	Carbamazepine cisapride efavirenz ergot alkaloids fluconazole long-acting barbiturates pimozide quinidine rifabutin rifampin ritonavir (high dose) sirolimus St. John’s wort	alfentanil benzodiazepines (midazolam, triazolam, alprazolam) calcium channel blockers cyclosporine  methadone NSAIDS omeprazole phenytoin statins (3A4 inhibitors) tacrolimus vinca alkaloids	coumarin derivatives fluconazole fentanyl long acting narcotics non-nucleoside reverse transcriptase inhibitors oral contraceptives with ethinyl estradiol and norethindrone analgesics protease inhibitors ritonavir (low-dose) sulfonylureas warfarin

\*Avoid concomitant use unless benefits outweigh the risks

## ADVERSE EFFECTS<sup>91,92,93,94,95,96,97,98,99,100,101,102,103,104,105</sup>

Drug	Nausea	Headache	Rash	Vomiting	Abd. Pain	Diarrhea	Pruritus	Elevated LFT
clotrimazole	reported	nr	nr	reported	nr	nr	reported	15
fluconazole (Diflucan) n=4,048	3.7	1.9	1.8	1.7	1.7	1.5	nr	reported
flucytosine (Ancobon)	reported	reported	reported	reported	reported	reported	reported	reported
griseofulvin	reported	reported	reported	reported	nr	reported	nr	reported
isavuconazonium (Cresemba)	27.6	16.7	8.6	24.9	16.7	23.7	8.2	17.1
itraconazole (Onmel)	reported	reported	nr	reported	reported	reported	nr	reported
itraconazole (Sporanox) n=112 200 mg daily for 12 weeks	3	10	3-4	reported	4	4	reported	4
itraconazole (Tolsura)	11	4	9	5	2	3	3	3
ketoconazole	3	< 1	nr	3	1.2	< 1	1.5	reported
miconazole (Oravig)	0.7-6.6	5-7.6	nr	0.7-3.8	1.4-2.5	6-9	nr	nr
nystatin	reported	nr	nr	reported	reported	reported	nr	nr
posaconazole suspension (Noxafil)	9-29	8-20	3-15	7-28	5-18	10-29	nr	3-6
fluconazole (oral pharyngeal candidiasis)	11	9	4	7	6	13		5-10
posaconazole delayed-release tablet (Noxafil)  (antifungal prophylaxis)	56	30	34	28	23	61	nr	reported
terbinafine n=465	2.6	12.9	5.6	reported	2.4	5.6	2.8	3.3
voriconazole (Vfend) n=1,655	5.4	3	5.3-7	4.4	< 2	< 2	< 2	1.8-12.4

Incidence is reported as a percentage. Adverse events data are obtained from prescribing information and therefore should not be considered comparative or all inclusive. Incidences for placebo indicated in parentheses. nr = not reported

Pyrexia at a rate of 59% has been reported with posaconazole delayed-release tablets.

Voriconazole is reported to be associated with abnormal visual disturbances (21% IV and oral therapy) which resolve with discontinuation of therapy. Fever, chills, tachycardia, and hallucinations are also noted as common adverse reactions. Reported adverse reactions in pediatric patients include pyrexia, epistaxis, hypertension, hypokalemia, cough, thrombocytopenia, peripheral edema, hyperglycemia, tachycardia, dyspnea, hypocalcemia, hypophosphatemia, mucosal inflammation, hallucinations,

hemoptysis, hypoalbuminemia, hypomagnesemia, renal impairment, abdominal distention, and upper respiratory tract infection.

In patients with normal gastrointestinal, renal, and hematologic function, flucytosine is generally associated with few adverse events, although rash, gastrointestinal discomfort, diarrhea (5% to 10%), and reversible elevations in hepatic enzymes are occasionally observed. In patients with renal dysfunction or in patients on concomitant amphotericin B, leukopenia, thrombocytopenia, and enterocolitis may occur. Flucytosine is associated with dose-dependent, potentially lethal bone marrow suppression.

Itraconazole (Onmel) has been associated with rare cases of hepatotoxicity including liver failure and death.

Fluconazole (Diflucan) clinical adverse effects were reported more often in patients infected with HIV but followed the same pattern as those patients without HIV. Postmarketing reports of adverse effects with fluconazole include, but are not limited to, fever, asthenia, fatigue, taste perversion, and insomnia (see package insert for full listing).

Incidents of pancreatitis have been reported with posaconazole (Noxafil) use.

Terbinafine tablets have been reported to be associated with taste disturbance and flatulence along with those adverse reactions listed in the table.

Incidence of rash with itraconazole was reported more often in immunocompromised patients receiving immunosuppressive medications.

## **SPECIAL POPULATIONS**<sup>106,107,108,109,110,111,112,113,114,115,116,117,118</sup>

### **Pediatrics**

Clotrimazole troches have been used in children ages 3 years and older. Nystatin has been used in infants.<sup>119</sup> The safety and efficacy of terbinafine tablets have not been established in pediatric patients.

Safety and effectiveness of griseofulvin have been established for children over age 2 years. Fluconazole safety and effectiveness data exist for children older than 6 months.

Safety and effectiveness of posaconazole (Noxafil) oral suspension and delayed-release tablets in pediatric patients less than 13 years of age have not been established. Safety and effectiveness of itraconazole have not been proven in pediatric patients; however, patients aged 6 months to 16 years have been treated with itraconazole with no serious unexpected adverse events.

Voriconazole (Vfend) is indicated for children ages  $\geq 2$  years. Dosing is weight- and indication-based for this population. There is a higher incidence of photosensitivity and elevated liver enzymes in this age group compared to adults, and a handful of commonly reported adverse reactions. Safety and efficacy in those patients younger than 2 years has not been established.

Safety and efficacy of isavuconazonium (Cresemba) has not been studied in persons under age 18 years.

No studies of flucytosine (Ancobon) in pediatric patients exist; however, published reports of use of flucytosine with and without amphotericin B in doses of 25 to 200 mg/kg per day are available. No unexpected serious adverse effects were reported.

Ketoconazole tablets have been used in children down to age 2 years. A single daily dose of 3.3mg/kg up to 6.6mg/kg has been used for this population. There have been no studies in those under age 2 years.

Safety and effectiveness of miconazole (Oravig) in pediatric patients less than the age of 16 years have not been established. The ability of pediatric patients to comply with the application instructions has not been evaluated. Use in younger children is not recommended due to potential risk of choking.

Safety and efficacy in patients less than 12 years has not been established for voriconazole.

## Pregnancy

Clotrimazole, posaconazole, itraconazole, ketoconazole, nystatin, miconazole (Oravig), and griseofulvin are Pregnancy Category C. Voriconazole is Pregnancy Category D.

Previously, terbinafine was assigned Pregnancy Category B, but this was replaced with descriptive text in compliance with the Pregnancy and Lactation Labeling Rule (PLLR). Available data on use of terbinafine in pregnant women are insufficient to inform of a drug-associated risk of major birth defects, miscarriage, or adverse effects on the mother or fetus.

Retrospective epidemiological studies suggest a potential risk of spontaneous abortion and congenital abnormalities in infants whose mothers were treated with fluconazole during the first trimester. Use during pregnancy should be avoided except in patients with severe or potentially life-threatening fungal infections in whom fluconazole may be used if the anticipated benefit outweighs the possible risk to the fetus.

There are no adequate and well-controlled studies of flucytosine (Ancobon) use in pregnant women. It should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus.

Data with itraconazole (Tolsura) use in pregnant women for the treatment of blastomycosis, histoplasmosis, or aspergillosis are insufficient to provide insight into potential risks in pregnant women. Itraconazole (Sporanox) has received reports of congenital abnormalities in post-marketing experience. Only use during pregnancy if the potential benefit outweighs fetal risk.

Posaconazole, itraconazole (Onmel, Sporanox, Tolsura), and miconazole (Oravig) may cause fetal harm as has been shown in animal data.

Two cases of conjoined twins have been reported with first trimester use of griseofulvin. Griseofulvin should not be used in pregnant patients. Griseofulvin therapy should be discontinued if the patient becomes pregnant during treatment, and potential hazards to the fetus should be explained.

Isavuconazonium is a pregnancy category C drug. Sound clinical studies have not been conducted in this population, however based on animal studies isavuconazole may cause fetal harm when administered to pregnant women. It is recommended that this agent be used in pregnant women only when the potential benefit outweighs the risk to the fetus.

## Geriatric

Transient or permanent hearing loss has been reported in elderly patients receiving treatment with itraconazole. Several of these reports included concurrent administration of quinidine which is contraindicated.

No dose adjustment needed in the elderly for isavuconazonium (Cresemba). Pharmacokinetics remained unchanged between the younger adults (18 to 64 years) and elderly ( $\geq 65$  years) population.

## Hepatic Impairment

For patients with mild to moderate cirrhosis (Child-Pugh Class A and B), use the standard loading dose regimens of voriconazole; however, reduce the maintenance dose of voriconazole by one-half. **A dosage adjustment for pediatric patients with hepatic impairment has not been established.**

There is limited data available with itraconazole (Onmel, Sporanox, Tolsura) tablets in patients with hepatic impairment, therefore use with caution. Further, use of itraconazole is strongly discouraged in patients with elevated liver enzymes or active liver disease or who have experienced liver toxicity with other medications.

Isavuconazonium does not require dose adjustment with mild or moderate hepatic impairment, but has not been studied in the presence of severe liver impairment; therefore, use with caution in patients who have a Child-Pugh Class C rating.

Ketoconazole oral therapy is contraindicated in persons with hepatic impairment. Assess and monitor patients for new and/or worsening of hepatic damage at baseline and weekly during therapy.

In the presence of mild to moderate hepatic impairment, voriconazole dosing should be half of the usual maintenance dose, the loading dose remains the same.

## Renal Impairment

Monitor posaconazole oral suspension and delayed-release tablets closely for breakthrough fungal infections in those patients with severe renal impairment.

There is limited data available with itraconazole (Onmel, Sporanox, Tolsura) in patients with renal impairment, therefore use with caution.

Orally administered voriconazole dosing is not affected by renal impairment; no dosing adjustment is necessary with oral dosing. **Avoid IV administration in adult patients with moderate to severe renal impairment (estimated creatinine clearance [CrCl],  $< 50$  mL/min). Dosage adjustment for pediatric patients with renal impairment has not been established.**

No dose adjustment of isavuconazonium needed in patients with mild, moderate, severe, or end-stage renal disease (ESRD).

Fluconazole is excreted renally as unchanged drug, there is no need to dose adjust with single dose therapy for vaginal candidiasis, but for renally impaired persons who will receive multiple doses, an initial loading dose of 50 to 400 mg should be administered followed by a daily dose based on creatinine clearance. Patients on dialysis should be administered 100% of the recommended dose after each session. On non-dialysis days, administer the dose based on creatinine clearance.

**Adult Dosing**

Drug	Oral Dosage Forms	Adult Dosage
clotrimazole	10 mg troche	<ul style="list-style-type: none"> <li>▪ Treatment: One troche (10 mg) 5 times per day for 14 consecutive days</li> <li>▪ Prophylaxis: One troche (10 mg) 3 times per day</li> </ul>
fluconazole (Diflucan)	50 mg, 100 mg, 150 mg, 200 mg tablets; 10 mg/mL, 40 mg/mL suspension;	<ul style="list-style-type: none"> <li>▪ Oropharyngeal candidiasis: 200 mg X 1 dose, then 100 mg daily for at least 2 weeks</li> <li>▪ Esophageal candidiasis: 200 mg X 1 dose, then 100 mg daily. Doses up to 400 mg/day may be used based on medical judgement. Treat for a minimum of 3 weeks and for at least 2 weeks following resolution of symptoms</li> <li>▪ Vaginal candidiasis: 150 mg orally X 1 dose</li> <li>▪ Urinary tract infections and peritonitis: 50 mg to 200 mg daily</li> <li>▪ Systemic candida infections: optimal dosage and duration have not been established; doses up to 400 mg/day have been studied in small numbers of patients</li> <li>▪ Cryptococcal meningitis: 400 mg X 1 dose, then 200 mg daily. Dosages up to 400 mg daily have been used. Recommended duration is 10 to 12 weeks.</li> <li>▪ Undergoing bone marrow transplant: 400 mg daily until neutrophils &gt; 1,000 cells/m<sup>3</sup> for 7 days</li> <li>▪ Renal impairment for multiple dosing based on creatinine clearance. Loading dose of 50 to 400mg followed by;                             <ul style="list-style-type: none"> <li>▪ Creatinine Clearance &gt; 50 = 100% recommended dose</li> <li>▪ CrCl ≤ 50 (no dialysis) = 50% of recommended dose</li> <li>▪ CrCl ≤ 50 (dialysis session) = 100% recommended dose</li> </ul> </li> </ul>
flucytosine (Ancobon)	250 mg, 500 mg capsules	<ul style="list-style-type: none"> <li>▪ 50 to 150 mg/kg/day in divided doses every 6 hours</li> </ul>
griseofulvin	Microsized: 125 mg/5 mL suspension; 500 mg tablets Ultramicrosized: 125 mg, 250 mg tablets	<p>Microsized:</p> <ul style="list-style-type: none"> <li>▪ Onychomycosis: 1 g orally once a day for at least 4 months (fingernails) or at least 6 months (toenails)</li> <li>▪ Tinea barbae: 500 to 1,000 mg orally once a day until infection has cleared</li> <li>▪ Tinea capitis: 500 mg orally once a day for 4 to 6 weeks</li> <li>▪ Tinea corporis: 500 mg orally once a day for 2 to 4 weeks</li> <li>▪ Tinea cruris: 500 mg orally once a day until infection has cleared</li> <li>▪ Tinea pedis: 1 g orally once a day for 4 to 8 weeks</li> </ul> <p>Ultramicrosized:</p> <ul style="list-style-type: none"> <li>▪ Onychomycosis : 750 mg orally in divided doses for at least 4 months (fingernails) or at least 6 months (toenails)</li> <li>▪ Tinea barbae: 375 mg orally once a day or 375 to 750 mg in divided doses until infection has cleared</li> <li>▪ Tinea capitis: 375 mg orally once a day or in divided doses for 4 to 6 weeks</li> <li>▪ Tinea corporis: 375 mg orally once a day or in divided doses for 2 to 4 weeks</li> <li>▪ Tinea cruris: 375 mg orally once a day or in divided doses until infection has cleared</li> <li>▪ Tinea pedis: 750 mg orally in divided doses for 4 to 8 weeks</li> </ul>

### Adult Dosing (continued)

Drug	Oral Dosage Forms	Adult Dosage
isavuconazonium (Cresemba)	186 mg capsule (equivalent to 100 mg isavuconazole);	<ul style="list-style-type: none"> <li>Take 2 capsules orally every 8 hours for a total of 6 doses (48 hours) as a loading dose, then take 2 capsules once daily (with or without food); Swallow whole, do not chew or crush</li> <li>Start the maintenance dose 12 to 24 hours after the last loading dose</li> <li>Switching between oral and IV is acceptable and does not require a repeat loading dose</li> </ul>
itraconazole (Onmel)	200 mg tablet	<ul style="list-style-type: none"> <li>Onychomycosis of the toenail: single 200 mg tablet orally once daily for 12 consecutive weeks; take with a full meal at the same time each day</li> </ul>
itraconazole (Sporanox)	100 mg capsule; 10 mg/mL solution	<ul style="list-style-type: none"> <li>Onychomycosis (toenail): 200 mg daily for 12 weeks</li> <li>Onychomycosis (fingernail): 2 treatment pulses, which consist of 200 mg twice daily for 1 week; The pulses are separated by a 3-week period without itraconazole</li> <li>Treatment of blastomycosis or histoplasmosis: 200 mg once daily; If no evidence of improvement or progressing disease, the dose can be increased by 100 mg, up to 400 mg daily; Doses greater than 200 mg should be given in 2 divided doses</li> <li>Treatment of life threatening situations should include a loading dose of 200 mg 3 times daily for the first 3 days; continue treatment for a minimum of 3 months and until clinical parameters and laboratory tests indicate active fungal infection has subsided</li> <li>Treatment of Aspergillosis: 200 mg to 400 mg daily</li> <li>Take the capsules with a full meal, swallow whole</li> </ul>
itraconazole (Tolsura)	65 mg capsule	<ul style="list-style-type: none"> <li>Blastomycosis and histoplasmosis: 130 mg (2 tablets) once daily; if no obvious improvement, the dose may be increased in 65 mg increments to a maximum of 260 mg/day (doses &gt; 130 mg/day should be given in 2 divided doses)</li> <li>Aspergillosis: 130 mg once or twice daily</li> <li>Treatment of life threatening situations should include a loading dose of 130 mg 3 times daily for the first 3 days; continue treatment for a minimum of 3 months and until clinical parameters and laboratory tests indicate active fungal infection has subsided</li> </ul>
ketoconazole	200 mg tablet	<ul style="list-style-type: none"> <li>200 mg to 400 mg daily</li> </ul>
miconazole (Oravig)	50 mg buccal tablets	<ul style="list-style-type: none"> <li>One 50 mg buccal tablet to the upper gum region (canine fossa) once daily for 14 consecutive days; Buccal tablet is applied after brushing teeth in the morning; Alternate gum site each day</li> <li>If the buccal tablet does not adhere or falls off within the first 6 hours, the same tablet should be repositioned immediately; If the tablet still does not adhere, a new tablet should be placed; If the buccal tablet is swallowed within the first 6 hours, the patient should drink a glass of water and a new tablet should be applied only once; If the buccal tablet falls off or is swallowed after it was in place for 6 hours or more, a new tablet should not be applied until the next regularly scheduled dose</li> <li>Chewing gum should be avoided</li> <li>Do not chew, crush, or swallow the tablets</li> </ul>

### Adult Dosing (continued)

Drug	Oral Dosage Forms	Adult Dosage
nystatin	500,000 unit tablets; 100,000 units/mL and 500,000 units/mL suspension	<ul style="list-style-type: none"> <li>▪ Gastrointestinal candidiasis: 500,000 to 1,000,000 units 3 times daily</li> <li>▪ Oral candidiasis: 400,000 to 600,000 units 4 times daily</li> </ul>
posaconazole (Noxafil)	40 mg/mL oral suspension; 100 mg delayed-release tablet	<ul style="list-style-type: none"> <li>▪ Prophylaxis of invasive fungal Infections: Oral suspension: 200 mg (5 mL) 3 times daily during or immediately following (within 20 minutes) a full meal or with a liquid nutritional supplement or with an acidic carbonated beverage in patients who cannot eat a full meal; For patients who cannot eat nor tolerate a supplement or an acidic carbonated beverage, alternative therapy should be considered</li> <li>▪ Delayed-release tablets: Loading dose of 300 mg (three 100 mg tablets) twice a day on the first day; Maintenance dose of 300 mg (three 100 mg tablets) once a day, starting on the second day; Tablets should be taken with food to enhance oral absorption; The tabs provide higher plasma drug exposure than does the suspension under both fed and fasted conditions, therefore, the table form is the preferred oral formulation</li> <li>▪ For both dosage forms, duration of therapy is based on recovery from neutropenia or immunosuppression</li> <li>▪ Oropharyngeal candidiasis: Loading dose of 100 mg (2.5 mL) twice daily on day 1 then 100 mg once daily for 13 days</li> <li>▪ Oropharyngeal candidiasis refractory to fluconazole and/or itraconazole: 400 mg (10 mL) twice daily; Duration to be determined by patient's severity of underlying disease and clinical response</li> <li>▪ Dosage is not interchangeable between the DR tablets and the suspension</li> </ul>
terbinafine	250 mg tablet	<ul style="list-style-type: none"> <li>▪ Onychomycosis (toenail): 250 mg daily for 12 weeks</li> <li>▪ Onychomycosis (fingernail): 250 mg daily for 6 weeks</li> </ul>

### Adult Dosing (continued)

Drug	Oral Dosage Forms	Adult Dosage
voriconazole (Vfend)	50 mg, 200 mg tablets; 40 mg/mL suspension; 200 mg powder for IV administration, 10 mg/mL following reconstitution	<ul style="list-style-type: none"> <li>IV load is required to initiate therapy for all infections except esophageal candidiasis</li> <li>Invasive aspergillosis, candidemia in nonneutropenic patients and other deep tissue candida infections, or scedosporiosis, or fusariosis: 6 mg/kg every IV 12 hours for the first 24 hours;</li> <li>After the first 24 hours, for invasive aspergillosis, or scedosporiosis or fusariosis: 4 mg/kg IV every 12 hours or 200 mg orally every 12 hours</li> <li>After first 24 hours for candidemia in nonneutropenic patients and other deep tissue candida infections: 3 to 4 mg/kg IV every 12 hours or 200 mg orally every 12 hours</li> <li>If the patients response is inadequate, oral dose may be increased to 300 mg every 12 hours (see Prescribing Information for more details)</li> <li>For adults weighing &lt; 40 kg, the oral maintenance dose is 100 mg orally every 12 hours; may increase to 150 mg every 12 hours if response is inadequate for maintenance</li> <li>For concurrent phenytoin or efavirenz therapy, oral and IV dosing should be increased (see Prescribing Information for details)</li> <li>Oral voriconazole should be taken 1 hour before or 1 hour after a meal</li> </ul>

### Pediatric Dosing

Drug	Oral Dosage Forms	Ages	Pediatric Dosage								
clotrimazole	10 mg troche	> 3 years	<ul style="list-style-type: none"> <li>Oropharyngeal candidiasis: One troche (10 mg) 5 times per day</li> </ul>								
fluconazole (Diflucan)	50 mg, 100 mg, 150 mg, 200 mg tablets; 10 mg/mL, 40 mg/mL suspension;	6 months to 13 years	<ul style="list-style-type: none"> <li>Oropharyngeal candidiasis: 6 mg/kg X 1; then 3 mg/kg daily for at least 2 weeks</li> <li>Esophageal candidiasis: 6 mg/kg X 1; then 3 mg/kg daily for at least 3 weeks; doses up to 12 mg/kg may be used based on medical judgement</li> <li>Cryptococcal meningitis: 12 mg/kg X 1; then 6 mg/kg once daily; doses up to 12 mg/kg daily have been used</li> <li>Systemic infections: 6 to 12 mg/kg daily</li> <li>Pediatric dose should not exceed 600 mg daily</li> <li>Equivalent dosing</li> </ul> <table border="1" data-bbox="852 1585 1425 1757"> <thead> <tr> <th>Pediatric dose</th> <th>Adult dose</th> </tr> </thead> <tbody> <tr> <td>3 mg/kg daily</td> <td>100 mg daily</td> </tr> <tr> <td>6 mg/kg daily</td> <td>200 mg daily</td> </tr> <tr> <td>12 mg/kg daily</td> <td>400 mg daily</td> </tr> </tbody> </table>	Pediatric dose	Adult dose	3 mg/kg daily	100 mg daily	6 mg/kg daily	200 mg daily	12 mg/kg daily	400 mg daily
Pediatric dose	Adult dose										
3 mg/kg daily	100 mg daily										
6 mg/kg daily	200 mg daily										
12 mg/kg daily	400 mg daily										

**Pediatric Dosing (continued)**

Drug	Oral Dosage Forms	Ages	Pediatric Dosage
griseofulvin	Microsized: 125 mg/5 mL suspension; 500 mg tablets  Ultramicrosized: 125, 250 mg tablets	> 2 years	Microsized: <ul style="list-style-type: none"> <li>▪ Pediatrics: 10 to 20 mg/kg daily (max: 1 g) given in 1 to 2 divided doses</li> <li>▪ Children weighing 30 to 50 pounds: 125 mg to 250 mg daily</li> <li>▪ Children weighing over 50 pounds: 250 mg to 500 mg daily</li> </ul> Ultramicrosized: <ul style="list-style-type: none"> <li>▪ Pediatrics: 3.3 to 7.3 mg/kg/day</li> <li>▪ Children weighing 35 to 60 pounds: 125 mg to 187.5 mg daily</li> <li>▪ Pediatric patients weighing over 60 pounds: 187.5 mg to 375 mg daily</li> </ul>
ketoconazole	200 mg tablet	> 2 years	<ul style="list-style-type: none"> <li>▪ 3.3 to 6.6 mg/kg/day</li> </ul>
nystatin	500,000 unit tablets; 100,000 units/mL and 500,000 units/mL suspension	Neonates and older	<ul style="list-style-type: none"> <li>▪ Oral candidiasis: 100,000 to 600,000 units 4 times daily</li> </ul>
voriconazole (Vfend)	50 mg, 200 mg tablets; 40 mg/mL suspension; 200 mg powder (10 mg/mL) for IV administration following reconstitution	> 2 years	<p>For patients ages <math>\geq</math> 15 years, refer to adult dosing; for patients ages 12 to 14 and body weight <math>\geq</math> 50 kg, refer to adult dosing</p> <p>Initiate therapy with an IV infusion regimen; only consider an oral regimen after there is significant clinical improvement</p> <p>The following dosing is for patients 2 to &lt; 12 years of age or 12 to 14 years of age with body weight &lt; 50 kg:</p> <ul style="list-style-type: none"> <li>▪ IV load is required to initiate therapy for all infections except esophageal candidiasis</li> <li>▪ Invasive aspergillosis, scedosporiosis, fusariosis, and candidemia in non-neutropenics and other deep tissue <i>Candida</i> infections: 9 mg/kg every 12 hours for the first 24 hours</li> <li>▪ Maintenance: 8 mg/kg IV every 12 hours or 9 mg/kg orally every 12 hours (not to exceed 350 mg orally every 12 hours)</li> <li>▪ Esophageal candidiasis 4 mg/kg IV every 12 hours or 9 mg/kg orally every 12 hours (maximum of 350 mg orally every 12 hours)</li> </ul>

## CLINICAL TRIALS

### Search Strategy

Articles were identified through searches performed on PubMed and review of information sent by manufacturers. Search strategy included the FDA-approved use of all drugs in this class. Randomized, controlled, comparative trials of oral agents used in the outpatient setting are considered the most relevant in this category. Many of the more recent studies have focused on inpatient use of the antifungal agents. Studies included for analysis in the review were published in English, performed with human participants, and randomly allocated participants to comparison groups. In addition, studies must contain clearly stated, predetermined outcome measure(s) of known or probable clinical importance, use data analysis techniques consistent with the study question, and include follow-up (endpoint assessment) of at least 80% of participants entering the investigation. Despite some inherent bias found in all studies including those sponsored and/or funded by pharmaceutical manufacturers, the studies in this therapeutic class review were determined to have results or conclusions that do not suggest systematic error in their experimental study design. While the potential influence of manufacturer sponsorship/funding must be considered, the studies in this review have also been evaluated for validity and importance.

Safety and efficacy for the treatment of aspergillosis, blastomycosis, and histoplasmosis with itraconazole (Tolsura) were established in open-label trials.<sup>135</sup>

### Aspergillosis

#### *isavuconazole (Cresemba) versus voriconazole (Vfend)*

A randomized, double-blind, non-inferiority active-controlled trial which evaluated the safety and efficacy of isavuconazole versus voriconazole for the primary treatment of invasive fungal disease caused by *Aspergillus* species or other filamentous fungi was conducted.<sup>136</sup> Each treatment group included 258 patients. Patients randomized to receive isavuconazole treatment were administered an IV loading dose of 372 mg of isavuconazonium sulfate (equivalent to 200 mg of isavuconazole) every 8 hours for the first 48 hours. Beginning on day 3, patients received IV or oral therapy of 372 mg of isavuconazonium sulfate (equivalent to 200 mg of isavuconazole) once daily. Patients randomized to receive voriconazole treatment were administered voriconazole IV with a loading dose of 6 mg/kg every 12 hours for the first 24 hours followed by 4 mg/kg IV every 12 hours for the following 24 hours. Therapy could then be switched to an oral formulation of voriconazole at a dose of 200 mg every 12 hours. In this trial, the protocol-defined maximum treatment duration was 84 days. Mean treatment duration was 47 days for both treatment groups, of which 8 to 9 days was by an intravenous route of administration. Results for overall success at end of treatment were 35% of isavuconazole treated patients compared to 38.9% of voriconazole-treated patients.

### Esophageal Candidiasis

#### *fluconazole (Diflucan) and voriconazole (Vfend)*

In a double-blind, placebo-controlled trial, 256 immunocompromised patients, most of whom were HIV-positive with biopsy-proven esophageal candidiasis, were randomized to voriconazole (400 mg for one dose; then 200 mg twice daily), fluconazole (400 mg for one dose; then 200 mg daily), or placebo. The study evaluated efficacy, tolerability, and safety.<sup>137</sup> Patients were on therapy for at least 7 days

after clinical signs and symptoms resolved or for a maximum of 6 weeks. Patients underwent endoscopy at day 43 to determine efficacy. Endoscopy-documented success (98.3% versus 95.1%, respectively), as well as symptomatic success (88% versus 91.1%, respectively), was similar between voriconazole and fluconazole. Visual disturbances were reported in 18% of voriconazole patients compared to 5% with fluconazole. More patients discontinued voriconazole due to laboratory abnormalities or treatment-related adverse effects.

## **Infection Prophylaxis in Immunocompromised Patients**

### ***posaconazole (Noxafil), fluconazole (Diflucan) and/or itraconazole (Sporanox)***

Due to the lack of other comparative data with posaconazole, this study is included in the review. In a randomized, multicenter study, safety and efficacy of posaconazole (n = 304), fluconazole (n = 240), and itraconazole (n = 58) were compared for invasive fungal infection prophylaxis in patients with prolonged neutropenia.<sup>138</sup> Patients were undergoing treatment for acute myelogenous leukemia or myelodysplastic syndrome. In this investigator-blinded study, patients received prophylaxis with the assigned treatment with each cycle of chemotherapy until recovery from neutropenia and complete remission occurred or until the occurrence of an invasive fungal infection or for up to 12 weeks. Proven or probable invasive fungal infections were reported in 2% of the posaconazole group and 8% in the fluconazole or itraconazole group (absolute reduction, 6%; 95% CI, -9.7 to -2.5; p<0.001). Invasive aspergillosis was significantly lower in the posaconazole group (1% versus 7%, p<0.001). Survival was significantly higher in the posaconazole group (16% mortality) than in the fluconazole/itraconazole group (22% mortality, p=0.04). Serious adverse effects were significantly more common in the posaconazole group (6% versus 2%; p=0.01). The most common adverse effects related to the gastrointestinal tract.

In a multicenter, randomized, double-blind trial, oral posaconazole and fluconazole were compared for prophylaxis against invasive fungal infections in patients with graft-versus-host disease (GVHD) who were receiving immunosuppressive therapy.<sup>139</sup> Six hundred allogeneic hematopoietic stem-cell transplant patients were enrolled. At the end of the 112-day treatment period, posaconazole and fluconazole were similarly effective in preventing all invasive fungal infections (5.3% and 9%, respectively; odds ratio [OR], 0.56; 95% CI, 0.3 to 1.07; p=0.07). Posaconazole was superior to fluconazole in preventing proven or probable invasive aspergillosis (2.3% and 7%; OR, 0.31; 95% CI, 0.13 to 0.75; p=0.006). Overall mortality was similar in the 2 groups; however, the number of deaths from invasive fungal infections was lower in the posaconazole group (1% and 4%, p=0.046). Treatment-related adverse effects were similar in both groups (36% for posaconazole and 38% for fluconazole).

## **Onychomycosis**

### ***terbinafine versus itraconazole (Sporanox)***

In a prospective, randomized, double-blind, multicenter study, researchers compared the efficacy and tolerability of continuous terbinafine with intermittent itraconazole for treatment of toenail onychomycosis.<sup>140</sup> The study included 496 patients diagnosed with toenail onychomycosis caused by a dermatophyte. Patients were randomly assigned to 4 parallel groups: terbinafine 250 mg per day for 12 or 16 weeks or itraconazole 400 mg per day for 1 week in every 4 weeks for 12 or 16 weeks. The primary outcome measure was mycological cure, defined as negative microscopy and negative culture of samples from the target toenail. At week 72, mycological cure rates were 75.5% in the 12-week terbinafine group and 80.8% in the 16-week terbinafine group, compared with 38.3% in the

itraconazole 12-week study group and 49.1% in the itraconazole 16-week group. All treatments were well tolerated, with no significant differences in the number or type of adverse events reported. Researchers concluded continuous terbinafine is more effective than intermittent itraconazole for the treatment of toenail onychomycosis.

In a 5-year, blinded, prospective follow-up study to the aforementioned study, the long-term effectiveness of terbinafine was compared to itraconazole in 151 patients.<sup>141</sup> At the end of 5 years, mycologic cure achieved with 1 treatment course was found in 46% and 13% of the terbinafine-treated and itraconazole-treated patients, respectively ( $p < 0.001$ ). Mycologic and clinical relapse rates were significantly higher in the itraconazole-treated group, 53% and 48%, respectively, compared to the terbinafine-treated group, 23% and 21%, respectively.

A prospective, investigator-blinded, long-term follow-up (1.25 to 7 years) study comparing 4 treatment regimens with itraconazole and terbinafine was conducted.<sup>142</sup> The 4 regimens were either terbinafine continuous, intermittent, or in combination with itraconazole, and pulsed itraconazole. Recurrence rate of onychomycosis was the outcome used to determine which of the 4 regimens was the most effective at decreasing the rate of re-infection. Although no statistical significance was found between the dosing regimens, it was determined that itraconazole therapy was associated with higher rates of recurrence (59%) than was terbinafine regimens (32% recurrence rate for continuous and 36% for intermittent). Combining the 2 drugs did not reduce the rate of recurrence of the infection as compared to monotherapy (57% rate of recurrence of infection for combination therapy).

### ***itraconazole (Onmel) versus itraconazole (Sporanox)***

The efficacy of itraconazole (Onmel) for the treatment of onychomycosis of the toenail was evaluated in a 12-week, randomized, placebo-controlled, third-party blinded, multicenter trial comparing one 200 mg Onmel tablet to 2 100 mg itraconazole capsules and placebo once daily tablets, in 791 patients.<sup>143</sup> The primary endpoint of Complete Cure at week 52, nine months after completion of study medication, was 22.3% and 1%, for Onmel and placebo, respectively. The Mycologic Cure rate was 44% and the Clinical Cure rate was 26% for subjects treated with Onmel. The Mycological Cure rate was 6% and the Clinical Cure rate was 3% for subjects treated with placebo. Efficacy results comparing a single 200 mg Onmel tablet to 200 mg of itraconazole capsules (two 100 mg capsules) were similar.

## **Oropharyngeal Candidiasis**

### ***miconazole (Oravig) versus clotrimazole troches***

In a randomized, double-blind, double-dummy trial, miconazole buccal 50 mg tablets daily were compared to clotrimazole 10 mg troches 5 times daily for 14 days in 577 HIV-positive patients with oropharyngeal candidiasis.<sup>144,145</sup> Patients were required to have symptoms and microbiological documentation of candidiasis for study entry. Clinical cure was defined as a complete resolution of signs and symptoms of oropharyngeal candidiasis at the test-of-cure visit (days 17 to 22). Clinical cure was achieved in 61% of miconazole patients compared to 65% of clotrimazole patients ( $p = NS$ ) in the intent to treat population. Clinical relapse occurred in 27.3% and 27.8% of patients, respectively. Mycological cure (eradication of *Candida* on days 17 to 22) occurred in 27.2% and 24.7% of patients, respectively. Adverse events were similar between treatments.

### ***posaconazole (Noxafil) versus fluconazole (Diflucan)***

Due to the lack of other comparative data with posaconazole, this study is included in the review. Posaconazole was compared to fluconazole in a multicenter, randomized, single-blinded trial evaluating efficacy and safety in the treatment of oropharyngeal candidiasis in patients with HIV/AIDS.<sup>146</sup> Patients (n = 350) were randomized to posaconazole or fluconazole 200 mg on day 1 then 100 mg daily for 13 days. Clinical success, defined as cure or improvement on day 14, was observed in 91.7% and 92.5% for posaconazole and fluconazole groups, respectively (95% CI, -6.61 to 5.04). Mycological success was 68% in both arms on day 14, but mycological success on day 42 was 40.6% and 26.4% for posaconazole and fluconazole, respectively (p=0.038). Clinical relapse rates were 31.5% for posaconazole and 38.2% for fluconazole. Adverse effects were similar.

## **META-ANALYSES**

A meta-analysis determined mycological cure rate in randomized clinical trials is consistently 76% for terbinafine and 63% for pulse dose itraconazole (Sporanox).<sup>147</sup> Thirty-six randomized, controlled trials evaluated the efficacy of terbinafine, itraconazole, fluconazole (Diflucan), and griseofulvin in the treatment of dermatophyte toenail onychomycosis. Studies were required to use a standard dosage regimen (pulse or continuous), treatment duration, and follow-up period. Mycological and clinical response rates were compared for the randomized controlled trials and open trials for each of the agents. Studies were pooled from earliest (1966) to most recent to determine the cumulative meta-analytical average. The overall cumulative meta-average for mycological cure rates were terbinafine 76 ± 3% (18 studies), itraconazole pulse 63 ± 7% (6 studies), itraconazole continuous 59 ± 5% (7 studies), fluconazole 48 ± 5% (3 studies), and griseofulvin 60 ± 6% (3 studies). When comparing randomized controlled trials and open-label trials, the cumulative meta-analytical average for mycological cure rates were significantly higher in the open-label trials for terbinafine, itraconazole pulse dose, and fluconazole.

A meta-analysis completed in 2011 reviewed itraconazole recurrence rates as compared to terbinafine recurrence rates. This analysis concluded that itraconazole had a higher rate of onychomycosis recurrence than did terbinafine.<sup>148</sup>

A Cochrane review found very few comparative trials on which to evaluate efficacy of prophylaxis of oropharyngeal candidiasis in HIV-positive patients.<sup>149</sup> It appeared that ketoconazole, fluconazole, itraconazole, and clotrimazole improved treatment outcomes in the treatment of oropharyngeal candidiasis. An update was performed evaluating clinical trials performed between 2005 and 2009.<sup>150</sup> Five additional studies were identified. Only 1 study was performed in children; therefore, little evidence exists. For adults, very few comparative trials for each comparison exist. Due to insufficient evidence, no conclusion could be made about the effectiveness of clotrimazole, nystatin, amphotericin B, itraconazole, or ketoconazole with regard to oropharyngeal candidiasis prophylaxis.

## **SUMMARY**

Oral antifungal agents are useful in the treatment of a variety of infections in both the immunocompetent and immunocompromised patient. Oral antifungals used in the outpatient setting generally treat fungal infections such as oropharyngeal candidiasis, urinary tract infections, superficial skin infections, and onychomycosis. Due to its excellent penetration into many tissues, fluconazole (Diflucan) is effective *Candida* treatment for a variety of infections, lacking concerns about pH-dependent absorption such as that seen with ketoconazole. Effective therapy for oropharyngeal

candidiasis includes fluconazole, itraconazole (Onmel, Sporanox), ketoconazole, nystatin, and clotrimazole. Voriconazole (Vfend) has been shown to have similar efficacy to fluconazole in the treatment of esophageal candidiasis; however, more adverse effects are reported with voriconazole. Intravenous loading doses are required during the first 24 hours of voriconazole therapy for all infections except esophageal candidiasis. Posaconazole (Noxafil) oral suspension has an indication for treatment of oropharyngeal candidiasis when refractory to itraconazole and/or fluconazole. Nystatin is also used to treat intestinal candidiasis and may be used in infants and children.

In comparative trials, terbinafine demonstrated higher treatment success rates of toenail onychomycosis in immunocompetent patients compared to itraconazole (Sporanox). Utility of griseofulvin for treatment of onychomycosis has decreased since the introduction of the azole antifungals and terbinafine. Duration of therapy is often longer than with other agents, which may result in increased adverse effects and require monitoring of liver, renal, and hematopoietic function. However, griseofulvin is still a useful agent in the treatment of many fungal skin infections that do not respond to topical therapies.

For serious fungal infections, isavuconazonium (Cresemba), posaconazole (Noxafil), flucytosine (Ancobon), voriconazole (Vfend), itraconazole (Sporanox, Tolsura), and fluconazole have indications for the treatment and/or prophylaxis of various serious fungal infections.

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