

NCCN Clinical Practice Guidelines in Oncology (NCCN Guidelines®)

Prevention and Treatment of Cancer-Related Infections

Version 1.2019 — October 25, 2018

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Prevention and Treatment of Cancer-Related Infections

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[NCCN Guidelines Panel Disclosures](#)

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Prevention and Treatment of Cancer-Related Infections

[NCCN Guidelines Prevention and Treatment of Cancer-Related Infections Panel Members](#) [Summary of the Guidelines Updates](#)

- [Antimicrobial Prophylaxis \(INF-1\)](#)
- [Antifungal Prophylaxis \(INF-2\)](#)
- [Prevention of Herpes Simplex Virus \(HSV\) and Varicella Zoster Virus \(VZV\) Reactivation or Disease \(INF-3\)](#)
- [Prevention of Cytomegalovirus \(CMV\) Reactivation or Disease \(INF-4\)](#)
- [Prevention of Hepatitis B Virus \(HBV\), Hepatitis C Virus \(HCV\), and Human Immunodeficiency Virus \(HIV\) Reactivation or Disease \(INF-5\)](#)
- [Antipneumocystis Prophylaxis \(INF-6\)](#)
- [General Recommendations for Vaccination in Patients with Cancer \(INF-7\)](#)
- [Recommended Vaccination Schedule After Autologous or Allogeneic HCT \(INF-8\)](#)

- [Initial Evaluation of Fever and Neutropenia \(FEV-1\)](#)
- [Initial Risk Assessment for Febrile Neutropenic Patients \(FEV-2\)](#)
- [Outpatient Therapy for Low-Risk Patients \(FEV-3\)](#)
- [Initial Empiric Therapy for Fever and Neutropenia \(FEV-5\)](#)
- [Site-Specific Evaluation and Therapy:](#)
 - ▶ [Mouth/Mucosal Membrane, Esophagus, and Sinus/Nasal \(FEV-6\)](#)
 - ▶ [Abdominal Pain, Perirectal Pain, Diarrhea, and Urinary Tract Symptoms \(FEV-7\)](#)
 - ▶ [Lung Infiltrates \(FEV-8\)](#)
- [Cellulitis/Skin and Soft Tissue Infections, Vascular Access Devices, Vesicular Lesions, Disseminated Papules or Other Lesions, and Central Nervous System Symptoms \(FEV-9\)](#)
- [Principles of Daily Follow-Up \(FEV-10\)](#)
- [Follow-Up Therapy for Responding Disease \(FEV-11\)](#)

[Antibacterial Agents Tables \(FEV-A\)](#)

[Antifungal Agents Tables \(FEV-B\)](#)

[Antiviral Agents Tables \(FEV-C\)](#)

[Risk Assessment Resources \(FEV-D\)](#)

Clinical Trials: NCCN believes that the best management for any patient with cancer is in a clinical trial. Participation in clinical trials is especially encouraged.

To find clinical trials online at NCCN Member Institutions, [click here: nccn.org/clinical_trials/clinicians.aspx](#).

NCCN Categories of Evidence and Consensus: All recommendations are category 2A unless otherwise indicated.

See [NCCN Categories of Evidence and Consensus](#).

The NCCN Guidelines® are a statement of evidence and consensus of the authors regarding their views of currently accepted approaches to treatment. Any clinician seeking to apply or consult the NCCN Guidelines is expected to use independent medical judgment in the context of individual clinical circumstances to determine any patient's care or treatment. The National Comprehensive Cancer Network® (NCCN®) makes no representations or warranties of any kind regarding their content, use or application and disclaims any responsibility for their application or use in any way. The NCCN Guidelines are copyrighted by National Comprehensive Cancer Network®. All rights reserved. The NCCN Guidelines and the illustrations herein may not be reproduced in any form without the express written permission of NCCN. ©2018.



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Prevention and Treatment of Cancer-Related Infections

Updates in Version 1.2019 of the NCCN Guidelines for Prevention and Treatment of Cancer-Related Infections from Version 1.2018 include:

[INF-1](#)

- Footnote d was updated: Pneumocystis prophylaxis ([See INF-6](#)). *For dosing, spectrum, and specific comments/cautions, see Antibacterial Agents (FEV-A), Antifungal Agents (FEV-B), Antiviral Agents (FEV-C) as indicated.*
- The following footnote was removed: "Although data support levofloxacin prophylaxis for low- and intermediate-risk patients, the panel discourages this practice in low-risk patients because of concerns about antimicrobial resistance; however, it can be considered in intermediate-risk patients."

[INF-2](#)

- "See Antipneumocystosis Prophylaxis (INF-6)" was added to Antifungal Prophylaxis.
- Footnote j was updated: "Itraconazole, voriconazole, and posaconazole are more potent inhibitors of hepatic cytochrome P450 3A4 isoenzymes than fluconazole and may significantly decrease the clearance of several agents used to treat cancer (eg, vincristine). *In select circumstances when standard therapy is contraindicated, such as drug interactions in patients with leukemia or the risk of QTc prolongation, some centers consider using echinocandins, amphotericin B at prophylactic doses, or isavuconazole, although studies have not directly tested these.*"

[INF-4](#)

- Letermovir was added as an option for primary prophylaxis for CMV+ allogeneic HCT recipients during the surveillance period with corresponding footnote t.
- "CMV reactivation detected" was added.

[INF-5](#)

- HIV positive
 - ▶ Therapy Considerations was updated: "*Consult ID/HIV expert to adjust dosing...*"
 - ▶ Surveillance was updated: "*Monthly HIV viral load monitoring during therapy then as clinically indicated (See NCCN Guidelines for Cancer in People Living with HIV).*"
- Footnote y was updated: "High risk of HBV is defined as patients with HBsAg+ serology or with prior resolved HBV infection (HBsAg-, HBsAb+, HBeAb+ serology or with increasing HBV viral load..."

[INF-8](#)

- Recombinant zoster vaccine was added to the table with corresponding footnote qq.

[FEV-4](#)

- Footnote e was updated: "The fluoroquinolone chosen should be based on ~~reliable Gram-negative bacillary activity, local antibacterial susceptibilities,~~ and the use of quinolone prophylaxis of fever and neutropenia."
- Footnote g was updated: "~~Not active~~ *Insufficient activity* against pseudomonas. Recommended for low-risk patients who may not require pseudomonas coverage."

[FEV-5](#)

- The following footnotes were removed:
 - ▶ Consider local antibiotic susceptibility patterns when choosing empiric therapy. At hospitals where infections by antibiotic-resistant bacteria (eg, MRSA, drug-resistant Gram-negative rods) are commonly observed, policies on initial empiric therapy of neutropenic fever may need to be tailored accordingly.
 - ▶ An initial meta-analysis of clinical trials reported an increase in mortality among patients receiving cefepime versus other beta-lactams (Yahav D, Paul M, Fraser A, et al. Lancet Infect Dis 2007;7:338-348). Subsequent meta-analyses, including one from the FDA, showed no difference in mortality (Kim PW, Wu YT, Cooper C, et al. Clin Infect Dis 2010;51:381-389; Freifeld AG, Sepkowitz K. Clin Infect Dis 2010;51:390-391). Based on these results, the FDA has determined that cefepime remains an appropriate therapy for its approved indications.

[FEV-8](#)

- "Mycobacterial" was added to the 4th sub-bullet under Evaluation.

[FEV-9](#)

- "and a peripheral culture" was added to the Vascular access devices (VAD) pathway.
- The first bullet under Additions to Initial Empiric Regimen for Disseminated papules or other lesions was updated: "Consider vancomycin *or other gram-positive coverage (See FEV-A).*"

[Continued](#)

Updates in Version 1.2019 of the NCCN Guidelines for Prevention and Treatment of Cancer-Related Infections from Version 1.2018 include:

[FEV-10](#)

- Follow-up Therapy for Neutrophils <500 cells/mcL: The first and second bullets are new.
- "The choice will depend on particular patient details; see Discussion for additional information" was added to footnote w."
- The following footnote was removed: "Antifungal treatment regimens are highly variable and may include preemptive or empiric antifungal therapy or anti-mold azoles."

[FEV-11](#)

- Last sub-bullet under Suggested Minimum Duration of Therapy for Documented Infection was updated: Influenza: "~~Osetamivir is approved by the FDA for A minimum 5 d course of osetamivir is standard based on data from ambulatory and otherwise healthy individuals with intact immune systems; some centers consider longer courses for the highly immunocompromised,² but there is no proven benefit to prolonged therapy (eg, at least 10 d) and until resolution of symptoms should be considered in the highly immunocompromised.~~"

[FEV-A \(1 of 4\)](#)

- Vancomycin
 - ▶ "For C. difficile: 125 mg PO every 6 h" was removed from the dosing column.
 - ▶ Footnote b was added to the last bullet in the Comments/Precautions column.
- Daptomycin
 - ▶ "with higher doses indicated for specific infections" was added to the dosing column.
 - ▶ The last bullet in the Comments/Precautions column was updated: "~~Consider an ID consult strongly recommended if using daptomycin above 6mg/kg.~~"
- Footnote b was updated: "*These are standard dosing recommendations is for adult patients; there are other situations where dose adjustments are required. Consult pediatric guidelines for recommended dosing in these pediatric patients. Adjustments should also be made for renal insufficiency and obese patients according to institutional guidelines.*"
- Footnote c was updated: "~~Consider Higher doses for certain indications are recommended for bloodstream infections. ID consult is strongly recommended.~~"

[FEV-A \(2 of 4\)](#)

- Doripenem was removed.
- Footnote e was updated: "*Emerging data may support extended or continuous infusion of beta-lactam therapies use for higher-potency against resistant cases. For highly resistant infections, see Discussion for recommendations regarding alternative antibiotics with restricted availability.*"

[FEV-A \(3 of 4\)](#)

- Aminoglycosides
 - ▶ Comments/Cautions column was updated: "~~Often~~ *Sometimes used as empiric part of combination therapy in seriously ill or hemodynamically unstable patients.*"
- Ciprofloxacin in combination with amoxicillin/clavulanate
 - ▶ The first bullet in the Spectrum column was updated: "*Ciprofloxacin has good activity against Gram-negative and atypical organisms (eg, Legionella spp.) but less activity than...*"
 - ▶ The last bullet in the Spectrum column is new.
- Moxifloxacin: The last bullet in the Spectrum column was updated: "~~Moxifloxacin has limited insufficient activity against Pseudomonas~~"
- "and other relevant pathogens, including *Toxoplasma gondii* and *Nocardia*" was added to the Spectrum column for TMP/SMX.

[FEV-B \(1 of 5\)](#)

- "Azoles as a class have important drug interactions, especially with the newer therapeutic agents. Please carefully review. Drug-drug interactions are common and need to be closely monitored (consult package inserts for details)." was added to the top of the page. Also for FEV-B (2 of 5).
- "Drug-drug interactions are common and need to be closely monitored (consult package inserts for details). Reversible liver enzyme abnormalities are observed" was removed from footnote a.

[FEV-C \(2 of 4\)](#)

- Letermovir is new to the page.

[FEV-C \(3 of 4\)](#)

- Ribavirin
 - ▶ "may be paired with IVIG (400–500 mg/kg every other day)" was removed from the Common Indication column.
 - ▶ The first bullet in the Comments/Cautions column is new.

Overall Infection Risk in Patients with Cancer ^a	Disease/Therapy Examples	Fever & Neutropenia Risk (See FEV-2)	Antimicrobial Prophylaxis ^d
Low	<ul style="list-style-type: none"> Standard chemotherapy regimens for most solid tumors Anticipated neutropenia less than 7 d 	Incidence low	<ul style="list-style-type: none"> Bacterial - None Fungal - None Viral - None unless prior HSV episode
Intermediate	<ul style="list-style-type: none"> Autologous HCT Lymphoma^c Multiple myeloma^c CLL^c Purine analog therapy (ie, fludarabine, clofarabine, nelarabine, cladribine) Anticipated neutropenia 7–10 d 	Incidence usually high, significant variability may exist	<ul style="list-style-type: none"> Bacterial - Consider fluoroquinolone prophylaxis during neutropenia^e Fungal - Consider prophylaxis during neutropenia and for anticipated mucositis (See INF-2); consider PCP prophylaxis (See INF-6) Viral - During neutropenia and longer depending on risk (See INF-3, INF-4, INF-5)
High ^b	<ul style="list-style-type: none"> Allogeneic HCT including cord blood Acute leukemia <ul style="list-style-type: none"> › Induction › Consolidation/maintenance Alemtuzumab therapy GVHD treated with high-dose steroids (>20 mg daily) Anticipated neutropenia greater than 10 d 	Incidence usually high, significant variability may exist	<ul style="list-style-type: none"> Bacterial - Consider fluoroquinolone prophylaxis during neutropenia^e Fungal - Consider prophylaxis during neutropenia (See INF-2); consider PCP prophylaxis (See INF-6) Viral - During neutropenia and longer depending on risk (See INF-3, INF-4, INF-5)

KEY: CLL = chronic lymphocytic leukemia, GVHD = graft-versus-host disease, HCT = hematopoietic cell transplant, HSV = herpes simplex virus, PCP = *p*neumocystis *p*neumonia

^a Categories of risk are based on several factors, including underlying malignancy, whether disease is in remission, duration of neutropenia, prior exposure to chemotherapy, and intensity of immunosuppressive therapy.

^b In high-risk patients, additional prophylaxis may be necessary; for example, consider penicillin and trimethoprim/sulfamethoxazole (TMP/SMX) for allogeneic HCT recipients with chronic GVHD.

^c This is a heterogenous disease. Therefore, treatment modalities and the type of malignancy affect risk level.

^d Pneumocystis prophylaxis ([See INF-6](#)). For dosing, spectrum, and specific comments/cautions, see [Antibacterial Agents \(FEV-A\)](#), [Antifungal Agents \(FEV-B\)](#), [Antiviral Agents \(FEV-C\)](#) as indicated.

^e For patients who are intolerant to fluoroquinolone, consider TMP/SMX or an oral third-generation cephalosporin (category 2B).

Note: All recommendations are category 2A unless otherwise indicated.

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Prevention and Treatment of Cancer-Related Infections

Overall Infection Risk in Patients with Cancer ^a	Disease/Therapy Examples	Antifungal Prophylaxis ^{f,i} See Antipneumocystis Prophylaxis (INF-6)	Duration
Intermediate to High	ALL	Consider: • Fluconazole ^j or micafungin ^k • Amphotericin B products ^l (category 2B)	Until resolution of neutropenia
	MDS (neutropenic)	Consider: • Posaconazole ^j (category 1) • Voriconazole, ^j fluconazole, ^j micafungin, ^k or amphotericin B products ^l (all category 2B)	
	AML (neutropenic)		
	Autologous HCT with mucositis ^g	Consider: • Fluconazole ^j or micafungin ^k (both category 1)	N/A
	Autologous HCT without mucositis	Consider no prophylaxis (category 2B)	
	Allogeneic HCT (neutropenic)	Consider: • Fluconazole ^j or micafungin ^k (both category 1) • Voriconazole, ^j posaconazole, ^j or amphotericin B products ^l (all category 2B)	Continue during neutropenia ^m
	Significant GVHD ^h	Consider: • Posaconazole ^j (category 1) • Voriconazole, ^j echinocandin, or amphotericin B products ^l (all category 2B)	Until resolution of significant GVHD

KEY: ALL = acute lymphoblastic leukemia, AML = acute myeloid leukemia, MDS = myelodysplastic syndromes, GVHD = graft-versus-host disease, HCT = hematopoietic cell transplant, HSV = herpes simplex virus

^a Categories of risk are based on several factors, including underlying malignancy, whether disease is in remission, duration of neutropenia, prior exposure to chemotherapy, and intensity of immunosuppressive therapy.

^f [See Antifungal Agents \(FEV-B\)](#) for dosing, spectrum, and specific comments/cautions.

^g Mucositis is a risk factor for candidemia in patients with hematologic malignancies and HCT recipients not receiving antifungal prophylaxis.

^h Consider antifungal prophylaxis in all patients with GVHD receiving immunosuppressive therapy.

ⁱ There is substantial variability in practice among NCCN Member Institutions. Physicians need to take into account local susceptibility patterns.

^j Itraconazole, voriconazole, and posaconazole are more potent inhibitors of hepatic cytochrome P450 3A4 isoenzymes than fluconazole and may significantly decrease the clearance of several agents used to treat cancer (eg, vincristine). In select circumstances when standard therapy is contraindicated, such as drug interactions in patients with leukemia or the risk of QTc prolongation, some centers consider using echinocandins, amphotericin B at prophylactic doses, or isavuconazole, although studies have not directly tested these.

^k All three agents in the class (micafungin, caspofungin, and anidulafungin) are considered by many to be interchangeable.

^l A lipid formulation is generally preferred based on less toxicity.

^m Some studies continue treatment up to day 75.

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PREVENTION OF HERPES SIMPLEX VIRUS (HSV) AND VARICELLA ZOSTER VIRUS (VZV) REACTIVATION OR DISEASE^o

Overall Infection Risk in Patients with Cancer ^a	Disease/Therapy Examples	Viral Infection or Reactivation	Antiviral Prophylaxis ⁿ	Minimum Duration
Low	• Standard chemotherapy regimens for solid tumors	HSV	None unless prior HSV episode	During active therapy including periods of neutropenia
Intermediate	• Autologous HCT • Lymphoma ^c • Multiple myeloma ^c • CLL ^c • Purine analog therapy (eg, fludarabine)	HSV VZV	Acyclovir Famciclovir Valacyclovir	HSV prophylaxis ^p • Consider during active therapy and possibly longer depending on degree of immunosuppression VZV prophylaxis ^q • Consider for at least 6–12 months after autologous HCT
High	• Acute leukemia	HSV		HSV prophylaxis during active therapy including periods of neutropenia ^p
	• Proteasome inhibitors	VZV		VZV prophylaxis during active therapy including periods of neutropenia ^q
High	• Alemtuzumab therapy • Allogeneic HCT • GVHD requiring steroid treatment	HSV VZV	HSV prophylaxis ^p • Minimum of 2 mo after alemtuzumab and until CD4 ≥200 cells/mcL VZV prophylaxis ^q • Prophylaxis should be considered for at least 1 y after allogeneic HCT	

KEY: CLL = chronic lymphocytic leukemia, GVHD = graft-versus-host disease, HCT = hematopoietic cell transplant, HSV = herpes simplex virus, VZV = varicella zoster virus

^a Categories of risk are based on several factors, including underlying malignancy, whether disease is in remission, duration of neutropenia, prior exposure to chemotherapy, and intensity of immunosuppressive therapy.

^c This is a heterogenous disease. Therefore, treatment modalities and the type of malignancy affect risk level.

ⁿ See [Antiviral Agents \(FEV-C\)](#) for dosing, spectrum, and specific comments/cautions.

^o For CMV antiviral prophylaxis, see [INF-4](#). For HBV, HCV, and HIV antiviral prophylaxis, see [INF-5](#).

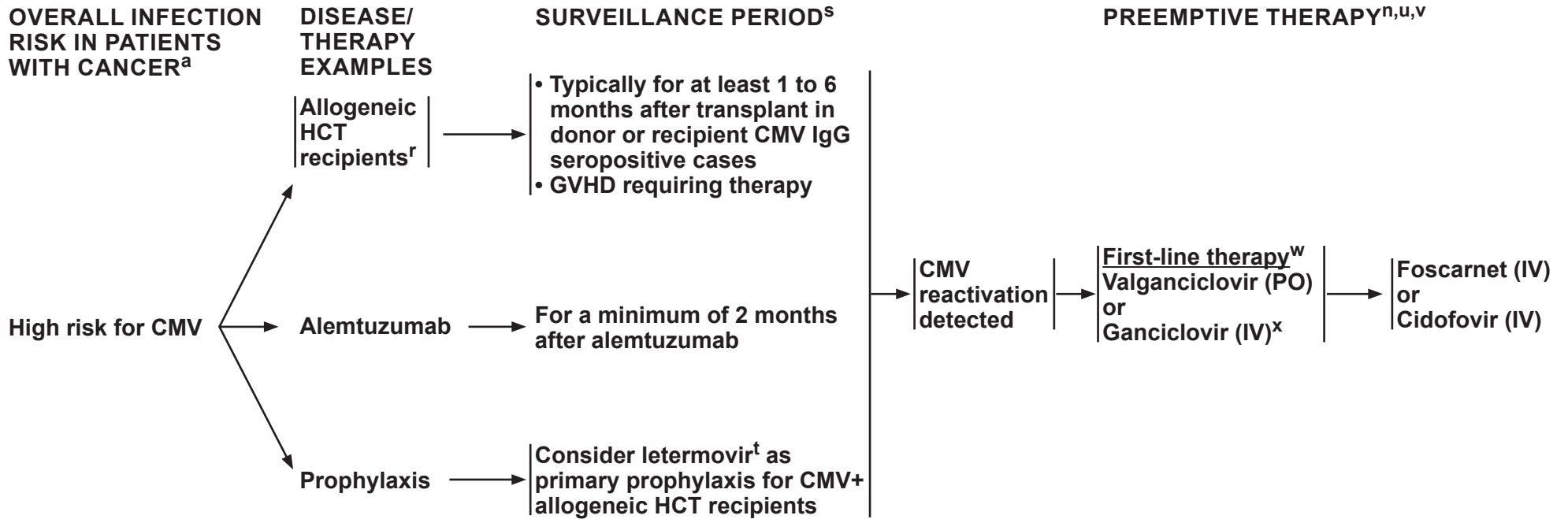
^p HSV prophylaxis is indicated in seropositive children.

^q For pediatric patients, prophylaxis for VZV is not routinely given unless there is a history of recurrent zoster infections or after first zoster while on myelosuppressive therapy, even if they are seropositive or vaccinated children.

Note: All recommendations are category 2A unless otherwise indicated.

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PREVENTION OF CYTOMEGALOVIRUS (CMV) REACTIVATION OR DISEASE



^a Categories of risk are based on several factors, including underlying malignancy, whether disease is in remission, duration of neutropenia, prior exposure to chemotherapy, and intensity of immunosuppressive therapy.

ⁿ See [Antiviral Agents \(FEV-C\)](#) for dosing, spectrum, and specific comments/cautions.

^r Higher risk transplant subgroups may exist and require different management strategies.

^s CMV surveillance consists of weekly monitoring by PCR.

^t Some centers consider the use of letermovir in high-risk patients. There are limited data available and its role is highly controversial. (See [Antiviral Agents \(FEV-C \[2 of 4\]\)](#))

^u Preemptive therapy is defined as administration of antiviral agents to asymptomatic patients at high risk for clinical infection based on laboratory markers of viremia. Duration of antiviral therapy generally is for 2 weeks and until CMV is no longer detected.

^v Clinicians should measure for end-organ disease and tailor duration of preemptive therapy accordingly.

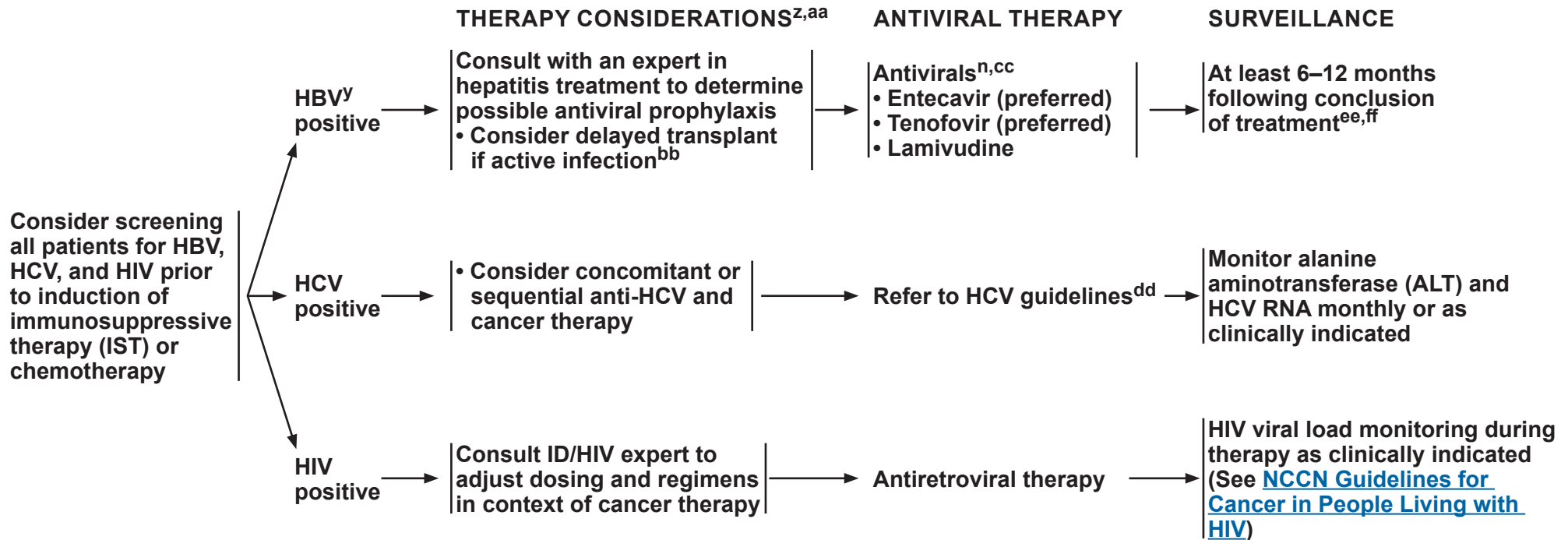
^w Typically therapy is initiated with oral valganciclovir unless there are absorption or toxicity issues and it would be continued at a minimum until a negative polymerase chain reaction (PCR). However, some centers prefer ganciclovir over valganciclovir.

^x Foscarnet or cidofovir should be used for cases of ganciclovir-resistant CMV or when ganciclovir is not tolerated (eg, ganciclovir-induced myelosuppression).

Note: All recommendations are category 2A unless otherwise indicated.

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PREVENTION OF HEPATITIS B VIRUS (HBV), HEPATITIS C VIRUS (HCV), AND HUMAN IMMUNODEFICIENCY VIRUS (HIV) REACTIVATION OR DISEASE



ⁿ See [Antiviral Agents \(FEV-C\)](#) for dosing, spectrum, and specific comments/cautions.

^y High risk of HBV is defined as patients with HBsAg+ serology or HBcAb+ serology or with increasing HBV viral load in patients planned for allogeneic HCT or anti-CD20, anti-CD52 monoclonal antibody therapy.

^z Diagnostic monitoring and treatment for HBV, HCV, and HIV are evolving fields; consultation with an infectious disease (ID) expert or hepatologist should be sought in the management of all patients with reactivation or disease.

^{aa} Drug interactions may complicate therapies. Consultation is recommended.

^{bb} Chronic hepatitis based on biopsy or active viral replication (ie, high levels of HBsAg+ and/or HBeAg+ or increasing HBV viral load). Biopsy should be performed if clinical suspicion of disease. In case of cirrhosis, reconsider decision for transplant.

^{cc} Although data were originally obtained with lamivudine, entecavir and tenofovir are preferred agents, especially when treating patients with active infections due to the low threshold of resistance with lamivudine.

^{dd} Therapy should be given by a provider experienced in Hepatitis C. See [American Association for the Study of Liver Diseases/Infectious Diseases Society of America HCV Guidelines](#).

^{ee} If viral load is consistently undetectable, treatment is considered prophylactic. If viral load fails to drop or previously undetectable PCR becomes positive, consult hepatologist and discontinue anti-CD20 antibody therapy.

^{ff} Duration of therapy may depend on various factors. For example, in patients receiving rituximab, the risk of reactivation continues after treatment is concluded and is increased if treatment is halted too early.

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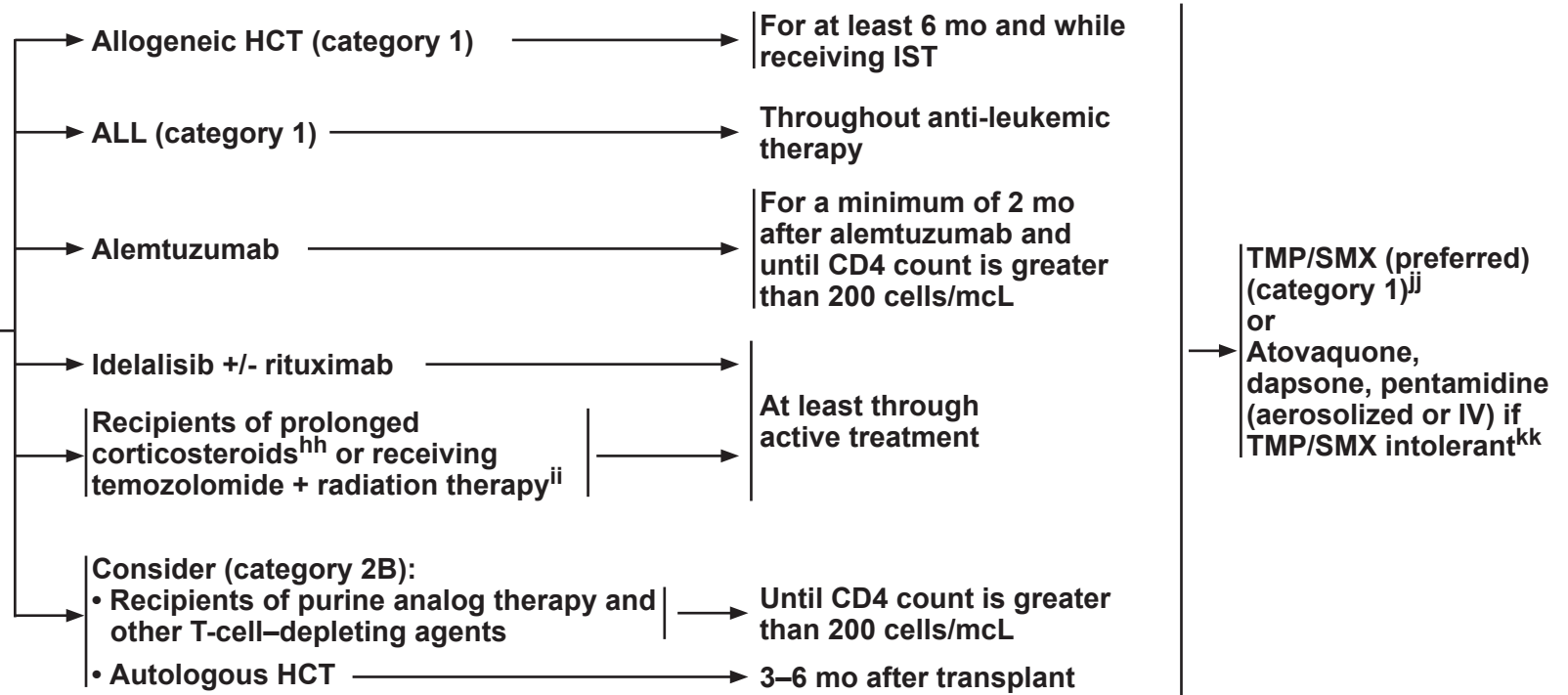
INFECTION RISK IN PATIENTS WITH CANCER^a

DISEASE/THERAPY EXAMPLES

DURATION OF PROPHYLAXIS

ANTIPNEUMOCYSTIS PROPHYLAXIS⁹⁹

High risk for
Pneumocystis jirovecii
(*Pneumocystis carinii*)



^a Categories of risk are based on several factors, including underlying malignancy, whether disease is in remission, duration of neutropenia, prior exposure to chemotherapy, and intensity of immunosuppressive therapy.

⁹⁹ See [Antibacterial Agents \(FEV-A\)](#) for dosing, spectrum, and specific comments/cautions.

^{hh} Risk of pneumocystis pneumonia (PCP) is related to the daily dose and duration of corticosteroid therapy. Prophylaxis against PCP can be considered in patients receiving the prednisone equivalent of 20 mg or more daily for 4 or more weeks.

ⁱⁱ PCP prophylaxis should be used when temozolomide is administered concomitantly with radiation therapy and should be continued until recovery from lymphocytopenia.

^{jj} TMP/SMX has additional benefit of activity against other pathogens including nocardia, toxoplasma, and listeria.

^{kk} The list of agents is alphabetical and does not reflect preference. Consider TMP/SMX desensitization or atovaquone, dapsone, or pentamidine (aerosolized or IV) when PCP prophylaxis is required in patients who are TMP/SMX intolerant. For patients receiving dapsone, assessing G6PD levels prior to initiating therapy is recommended.

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GENERAL RECOMMENDATIONS FOR VACCINATION IN PATIENTS WITH CANCER^{ll,mm}

- **General comments:**

- ▶ Live vaccines should NOT be administered during chemotherapy or periods of significant immunosuppression, such as treatment of GVHD.
- ▶ The safety of vaccines in patients receiving immunostimulatory drugs has not been established.
- ▶ All household members should be up-to-date with vaccines.

- **Influenza vaccination:** Patients with hematologic or solid tumor malignancies should receive inactivated influenza vaccine annually.

- **Pneumococcal vaccination:** The conjugate pneumococcal vaccine (PCV13) should be administered to newly diagnosed adults with cancer who are pneumococcal vaccine-naïve, followed by the polysaccharide pneumococcal vaccine (PPSV23) at least 8 weeks later. Subsequent doses of PPSV23 should follow current PPSV23 recommendations for adults at high risk. For patients who have previously received PPSV23, the PCV13 dose should be given at least 1 year after the last PPSV23 dose. For those who require additional doses of PPSV23, the first such dose should be given no sooner than 8 weeks after the PCV13 dose.

- **Meningococcal vaccination:** The addition of serogroup B meningococcal vaccination has been recommended for patients at increased risk for meningococcal disease. These at-risk patients include those with persistent complement component deficiencies or taking eculizumab or patients with anatomic or functional asplenia. Depending on the vaccine, it is available in a 2-dose or 3-dose series.

- **Human papillomavirus (HPV) vaccination:** The recombinant 3-dose HPV vaccine should be offered to patients of both sexes up to 26 years of age.

- **Travel vaccines:** ID consult for travel vaccines is recommended.

^{ll} Vaccination should be deferred in patients who are unlikely to respond (eg, patients who received anti-B-cell antibodies within 6 months, induction and consolidation chemotherapy for acute leukemia).

^{mm} For prevention of infection in cancer survivors, including vaccination recommendations, [see the NCCN Guidelines for Survivorship](#).

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RECOMMENDED VACCINATION SCHEDULE AFTER AUTOLOGOUS OR ALLOGENEIC HCT

Inactivated Vaccinesⁿⁿ	Recommended Timing After HCT	Number of Doses
DTaP (Diphtheria/Tetanus/Acellular Pertussis)	6–12 mo	3
Haemophilus influenzae type b (Hib)	6–12 mo	3
Pneumococcal vaccination • Conjugated 13-valent vaccine • Upon completion of PCV13 series, then PPSV23	6–12 mo ≥12 mo	3 1
Hepatitis A^{oo} (Hep A)	6–12 mo	2
Hepatitis B^{oo} (Hep B)	6–12 mo	3
Meningococcal conjugate vaccine^{pp}	6–12 mo	1–2
Influenza (injectable)	4–6 mo	1, annually
Inactivated Polio vaccine	6–12 mo	3
Recombinant zoster vaccine^{qq}	May be considered after autologous HCT	2

[See Live Vaccines on INF-9](#)

ⁿⁿ Inactivated vaccines may be given as a combined vaccine. Vaccination may be postponed for patients receiving >20 mg of prednisone.

^{oo} Strongly consider if clinically indicated. May consider Hep A and B combined vaccine if immunization for both is needed.

^{pp} Meningococcal B vaccine should be considered for high-risk patients such as patients with asplenia or complement deficiency or patients receiving eculizumab.

^{qq} There are significant questions and limited data available about the efficacy of this vaccine in patients with HCT. Efficacy in allogeneic HCT, in the presence of GVHD, or ongoing immunosuppression have not been established. Some centers are considering its use, but the efficacy data based on [clinicaltrials.gov](#) identifier NCT01610414 for autologous HCT recipients is pending publication.

Note: All recommendations are category 2A unless otherwise indicated.

Clinical Trials: NCCN believes that the best management of any patient with cancer is in a clinical trial. Participation in clinical trials is especially encouraged.

RECOMMENDED VACCINATION SCHEDULE AFTER AUTOLOGOUS OR ALLOGENEIC HCT

Live Vaccines	Recommended Timing After HCT	Number of Doses
Measles/Mumps/Rubella (MMR)^{rr}	≥24 mo (if no GVHD or ongoing immunosuppression and patient is seronegative for measles, mumps, and/or rubella)	1–2
Varicella vaccine^{rr}	≥24 mo (if no GVHD or ongoing immunosuppression and patient is seronegative for varicella)	1
Zoster vaccine^{rr,ss} (category 3)	May be considered at ≥24 mo (if no GVHD or ongoing immunosuppression)	1

^{rr} MMR and varicella/zoster vaccines may be given together or 4 weeks apart.

^{ss} Because of insufficient data on safety and efficacy of zoster vaccine among HCT recipients, physicians should assess the immune status of each recipient on a case-by-case basis and determine the risk for infection before using the vaccine.

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CLINICAL PRESENTATION

INITIAL EVALUATION OF FEVER AND NEUTROPENIA

MICROBIOLOGIC EVALUATION

- Fever:**
- Single temperature equivalent to $\geq 38.3^{\circ}\text{C}$ orally
- or
- Equivalent to $\geq 38.0^{\circ}\text{C}$ orally over 1-h period
- Neutropenia:**
- < 500 neutrophils/mcL or
 - < 1000 neutrophils/mcL and a predicted decline to ≤ 500 /mcL over the next 48 h

- Complete H&P including supplemental history:
 - ▶ Major comorbid illness
 - ▶ Time since last chemotherapy
 - ▶ Recent antibiotic therapy/prophylaxis
 - ▶ Medications
 - ▶ Use of devices
- Epidemiologically relevant exposures (eg, marijuana use, cigarette smoking)
- Laboratory/radiology assessment:
 - ▶ CBC including differential, electrolytes, chemistry panel, and LFTs
 - ▶ Consider chest x-ray and urinalysis

- Blood culture x 2 sets (one set consists of 2 bottles). Options include:
 - ▶ One peripheral + one catheter (preferred)^a
 - or
 - ▶ Both peripheral
 - or
 - ▶ Both catheter (if unable to obtain a peripheral blood)
- Urine culture (if symptoms, urinary catheter, or abnormal urinalysis)
- Site-specific culture:
 - ▶ Diarrhea (*Clostridium difficile* assay, enteric pathogen screen)
 - ▶ Skin (aspirate/biopsy of skin lesions)
 - ▶ Vascular access cutaneous site with inflammation (consider routine/fungal/mycobacterial)
- Viral diagnostics:
 - ▶ PCR- and direct fluorescence antibody (DFA)-based tests
 - ▶ Vesicular/ulcerated lesions on skin or mucosa
 - ▶ Throat or nasopharynx for respiratory virus symptoms, especially during outbreaks

[See Initial Risk Assessment \(FEV-2\)](#)

^a Preferred for distinguishing catheter-related infections from secondary sources.

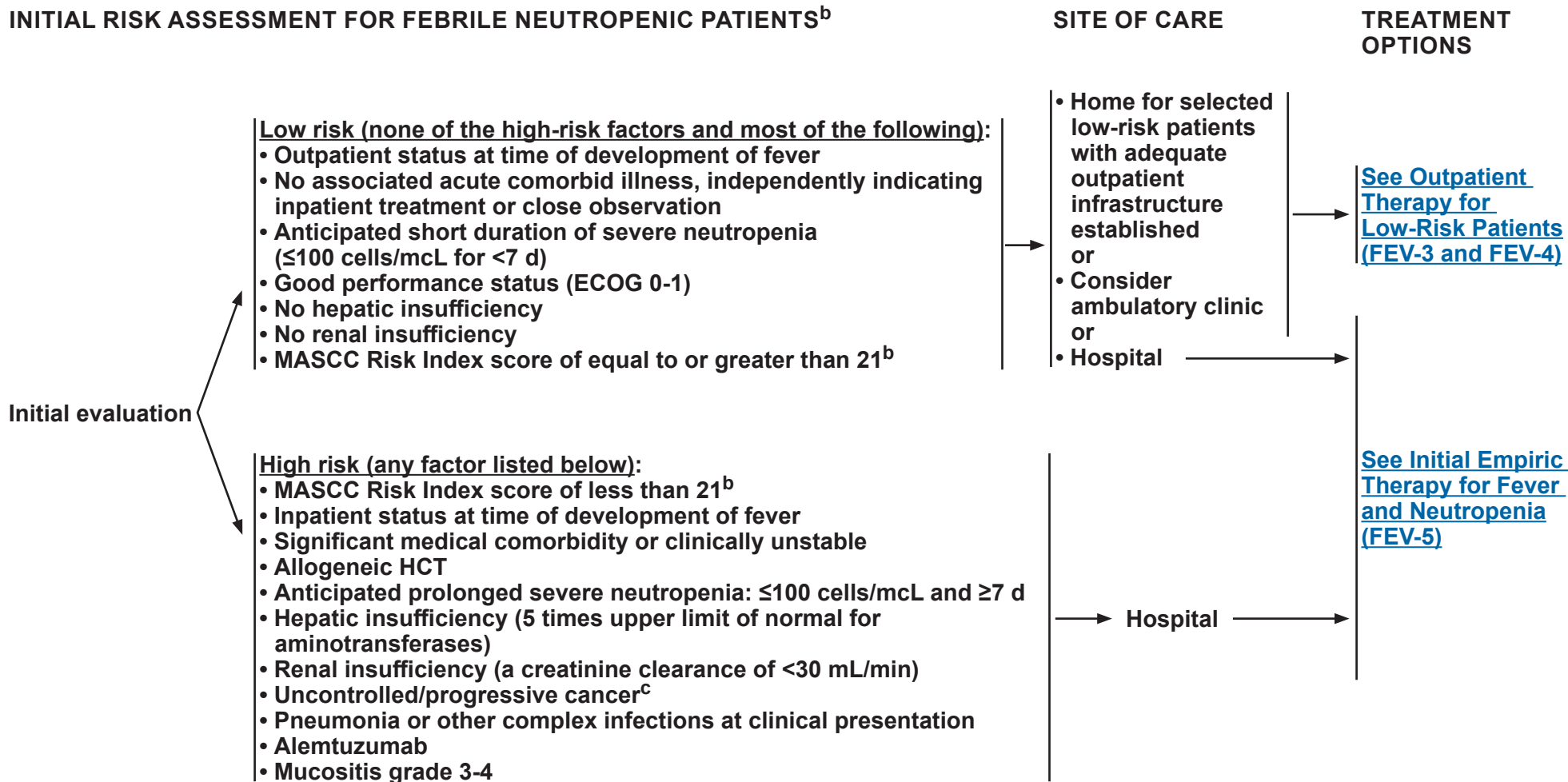
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Prevention and Treatment of Cancer-Related Infections

INITIAL RISK ASSESSMENT FOR FEBRILE NEUTROPENIC PATIENTS^b



^b Risk categorization refers to risk of serious complications, including mortality, in patients with neutropenic fever. Risk stratification is validated in adults; no generalizable, cross-validated, risk-stratified management exists for pediatric patients with febrile neutropenia. [See Risk Assessment Resources \(FEV-D\)](#).

^c Uncontrolled/progressive cancer is defined as any patients with leukemia not in complete remission, or patients without leukemia with evidence of disease progression after more than 2 courses of chemotherapy.

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OUTPATIENT THERAPY FOR LOW-RISK PATIENTS

INDICATION

Patient determined to be in low-risk category on presentation with fever and neutropenia^b

ASSESSMENT

- Careful examination
- Review lab results: no critical values
- Review social criteria for home therapy
 - ▶ Patient consents to home care
 - ▶ 24-h home caregiver available
 - ▶ Telephone
 - ▶ Access to emergency facilities
 - ▶ Adequate home environment
 - ▶ Distance within approximately one hour of a medical center or treating physician's office
- Assess for oral antibiotic therapy
 - ▶ No nausea and vomiting
 - ▶ Able to tolerate oral medications
 - ▶ Not on prior fluoroquinolone prophylaxis

MANAGEMENT

[See Treatment and Follow-up \(FEV-4\)](#)

OR

Consider observation period (2–12 h) (category 2B) in order to:

- Confirm low-risk status and ensure stability of patient
- Observe and administer first dose of antibiotics and monitor for reaction
- Organize discharge plans to home and follow-up
- Patient education
- Telephone follow-up within 12–24 h

^b Risk categorization refers to risk of serious complications, including mortality, in patients with neutropenic fever. Risk stratification is validated in adults; no generalizable, cross-validated, risk-stratified management exists for pediatric patients with febrile neutropenia. [See Risk Assessment Resources \(FEV-D\)](#).

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OUTPATIENT THERAPY FOR LOW-RISK PATIENTS

TREATMENT OPTIONS

- Intravenous (IV) antibiotics at home
- Daily long-acting IV agent ± oral therapy
 - ▶ Home or office
- Oral therapy only^d:
 - ▶ Ciprofloxacin^e plus amoxicillin/clavulanate^f (category 1)
 - ▶ Levofloxacin^e
 - ▶ Moxifloxacin^{e,9} (category 1)

FOLLOW-UP

- Patient should be monitored daily
- Daily assessment (clinic or home visit) for the first 72 h to assess response, toxicity, and compliance; if responding, then telephone follow-up daily thereafter.
- Specific reasons to return to clinic:
 - ▶ Any positive culture
 - ▶ New signs/symptoms reported by the patient
 - ▶ Persistent or recurrent fever at 3–5 d
 - ▶ Inability to continue prescribed antibiotic regimen (ie, oral intolerance)
 - ▶ Office visit for infusion of IV antibiotics

^dCriteria for oral antibiotics: no nausea or vomiting, patient able to tolerate oral medications, and patient not on prior fluoroquinolone prophylaxis.

^eThe fluoroquinolone chosen should be based on the use of quinolone prophylaxis of fever and neutropenia.

^f Use clindamycin in place of amoxicillin-clavulanate for penicillin-allergic patients.

⁹Insufficient activity against pseudomonas. Recommended for low-risk patients who may not require pseudomonas coverage.

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INITIAL EMPIRIC THERAPY FOR FEVER AND NEUTROPENIA^h

Initial antibiotic therapy should be based on:

- Infection risk assessment ([See FEV-2](#))
- Broad-spectrum coverage including antipseudomonal activity
- Potential infecting organisms, including multidrug-resistant organisms (MDROs)
- Colonization with or prior infection with methicillin-resistant *Staphylococcus aureus* (MRSA)
- Site of infection
- Local antibiotic susceptibility patterns
- Organ dysfunction/drug allergy
- Previous antibiotic therapy
- Bactericidal nature of the antibiotic

- IV antibiotic therapy^{i,j}**
- Typically monotherapy
 - ▶ Cefepime (category 1)
 - ▶ Imipenem/cilastatin (category 1)
 - ▶ Meropenem (category 1)
 - ▶ Piperacillin/tazobactam (category 1)
 - ▶ Ceftazidime^k (category 2B)
 - IV combination therapy could be considered, especially in circumstances where antimicrobial resistance is suspected

- Consider oral antibiotic therapy for select low-risk patients:
 - ▶ Ciprofloxacin + amoxicillin/clavulanate (category 1)^f
 - ▶ Moxifloxacin^{e,g} (category 1)
 - ▶ Levofloxacin^e
- Oral antibiotic regimen not recommended if patient received prior quinolone prophylaxis

Site-Specific Evaluation and Therapy:
Mouth, Esophagus and Sinus/Nasal ([FEV-6](#))

Abdominal Pain, Perirectal Pain, Diarrhea, Urinary Tract Symptoms ([FEV-7](#))

Lung Infiltrates ([FEV-8](#))

Cellulitis, Vascular Access Devices, Vesicular Lesions, Disseminated Papules or Other Lesions, Central Nervous System Symptoms ([FEV-9](#))

OR
Follow-up ([FEV-10](#))

^e The fluoroquinolone chosen should be based on the use of quinolone prophylaxis of fever and neutropenia.

^f Use clindamycin in place of amoxicillin-clavulanate for penicillin-allergic patients.

^g Insufficient activity against pseudomonas. Recommended for low-risk patients who may not require pseudomonas coverage.

^h [See Antibacterial Agents \(FEV-A\)](#) for dosing, spectrum, and specific comments/cautions.

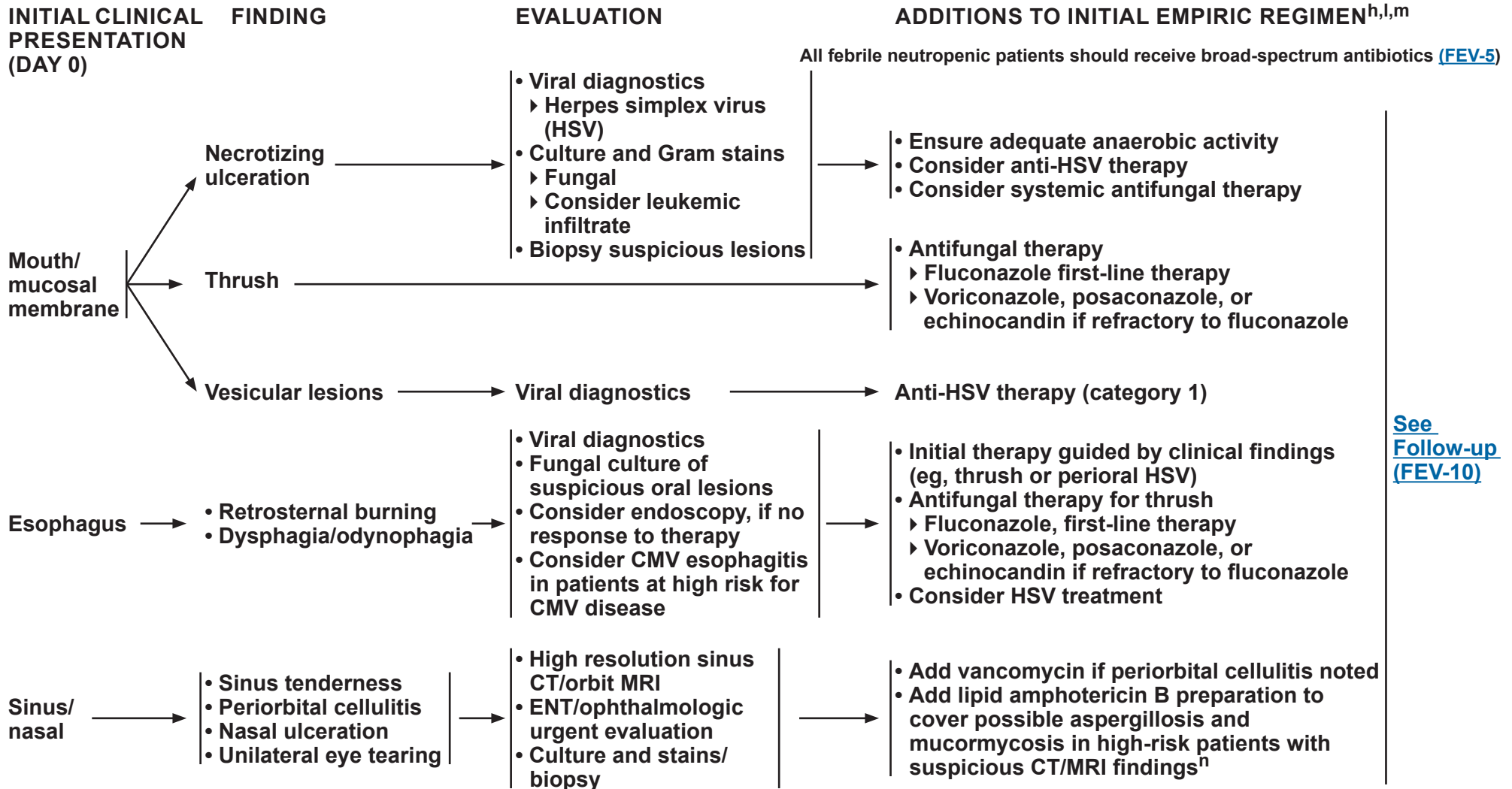
ⁱ Choice of antibiotic may depend on local antibiotic susceptibility patterns and individual patient syndromes.

^j In patients treated with escalated dosing, reassess after 48–72 hours and consider de-escalation.

^k Weak Gram-positive coverage and increased breakthrough infections limit utility.

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See
[Follow-up \(FEV-10\)](#)

^h See [Antibacterial Agents \(FEV-A\)](#) for dosing, spectrum, and specific comments/cautions.

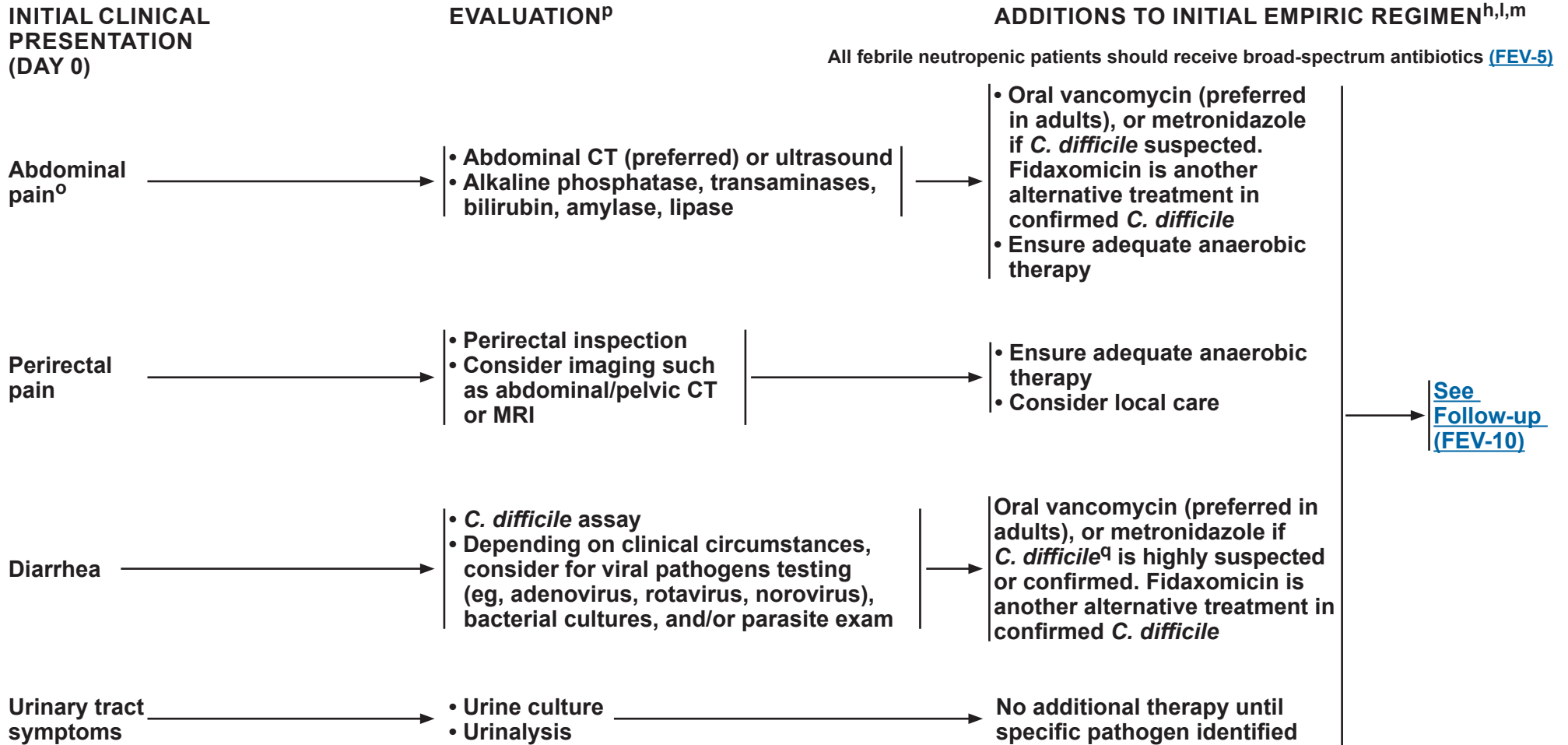
^l See [Antifungal Agents \(FEV-B\)](#) for dosing, spectrum, and specific comments/cautions.

^m See [Antiviral Agents \(FEV-C\)](#) for dosing, spectrum, and specific comments/cautions. The antivirals are not equal in terms of efficacy, side effects, and resistance.

ⁿ Posaconazole or isavuconazonium sulfate can be considered for patients who have invasive, refractory infections or who have intolerance to amphotericin B formulations. Posaconazole is not approved by the FDA as primary therapy or secondary therapy for refractory invasive fungal infections.

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^h See [Antibacterial Agents \(FEV-A\)](#) for dosing, spectrum, and specific comments/cautions.

^l See [Antifungal Agents \(FEV-B\)](#) for dosing, spectrum, and specific comments/cautions.

^m See [Antiviral Agents \(FEV-C\)](#) for dosing, spectrum, and specific comments/cautions. The antivirals are not equal in terms of efficacy, side effects, and resistance.

^o Surgical and other subspecialty (eg, gastroenterology, interventional radiology) consultations should be considered for these situations as clinically indicated.

^P Lab studies include CMV antigens/PCR and abdominal/pelvic CT.

^q See [Discussion section](#) for adjunctive treatments for difficult *C. difficile* cases.

Note: All recommendations are category 2A unless otherwise indicated.

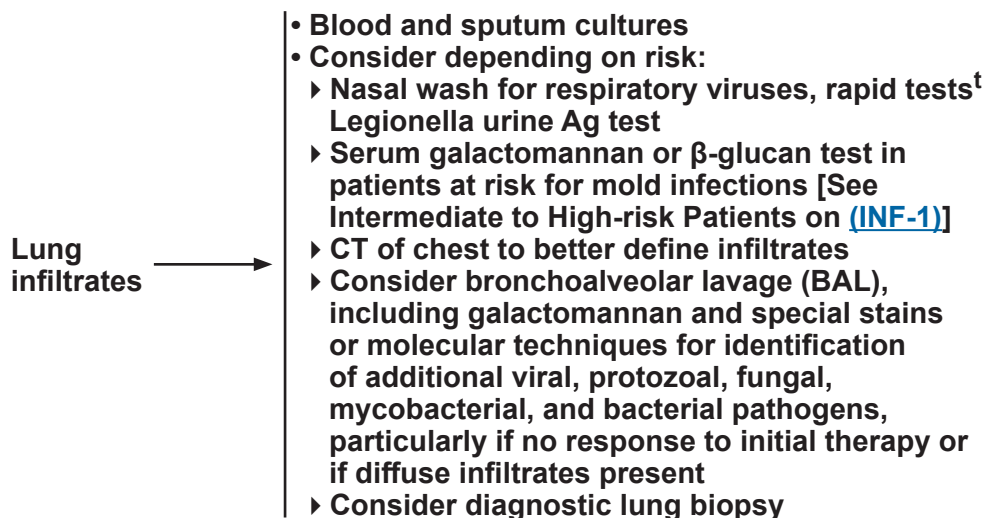
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NCCN Guidelines Version 1.2019

Prevention and Treatment of Cancer-Related Infections

INITIAL CLINICAL EVALUATION^{r,s} PRESENTATION (DAY 0)



ADDITIONS TO INITIAL EMPIRIC REGIMEN^{h,l,m}

All febrile neutropenic patients should receive broad-spectrum antibiotics ([FEV-5](#))

- Consider adding coverage for atypical bacteria (azithromycin, doxycycline, or fluoroquinolone)
- Consider adding:
 - Mold-active antifungal agent [See Intermediate to High-risk Patients on [\(INF-1\)](#)]
 - Antiviral therapy during peak influenza season in local area^u
 - TMP/SMX if possible *Pneumocystis jirovecii* etiology
 - Vancomycin or linezolid if MRSA suspected
- Re-evaluate for ability to de-escalate

→ [See Follow-up \(FEV-10\)](#)

^h See [Antibacterial Agents \(FEV-A\)](#) for dosing, spectrum, and specific comments/cautions.

^l See [Antifungal Agents \(FEV-B\)](#) for dosing, spectrum, and specific comments/cautions.

^m See [Antiviral Agents \(FEV-C\)](#) for dosing, spectrum, and specific comments/cautions. The antivirals are not equal in terms of efficacy, side effects, and resistance.

^r Other diagnoses to consider include pulmonary edema, hemorrhage, and drug toxicities.

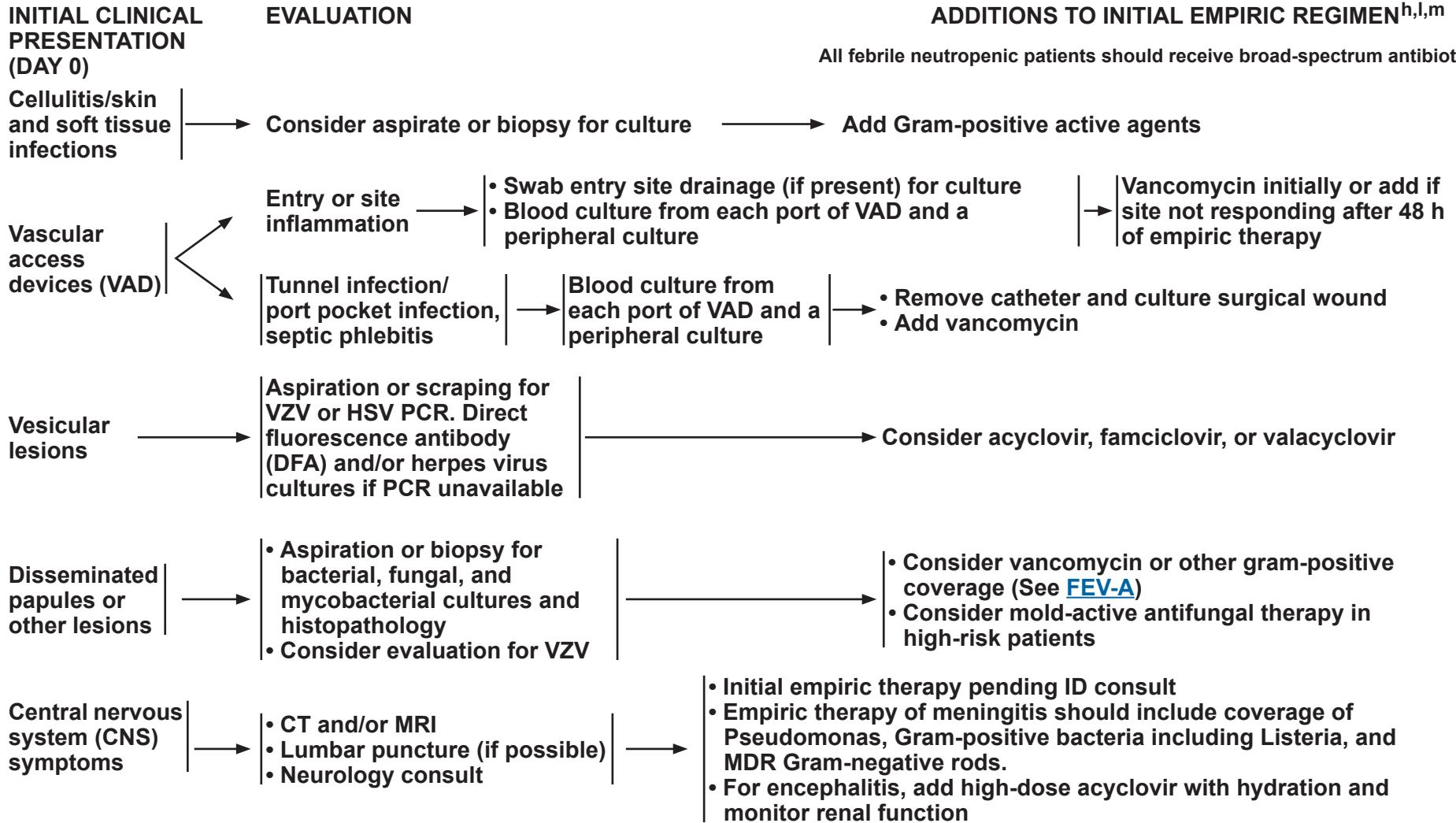
^s Assess for health care-acquired pneumonia and/or resistant pathogens.

^t Rapid immunofluorescent viral antigen tests may be negative for H1N1 (swine flu).

^u Antiviral susceptibility of influenza strains is variable and cannot be predicted based on prior influenza outbreaks. In cases of seasonal influenza and pandemic strains (eg, H1N1), it is necessary to be familiar with susceptibility patterns and guidelines on appropriate antiviral treatment.

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All febrile neutropenic patients should receive broad-spectrum antibiotics ([FEV-5](#))

See [Follow-up \(FEV-10\)](#)

^hSee [Antibacterial Agents \(FEV-A\)](#) for dosing, spectrum, and specific comments/cautions.

^lSee [Antifungal Agents \(FEV-B\)](#) for dosing, spectrum, and specific comments/cautions.

^mSee [Antiviral Agents \(FEV-C\)](#) for dosing, spectrum, and specific comments/cautions. The antivirals are not equal in terms of efficacy, side effects, and resistance.

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RESULTS OF DAILY MONITORING

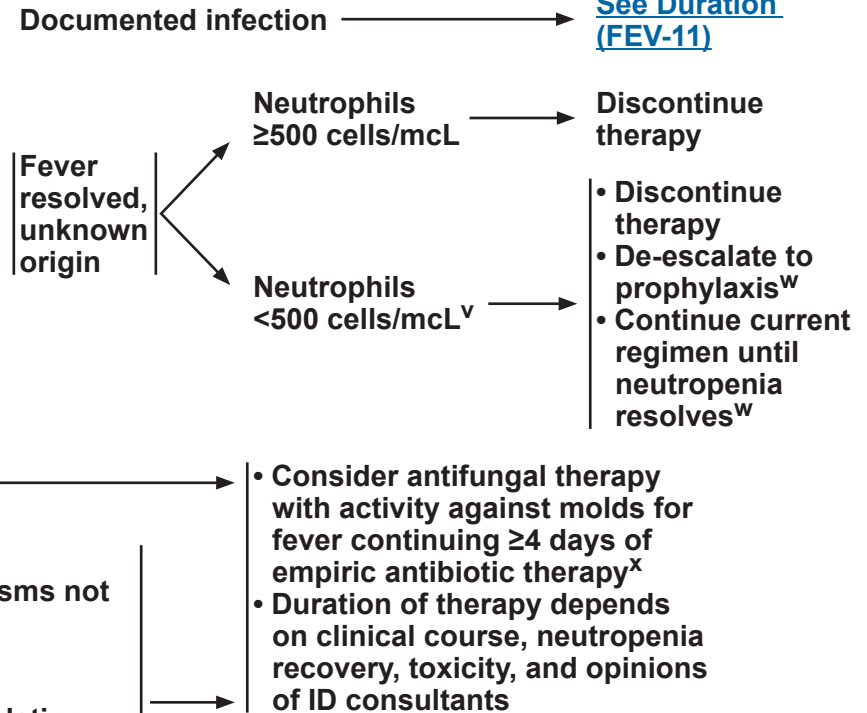
- Clinically stable or improving
 - Fever decreasing
-
- No change in initial empiric regimen
 - Modify regimen based only on new clinical or microbiologic data
 - Empiric regimen should be continued at least until absolute neutrophil count (ANC) is ≥ 500 cells/mcL and increasing

- Persistently febrile
 - Otherwise clinically stable
-

- Not responding/clinically worsening
 - Persistently febrile
 - Persistent bacteremia
-

- Broaden coverage based on clinical and microbiologic data to include other organisms not covered by initial empiric regimen
- Consider imaging studies and further microbiological testing
- Consider adding granulocyte colony-stimulating factor (G-CSF) or granulocyte-macrophage colony-stimulating factor (GM-CSF) (category 2B)
- ID consult

FOLLOW-UP THERAPY



^v In the case of prolonged neutropenia (>14 days), consider judicious assessment of empiric therapy.

^w In patients who defervesce, it may be appropriate in some cases to de-escalate to fluoroquinolone. The choice will depend on particular patient details; see [Discussion](#) for additional information.

^x The timing to add empiric antifungal therapy varies with the risk of invasive mold infection but generally ranges between 4–7 days of neutropenic fever. In patients at high risk for mold infection (ie, neutropenia >10 days, allogeneic HCT recipients, high-dose corticosteroids), the panel recommends adding empiric antifungal therapy after the fourth day unless patient is receiving prophylaxis directed against molds.

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FOLLOW-UP THERAPY FOR RESPONDING DISEASE

Documented infection →

- Targeted treatment of documented infections should be done
- Reassessment of empiric Gram-negative therapy should be considered
- De-escalation and duration of antimicrobial therapy may be individualized based on:
 - ▶ Neutrophil recovery
 - ▶ Rapidity of defervescence
 - ▶ Specific site of infection
 - ▶ Infecting pathogen
 - ▶ Patient's underlying illness

SUGGESTED MINIMUM DURATION OF THERAPY FOR DOCUMENTED INFECTION^{h,l,m}

These are general guidelines and may need to be revised for individual patients.

- Skin/soft tissue: 7–14 d
- Bloodstream infection
 - ▶ Gram-negative: 10–14 d^y
 - ▶ Gram-positive: 7–14 d^y
 - ▶ *S. aureus*: typically requires 4 weeks after first negative blood culture; treatment may need to be prolonged in cases of endovascular involvement; encourage ID consult
 - ▶ Yeast: ≥2 wks after first negative blood culture
 - ▶ Catheter removal favored for bloodstream infections with *Candida*, *S. aureus*, *Pseudomonas aeruginosa*, *Corynebacterium jeikeium*, *Acinetobacter*, *Bacillus* organisms, atypical mycobacteria, yeasts, molds, vancomycin-resistant enterococci (VRE), *Stenotrophomonas maltophilia*, and other multidrug-resistant organisms (MDROs)
- Bacterial sinusitis: 7–14 d
- Catheter removal for septic phlebitis, tunnel infection, or port pocket infection
- Bacterial pneumonia: 7–14 d
- Fungal (mold and yeast):
 - ▶ *Candida*: minimum of 2 wks after first negative blood culture
 - ▶ Mold (eg, *Aspergillus*): minimum of 12 wks
- Viral:
 - ▶ HSV/VZV: 7–10 d (category 1); acyclovir, valacyclovir, or famciclovir (uncomplicated, localized disease to the skin)
 - ▶ Influenza: A minimum 5 d course of oseltamivir is standard based on data from ambulatory and otherwise healthy individuals with intact immune systems; some centers consider longer courses for the highly immunocompromised,^z but there is no proven benefit to prolonged therapy

^h See [Antibacterial Agents \(FEV-A\)](#) for dosing, spectrum, and specific comments/cautions.

^l See [Antifungal Agents \(FEV-B\)](#) for dosing, spectrum, and specific comments/cautions.

^m See [Antiviral Agents \(FEV-C\)](#) for dosing, spectrum, and specific comments/cautions. The antivirals are not equal in terms of efficacy, side effects, and resistance.

^y Longer courses may be necessary for more complicated infections.

^z Some centers use a higher dose (eg, 150 mg).

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ANTIBACTERIAL AGENTS: GRAM-POSITIVE ACTIVITY

Gram-Positive Agents^a	Dose^b	Spectrum^d	Comments/Precautions
Vancomycin	15 mg/kg IV every 12 h	Gram-positive organisms, with exception of VRE and a number of rare Gram-positive organisms	IV formulation <ul style="list-style-type: none"> • Should not be considered as routine therapy for neutropenia and fever unless certain risk factors are present (See FEV-D) • Dosing individualized with monitoring of levels • Loading dose^b may be considered
Daptomycin	6 mg/kg/d IV^c with higher doses indicated for specific infections	<ul style="list-style-type: none"> • Gram-positive organisms • Has in vitro activity against VRE but is not FDA-approved for this indication 	<ul style="list-style-type: none"> • Weekly creatine phosphokinase (CPK) to monitor for rhabdomyolysis • Not indicated for pneumonia due to inactivation by pulmonary surfactant • ID consult strongly recommended
Linezolid	600 mg PO/IV every 12 h	Gram-positive organisms, including VRE	<ul style="list-style-type: none"> • Hematologic toxicity (typically with prolonged cases, >2 wks) may occur; thrombocytopenia most common (0.3%–10%) • Serotonin syndrome is rare; use cautiously with selective serotonin reuptake inhibitors (SSRIs)¹ • Treatment option for VRE and MRSA • Peripheral/optic neuropathy with long-term use

^a These drugs are not recommended as monotherapy for fever in the setting of neutropenia and should only be added if high suspicion of infection with resistant Gram-positive organisms or if certain risk factors are present. ([See FEV-D](#))

^b These are standard dosing recommendations for adult patients; there are other situations where dose adjustments are required. Consult pediatric guidelines for recommended dosing in pediatric patients. Adjustments should also be made for renal insufficiency and obese patients according to institutional guidelines.

^c Higher doses are recommended for bloodstream infections. ID consult is strongly recommended.

^d Once culture data are available, directed therapy may be initiated following an ID consult as appropriate for Gram-positive pathogens.

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[Continued](#)
[References](#)

FEV-A
1 OF 4

ANTIBACTERIAL AGENTS: ANTI-PSEUDOMONAL^e

Anti-Pseudomonal Agents	Dose ^b	Spectrum ^f	Comments/Precautions
Cefepime	2 g IV every 8 h	<ul style="list-style-type: none"> Broad-spectrum activity against most Gram-positive and Gram-negative organisms Not active against most anaerobes and <i>Enterococcus spp</i> 	<ul style="list-style-type: none"> Use for suspected/proven CNS infection with susceptible organism Empiric therapy for neutropenic fever (category 1) Mental status changes may occur, especially in the setting of renal dysfunction
Ceftazidime	2 g IV every 8 h	<ul style="list-style-type: none"> Poor Gram-positive activity <ul style="list-style-type: none"> Breakthrough streptococcal infections reported Not active against most anaerobes and <i>Enterococcus spp</i>. 	<ul style="list-style-type: none"> Use for suspected/proven CNS infection with susceptible organism Empiric therapy for neutropenic fever (category 2B; due to resistance among certain Gram-negative rods)
Imipenem/cilastatin sodium	500 mg IV every 6 h	<ul style="list-style-type: none"> Broad-spectrum activity against most Gram-positive, Gram-negative, and anaerobic organisms Preferred against extended-spectrum beta-lactamase (ESBL) and serious Enterobacter infections Carbapenem-resistant Gram-negative rod infections are an increasing problem at a number of centers 	<ul style="list-style-type: none"> Use for suspected intra-abdominal source Meropenem is preferred over imipenem for suspected/proven CNS infection Carbapenems may lower seizure threshold in patients with CNS malignancies or infection or with renal insufficiency Empiric therapy for neutropenic fever (category 1) Data are limited, but it is expected that doripenem, like meropenem, would be efficacious
Meropenem	1–2 g IV every 8 h		
Piperacillin/tazobactam	4.5 g IV every 6 h Some institutions use extended infusion: 3.375 g every 8 h	<ul style="list-style-type: none"> Broad-spectrum activity against most Gram-positive, Gram-negative, and anaerobic organisms 	<ul style="list-style-type: none"> Use for suspected intra-abdominal source Not recommended for meningitis Empiric therapy for neutropenic fever (category 1)

^b These are standard dosing recommendations for adult patients; there are other situations where dose adjustments are required. Consult pediatric guidelines for recommended dosing in pediatric patients. Adjustments should also be made for renal insufficiency and obese patients according to institutional guidelines.

^e Emerging data may support extended or continuous infusion of beta-lactam therapies. For highly resistant infections, see [Discussion](#) for recommendations regarding alternative antibiotics with restricted availability.

^f None of these agents are active against MRSA or VRE.

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[Continued](#)



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Prevention and Treatment of Cancer-Related Infections

ANTIBACTERIAL AGENTS: OTHER

Other Antibacterial Agents	Dose ^b	Spectrum	Comments/Cautions
Aminoglycosides • Amikacin • Gentamicin • Tobramycin	Consider extended interval dosing ^c	Activity primarily against Gram-negative organisms	Sometimes used as part of combination therapy in seriously ill or hemodynamically unstable patients
Ciprofloxacin ^g in combination with Amoxicillin/clavulanate	500–750 mg PO every 12 hours or 400 mg IV every 8–12 h 875 mg PO every 12 h ^h	<ul style="list-style-type: none"> Ciprofloxacin has good activity against Gram-negative and atypical organisms (eg, <i>Legionella</i> spp.) but less activity than “respiratory” fluoroquinolones against Gram-positive organisms Ciprofloxacin alone has no activity against anaerobes Addition of amoxicillin/clavulanate is effective with aerobic Gram-positive organisms and anaerobes 	<ul style="list-style-type: none"> Oral antibiotic combination therapy in low-risk patients Avoid for empiric therapy if patient recently treated with fluoroquinolone prophylaxis Increasing Gram-negative resistance in many centers Data support fluoroquinolones for prophylaxis; however, in other clinical scenarios the risk:benefit analysis should be evaluated. Fluoroquinolone side effects should be taken into consideration (see the FDA warnings)
Levofloxacin	500–750 mg oral or IV daily	<ul style="list-style-type: none"> Good activity against Gram-negative and atypical organisms (eg, <i>Legionella</i> spp.) Improved Gram-positive activity compared to ciprofloxacin Levofloxacin has no activity against anaerobes Moxifloxacin has insufficient activity against <i>Pseudomonas</i> 	<ul style="list-style-type: none"> Prophylaxis may increase bacterial resistance and superinfection² Limited studies as empiric therapy in patients with fever and neutropenia Prophylaxis in neutropenic patients^{3,4} Data support fluoroquinolones for prophylaxis; however, in other clinical scenarios the risk:benefit analysis should be evaluated. Fluoroquinolone side effects should be taken into consideration (see the FDA warnings)
Moxifloxacin	400 mg oral or IV daily		
Metronidazole	500 mg infused or oral every 6–8 h	Good activity against anaerobic organisms	
Trimethoprim/sulfamethoxazole (TMP/SMX)	Prophylaxis (PJP): Single or double strength daily or double strength 3 times per wk Therapy: 15 mg/kg daily in divided doses every 6–8 h based on the trimethoprim component	Activity against <i>P jirovecii</i> and other relevant pathogens, including <i>Toxoplasma gondii</i> and <i>Nocardia</i>	<ul style="list-style-type: none"> Highly effective as prophylaxis against <i>P. jirovecii</i> in high-risk patients (See INF-6) Monitor for renal insufficiency, myelosuppression, hepatotoxicity, and hyperkalemia

^b These are standard dosing recommendations for adult patients; there are other situations where dose adjustments are required. Consult pediatric guidelines for recommended dosing in pediatric patients. Adjustments should also be made for renal insufficiency and obese patients according to institutional guidelines.

^g Consider adding a second agent in cases of severe infection based on local susceptibility pattern.

^h Although study data list 500 mg every 8 h, common practice uses amoxicillin/clavulanate 875 mg every 12 h.

Note: All recommendations are category 2A unless otherwise indicated.

Clinical Trials: NCCN believes that the best management of any patient with cancer is in a clinical trial. Participation in clinical trials is especially encouraged.

References

ANTIBACTERIAL AGENTS – REFERENCES

- ¹ Boyer EW, Shannon M. The serotonin syndrome. N Engl J Med 2005;352:1112-1120.
- ² Baden LR. Prophylactic antimicrobial agents and the importance of fitness. N Engl J Med 2005;353:1052-1054.
- ³ Bucaneve G, Micozzi A, Menichetti F, et. al. Levofloxacin to prevent bacterial infection in patients with cancer and neutropenia. N Engl J Med 2005;353:977-987.
- ⁴ Cullen M, Billingham SN, Gaunt C, et. al. Antibacterial prophylaxis after chemotherapy for solid tumors and lymphomas. N Engl J Med 2005;353:988-998.

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ANTIFUNGAL AGENTS: AZOLES

Azoles as a class have important drug interactions, especially with the newer therapeutic agents. Please carefully review. Drug-drug interactions are common and need to be closely monitored (consult package inserts for details).

Azoles ^a	Dose	Spectrum	Comments/Cautions
Fluconazole	In adults with normal renal function: 400 mg IV/PO daily	<ul style="list-style-type: none"> Active against <i>Candida</i> Active against coccidioidomycosis and <i>C. neoformans</i> 	<ul style="list-style-type: none"> <i>Candida glabrata</i> is associated with variable resistance in vitro, <i>Candida krusei</i> is intrinsically resistant, and <i>C. auris</i> may be resistant Inactive against molds (eg, <i>Aspergillus</i> sp., Zygomycetes)
Isavuconazonium sulfate	Loading dose 372 mg IV/PO every 8 h x 6 doses then maintenance dose 372 mg IV/PO daily	<ul style="list-style-type: none"> Active against invasive aspergillosis and mucormycosis in patients with cancer and in HCT recipients^{1,2,3} 	<ul style="list-style-type: none"> Can be considered in patients intolerant or refractory to first-line anti-mold therapy May shorten QTc interval
Itraconazole ^b	400 mg PO daily; Loading dose 200 mg PO TID x 3 days, then maintenance dose 200 mg PO BID	<ul style="list-style-type: none"> Active against <i>Candida</i>, <i>Aspergillus</i> sp., and some of the rarer molds Active against dimorphic fungi and <i>C. neoformans</i> 	<ul style="list-style-type: none"> Itraconazole has negative inotropic properties and is contraindicated in patients with significant cardiac systolic dysfunction H2 blockers and proton pump inhibitors (PPIs) may inhibit absorption of capsule formulation

^a Azoles inhibit fungal cell membrane synthesis and inhibit cytochrome P450 isoenzymes that may lead to impaired clearance of other drugs metabolized by this pathway. Fluconazole is a less potent inhibitor of cytochrome P450 isoenzymes than the mold-active azoles. QT prolongation and interactions have been reported.

^b Therapeutic drug monitoring (TDM) is an ongoing area of research; TDM should be considered in consultation with ID specialists. ([See Discussion](#)).

Note: All recommendations are category 2A unless otherwise indicated.

Clinical Trials: NCCN believes that the best management of any patient with cancer is in a clinical trial. Participation in clinical trials is especially encouraged.

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ANTIFUNGAL AGENTS: AZOLES

Azoles as a class have important drug interactions, especially with the newer therapeutic agents. Please carefully review. Drug-drug interactions are common and need to be closely monitored (consult package inserts for details).

Azoles ^a	Dose	Spectrum	Comments/Cautions
Posaconazole ^b	<ul style="list-style-type: none"> • Prophylaxis: <ul style="list-style-type: none"> ▶ Loading dose 300 mg PO tablet BID on day 1 and then maintenance dose 300 mg PO daily ▶ Loading dose 300 mg IV every 12 h on Day 1 and then maintenance dose 300 mg IV daily 	<ul style="list-style-type: none"> • Effective as prophylaxis in neutropenic patients with myelodysplastic syndrome and acute myeloid leukemia,⁷ and in HCT recipients with significant GVHD⁸ • Active against <i>Candida</i>, <i>Aspergillus</i> sp., some <i>Zygomycetes</i> sp., and some of the rarer molds • Active against dimorphic fungi and <i>C. neoformans</i> 	<ul style="list-style-type: none"> • Evaluated as treatment of refractory infection (but not FDA-approved) in several invasive fungal diseases • Liquid formulation has different dosing than tablet and should be administered with a full meal or liquid nutritional supplement or an acidic carbonated beverage. Tablet is better absorbed, though it should be taken with food. • Alternative antifungal therapy should be considered for patients who cannot eat a full meal or tolerate an oral nutritional supplement • PPIs decrease posaconazole plasma concentration with oral solution
Voriconazole ^b	<ul style="list-style-type: none"> • Treatment of invasive aspergillosis⁴ <ul style="list-style-type: none"> ▶ Loading dose: 6 mg/kg IV or 400 mg PO q12h x 2 doses on Day 1 ▶ Maintenance: 4 mg/kg IV q12h OR the following oral maintenance dosing <ul style="list-style-type: none"> ◇ ≥ 40 kg: 200 mg PO q12h ◇ < 40 kg: 100 mg PO q12h • Treatment of candidemia in non-neutropenic patients⁵ <ul style="list-style-type: none"> ▶ Loading dose: 6 mg/kg IV or 400 mg PO q12h x 2 doses on Day 1 ▶ Maintenance: 3–4 mg/kg IV q12h OR the following oral maintenance dosing <ul style="list-style-type: none"> ◇ ≥ 40 kg: 200 mg PO q12h ◇ < 40 kg: 100 mg PO q12h 	<ul style="list-style-type: none"> • Active against <i>Candida</i>, <i>Aspergillus</i> sp., and some of the rarer molds • Active against dimorphic fungi and <i>C. neoformans</i> • Standard of care as primary therapy for invasive aspergillosis (category 1)^{4,6} • Effective in candidemia in non-neutropenic patients⁵ 	<ul style="list-style-type: none"> • Poor activity against <i>Zygomycetes</i> • Long-term complications resulting from metabolic irregularities may include increased risk for squamous cell carcinoma and hyperphosphatemia • Fluorosis may occur with prolonged use and is associated with bone/muscle pain • Evidence for combination therapy remains limited⁹ • IV formulation should be used with caution in patients with significant renal dysfunction • Visual disturbances and hallucinations may occur on therapy

^a Azoles inhibit fungal cell membrane synthesis and inhibit cytochrome P450 isoenzymes that may lead to impaired clearance of other drugs metabolized by this pathway. Fluconazole is a less potent inhibitor of cytochrome P450 isoenzymes than the mold-active azoles. QT prolongation and interactions have been reported.

^b Therapeutic drug monitoring (TDM) is an ongoing area of research; TDM should be considered in consultation with ID specialists. ([See Discussion](#)).

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Prevention and Treatment of Cancer-Related Infections

ANTIFUNGAL AGENTS: EMPIRIC AMPHOTERICIN B FORMULATIONS^c

Aphotericin B Formulations^d	Dose	Spectrum	Comments/Cautions^f
Amphotericin B deoxycholate (AmB-D)	Varies by indication, generally 0.5–1.5 mg/kg IV daily	Broad spectrum of antifungal activity including <i>Candida Aspergillus</i> sp. (excluding <i>Aspergillus terreus</i>), Zygomycetes, rarer molds, <i>C. neoformans</i>, and dimorphic fungi	<ul style="list-style-type: none"> • Substantial infusional and renal toxicity including electrolyte wasting • Saline loading may reduce nephrotoxicity • Infusional toxicity may be managed with anti-pyretics, an anti-histamine, and meperidine (for rigors)
Amphotericin B lipid complex (ABLC)	5 mg/kg/IV daily for invasive mold infections		Reduced infusional and renal toxicity compared to AmB-D
Liposomal amphotericin B (L-AMB)	3–5 mg/kg IV daily^{10,e}		Reduced infusional and renal toxicity compared to AmB-D

^c Can be considered for prophylaxis with ID consult for appropriate dosing recommendations.

^d Broad spectrum of antifungal activity. Significant infusional and renal toxicity, though less so with lipid formulations.

^e The vast majority of subjects in this trial had invasive aspergillosis; optimal dosing of L-AMB for other mold infections (such as mucormycosis with 5 mg/kg/d IV) was as effective but less toxic than 10 mg/kg/d as initial therapy for invasive mold infections.

^f Slowing the rate of infusion is an additional way to manage amphotericin infusion reactions.

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Prevention and Treatment of Cancer-Related Infections

ANTIFUNGAL AGENTS: ECHINOCANDINS

<u>Echinocandins</u> ^{9,9}	<u>Dose</u>	<u>Spectrum</u>	<u>Comments/Cautions</u>
Anidulafungin	200 mg IV x 1 dose, then 100 mg/IV daily	<ul style="list-style-type: none"> • Primary therapy for candidemia and invasive candidiasis (category 1)¹¹ • <i>C. auris</i> may be resistant to echinocandins • May be used as part of a second-line or subsequent regimen for invasive aspergillosis • Not reliable or effective against other fungal pathogens 	<ul style="list-style-type: none"> • Echinocandins have poor CNS penetration • Excellent safety profile
Caspofungin	<ul style="list-style-type: none"> • 70 mg IV x 1 dose, then 50 mg IV daily (35 mg IV daily for patients with moderate liver disease) • Some investigators use 70 mg IV daily as therapy for aspergillosis in second-line therapy 		
Micafungin	<ul style="list-style-type: none"> • 100 mg IV daily for candidemia and 50–100 mg/d IV as prophylaxis • 150 mg IV daily used at some centers for <i>Aspergillus</i> sp. infection in second-line therapy 		

⁹A number of centers use combination voriconazole and an echinocandin for invasive aspergillosis based on clinical data. Evidence for combination therapy remains limited.

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[References](#)



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ANTIFUNGAL AGENTS – REFERENCES

- ¹Maertens JA, Raad II, Marr KA, et al. Isavuconazole versus voriconazole for primary treatment of invasive mold disease caused by aspergillus and other filamentous fungi (SECURE): a phase 3, randomized-controlled, non-inferiority trial. *Lancet* 2016;387:760-9.
- ²Marty FM, Ostrosky-Zeichner L, Cornely OA, et al. Isavuconazole treatment for mucormycosis: a single-arm open-label trial and case-control analysis. *Lancet Infect Dis* 2016;16(7):828-837.
- ³Patterson TF, Thompson GR, 3rd, Denning DW, et al. Practice Guidelines for the Diagnosis and Management of Aspergillosis: 2016 Update by the Infectious Diseases Society of America. *Clin Infect Dis* 2016;63(4):e1-e60.
- ⁴Herbrecht R, Denning DW, Patterson TF, et al. Voriconazole versus amphotericin B for primary therapy of invasive aspergillosis. *N Engl J Med* 2002;347:408-15.
- ⁵Kullberg BJ, Sobel JD, Ruhnke M, et al. Voriconazole versus a regimen of amphotericin B followed by fluconazole for candidaemia in non neutropenic patients: a randomised non-inferiority trial. *Lancet* 2005;366:1435-42.
- ⁶Walsh TJ et al. Treatment of Aspergillosis: Clinical Practice Guidelines of the Infectious Diseases Society of America. *Clin Infect Dis* 2008;46:327-360.
- ⁷Cornely OA, Maertens J, Winston DJ, et al. Posaconazole vs. fluconazole or itraconazole prophylaxis in patients with neutropenia. *N Engl J Med* 2007;356:348-59.
- ⁸Ullmann AJ, Lipton JH, Vesole DH, et al. Posaconazole or fluconazole for prophylaxis in severe graft-versus-host disease. *N Engl J Med* 2007;356:335-47.
- ⁹Marr KA, Schlamm HT, Herbrecht R, et al. Combination antifungal therapy for invasive aspergillosis: a randomized trial. *Ann Intern Med* 2015;162:81-89.
- ¹⁰Cornely O, Maertens J, Bresnik M, et al. Liposomal amphotericin B as initial therapy for invasive mold infection: a randomized trial comparing a high-loading dose regimen with standard dosing (AmBiload trial). *Clin Infect Dis* 2007;44:1289-97.
- ¹¹Mora-Duarte J, Betts R, Rotstein C, et al. Comparison of caspofungin and amphotericin B for invasive candidiasis. *N Engl J Med* 2002;347:2020-9.

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ANTIVIRAL AGENTS^a

Agent	Common Indication ^b	Spectrum	Comments/Cautions
Acyclovir	<ul style="list-style-type: none"> • Prophylaxis^c: HSV (400–800 mg PO BID); VZV in allogeneic HCT recipients (800 mg PO BID)¹ • Post-VZV exposure prophylaxis: 800 mg PO 5 times daily • Treatment: Significant mucocutaneous HSV (5 mg/kg IV every 8 h for 7–10 d); single dermatomal VZV (800 mg PO 5 times daily or 10 mg/kg IV every 8 h for 7–10 d); disseminated HSV or VZV including viral encephalitis (10 mg/kg IV every 8 h)³ 	HSV VZV	<ul style="list-style-type: none"> • Hydration to avoid crystal nephropathy with high dose • Dosing based on ideal body weight • CMV in allogeneic HCT recipients (800 mg PO QID)^{2,d} for patients unable to tolerate oral therapy, 250 mg/m² IV every 12 h
Famciclovir	<ul style="list-style-type: none"> • Prophylaxis: HSV or VZV (250 mg PO BID) • Treatment: HSV (250 mg PO TID) or VZV (500 mg PO TID)^{5,6} 	HSV VZV	No data for oncologic-related prophylaxis
Ganciclovir	<ul style="list-style-type: none"> • Preemptive therapy for CMV: 5 mg/kg every 12 h for 2 wks; if CMV remains detectable, further ID evaluation may be required • Treatment: CMV disease (5 mg/kg every 12 h for 2 wks followed by 5–6 mg/kg daily for at least an additional 2–4 wks and resolution of all symptoms). Consider adding intravenous immunoglobulin (IVIG) for CMV pneumonia. Formulations and dosages of IVIG vary in different series 	CMZ HSV VZV	<ul style="list-style-type: none"> • May cause bone marrow suppression • Clinical data are limited for HHV-6 and HHV-8
Valacyclovir	<ul style="list-style-type: none"> • Prophylaxis^c: HSV or VZV (500 mg PO BID or TID) • Treatment: HSV or VZV (valacyclovir 1 gm PO TID)³ 	HSV VZV	• CMV in allogeneic HCT recipients (2 gm PO QID) ^{d,4}
Valganciclovir	<ul style="list-style-type: none"> • Prophylaxis: CMV (900 mg daily)^e • Preemptive therapy for CMV: Induction with 900 mg PO BID for at least 2 wks and until negative test; consider additional 900 mg PO daily for at least 7 days after a negative test for maintenance 	CMZ HSV VZV	<ul style="list-style-type: none"> • May cause bone marrow suppression • Clinical data are limited for HHV-6 and HHV-8

^a Requires dose adjustment in patients with renal insufficiency.

^b Dosing is for adult patients. Consult pediatric guidelines for recommended dosing in these patients.

^c Antiviral prophylaxis should be targeted to specific high-risk patients ([see INF-3](#)). In non-transplant, high-risk patients, prophylaxis should be administered to patients seropositive for HSV or VZV (or with a history of chicken pox). In HCT recipients, prophylaxis is only indicated if either the donor or recipient is seropositive for the virus in question. The indicated doses for antiviral agents are for adults with normal renal function; consult package insert for dose modification in pediatric patients and in patients with renal impairment. Prophylactic antiviral doses may be higher than those routinely used in immunocompetent persons (eg, for recurrent cold sores). There is substantial variability in the prophylactic doses of acyclovir used in different clinical trials in patients with hematologic malignancies and in HCT recipients.

^d High-dose acyclovir and valacyclovir have been used as prophylaxis for CMV. Because these agents have weak activity against CMV, a strategy of CMV surveillance and preemptive therapy with ganciclovir, valganciclovir, or foscarnet is required among patients at high risk for CMV disease.

^e In general, the strategy of CMV surveillance testing by PCR followed by preemptive anti-CMV therapy for a positive result is favored over universal long-term prophylaxis in allogeneic HCT patients.

Note: All recommendations are category 2A unless otherwise indicated.

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ANTIVIRAL AGENTS^a

Agent	Common Indication ^b	Spectrum	Comments/Cautions
Cidofovir ^f	Treatment: Cidofovir 5 mg/kg IV every wk for 2 wks, followed by cidofovir 5 mg/kg every 2 wks with probenecid 2 gm PO 3 h before the dose, followed by 1 gm PO 2 h after the dose and 1 gm PO 8 h after the dose and IV hydration	CMV HZV VZV Adenovirus	<ul style="list-style-type: none"> Ocular toxicity, bone marrow toxicity Hydration and probenecid required to reduce nephrotoxicity Third-line for CMV
Foscarnet	Prophylaxis for CMV: 60 mg/kg IV every 8–12 h for 7 d, followed by 90–120 mg/kg IV daily until day 100 after HCT ^{e,7,8} Preemptive therapy for CMV: Induction for 2 wks, either 60 mg/kg IV every 8 h or 90 mg/kg IV every 12 h Therapy: Acyclovir-resistant HSV (40 mg/kg every 8 h for 7–10 days); CMV disease (90 mg/kg every 12 h for 2 wks followed by 120 mg/kg daily for at least an additional 2–4 wks and resolution of all symptoms). Add IVIG for CMV pneumonia.	HSV VZV CMV	<ul style="list-style-type: none"> Drug of choice for acyclovir-resistant HSV and VZV and ganciclovir-resistant CMV Nephrotoxic; monitor electrolytes Clinical data are limited for HHV-6 and HHV-8
Letermovir	Primary prophylaxis for CMV+ allogeneic HCT recipients: 480 mg PO daily or daily IV infusion over 1 hour through beginning between day 0 and 28 post-transplantation and continue for 100 days post-transplant. Reduce dose to 240 mg PO/IV daily if co-administered with cyclosporine.	CMV	<ul style="list-style-type: none"> Has not been studied as an agent for treatment Has multiple drug interactions; see package insert. Lacks activity against other herpes group virus (including HSV and VZV)
Oseltamivir ^g	Prophylaxis: 75 mg PO daily ^{h,9} Treatment: 75 mg BID	Influenza A & B	May cause nausea (improved when taken with food)
Zanamivir ^g	Prophylaxis: 2 oral inhalations (5 mg/inhalation) daily Treatment: 2 oral inhalations (5 mg/inhalation) BID	Influenza A & B	Duration influenced by nature of exposure (ongoing vs. time limited); may cause bronchospasm

^a Requires dose adjustment in patients with renal insufficiency.

^b Dosing is for adult patients. Consult pediatric guidelines for recommended dosing in these patients.

^e In general, the strategy of CMV surveillance testing by PCR followed by preemptive anti-CMV therapy for a positive result is favored over universal long-term prophylaxis in allogeneic HCT patients.

^f A dose of 1 mg/kg administered three times a week is common for less severe adenovirus infections.

^g Consider IV peramivir for patients who cannot have oral oseltamivir or inhaled zanamivir.

^h Prophylaxis among highly immunocompromised persons during community and nosocomial outbreaks of influenza A should be considered.

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ANTIVIRAL AGENTS

Agent	Common Indication ^b	Spectrum	Comments/Cautions
Intravenous immunoglobulin (IVIG)	<p>Doses of IVIG vary among different studies and different viral illnesses.</p> <p>Some data exist for use in the following:</p> <ul style="list-style-type: none"> Parvovirus B19¹⁰, 400–500 mg/kg IV daily for 5 days Adjunctive therapy for CMV and respiratory syncytial virus (RSV) pneumonitis, 400 mg/kg IV every other day for 3–5 doses 	RSV Parvovirus B19 CMV	<ul style="list-style-type: none"> Pathogen-specific immunoglobulin or monoclonal antibodies may be considered CMV-specific IVIG is not more efficacious than standard IVIG
Ribavirin (category 3)	<p>Consider for treatment of lower respiratory tract RSV disease^{i,11,12}:</p> <ul style="list-style-type: none"> 600–800 mg PO BID 6 gm administered by continuous inhalation via SPAG-2 nebulizer over 12–18 h daily or 2 g over 2 h TID 	RSV	<ul style="list-style-type: none"> Limit to patients undergoing stem cell transplant or with leukemia Experience in immunocompromised adults with RSV disease is limited, but should be considered given potential morbidity and mortality associated with RSV infection Ribavirin is teratogenic; precautions are required during administration (see package insert)
Entecavir	0.5 mg PO daily (nucleoside-treatment-naïve with compensated liver disease); or 1 mg PO daily (lamivudine-refractory or known lamivudine-resistant mutations or decompensated liver disease)	HBV	<ul style="list-style-type: none"> Entecavir and tenofovir monotherapy are generally preferred. Choice of agent is heavily influenced by the overall condition of the patient, renal insufficiency, and the type of chemotherapy planned. Combination therapy is not generally recommended unless viral load is significantly elevated. Potential for HBV resistance: <ul style="list-style-type: none"> ▶ Lamivudine: high (especially as monotherapy) ▶ Tenofovir: none reported to date ▶ Entecavir: low Dose adjustment recommended for renal impairment Lactic acidosis and severe hepatomegaly with steatosis reported with nucleoside analogues Tenofovir has potential for nephrotoxicity; monitor for renal function
Lamivudine	100 mg PO daily		
Tenofovir	<p>Tenofovir disoproxil fumarate (DF) 300 mg PO daily</p> <p>Tenofovir alafenamide (TAF) 25 mg PO daily</p>		

^b Dosing is for adult patients. Consult pediatric guidelines for recommended dosing in these patients.

ⁱ Inhaled ribavirin is only FDA approved for hospitalized infants and young children with severe lower respiratory tract RSV disease.

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References

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ANTIVIRAL AGENTS – REFERENCES

- ¹Boeckh M, Kim HW, Flowers MED, Meyers JD, and Bowden RA. Long-term acyclovir for prevention of varicella zoster virus disease after allogeneic hematopoietic cell transplantation -- a randomized double-blind placebo-controlled study. *Blood* 2006;107:1800-1805.
- ²Zaia JA. Prevention and management of CMV-related problems after hematopoietic stem cell transplantation. *Bone Marrow Transplant* 2002;29:633-638.
- ³Gilbert DN, Moellering RC, Sande MA. *The Sanford Guide to Antimicrobial Therapy* (37th ed.). Hyde Park, VT: Jeb E. Sanford Publishers. 2007.
- ⁴Ljungman P, de La Camara R, Milpied N, et al. Randomized study of valacyclovir as prophylaxis against cytomegalovirus reactivation in recipients of allogeneic bone marrow transplants. *Blood* 2002;99:3050-3056.
- ⁵Frechette G, Romanowski B. Efficacy and safety of famciclovir for the treatment of HSV infection in HIV+ patients. *Can J Infect Dis* 1997; 8(Suppl A):44A.
- ⁶Schacker T, Hu H, Koelle DM, et al. Famciclovir for the suppression of symptomatic and asymptomatic herpes simplex virus reactivation in HIV-infected persons: A double-blind, placebo-controlled trial. *Ann Intern Med* 1998;128:21-28.
- ⁷Tomblyn M, Chiller T, Einsele H, et al. Guidelines for preventing infectious complications among hematopoietic cell transplantation recipients: a global perspective. *Biol Blood Marrow Transplant* 2009;15:1143-1238.
- ⁸Reusser P, Einsele H, Lee J, et al. Randomized multicenter trial of foscarnet versus ganciclovir for preemptive therapy of cytomegalovirus infection after allogeneic stem cell transplantation. *Blood* 2002;99:1159-1164.
- ⁹Vu D, Peck AJ, Nichols WG, et al. Safety and tolerability of oseltamivir prophylaxis in hematopoietic stem cell transplant recipients: a retrospective case-control study. *Clin Infect Dis* 2007;45:187-193.
- ¹⁰Heegaard Ed, Brown KE. Human parvovirus B19. *Clin Microbial Rev* 2002;15:485-505.
- ¹¹Whimbey E, Champlin RE, Englund JA, et al. Combination therapy with aerosolized ribavirin and intravenous immunoglobulin for respiratory syncytial virus disease in adult bone marrow transplant recipients. *Bone Marrow Transplant* 1995;16:393-399.
- ¹²Marcelin JR, Wilson JW, Razonable RR. Oral ribavirin therapy for respiratory syncytial virus infections in moderately to severely immunocompromised patients. *Transpl Infect Dis* 2014;16:242-250.

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Prevention and Treatment of Cancer-Related Infections

Discussion

This discussion is being updated to correspond with the newly updated algorithm. Last updated 12/01/17

NCCN Categories of Evidence and Consensus

Category 1: Based upon high-level evidence, there is uniform NCCN consensus that the intervention is appropriate.

Category 2A: Based upon lower-level evidence, there is uniform NCCN consensus that the intervention is appropriate.

Category 2B: Based upon lower-level evidence, there is NCCN consensus that the intervention is appropriate.

Category 3: Based upon any level of evidence, there is major NCCN disagreement that the intervention is appropriate.

All recommendations are category 2A unless otherwise indicated.

Discussion
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progress

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Prevention and Treatment of Cancer-Related Infections

Overview

There is an increased risk of infection in patients with cancer that results in higher morbidity and mortality. In certain instances, the malignancy itself can predispose patients to severe or recurrent infections. Neutropenia has been recognized as a major risk factor for the development of infections in patients with cancer undergoing chemotherapy. Effective strategies to anticipate, prevent, and manage these infectious complications have led to improved outcomes.¹⁻⁴ Due to advances in antimicrobial therapy, it is less common for patients with acute leukemia or patients undergoing hematopoietic cell transplantation (HCT) to die from infections during the neutropenic period.

Although neutropenia remains a key risk factor for infections, other immunocompromised states pose at least equal risk. Allogeneic HCT recipients with neutrophil recovery who require intensive immunosuppressive therapy (IST) for graft-versus-host disease (GVHD) are an example of non-neutropenic patients at great risk for common bacterial, viral, and opportunistic infections.⁵⁻⁸ The spectrum of infectious diseases in allogeneic HCT recipients with GVHD is distinct from neutropenia. The NCCN Clinical Practice Guidelines in Oncology (NCCN Guidelines®) for Prevention and Treatment of Cancer-Related Infections discuss infections in neutropenic and immunocompromised non-neutropenic patients with cancer. In addition to corticosteroids and purine analogs, the increased use of monoclonal antibodies, proteasome inhibitors, and other emerging cancer therapeutics has generated an ever more complex assessment of the immunocompromised patient. The scope of these guidelines is to address infections that may be seen in all of these immunocompromised populations.

The NCCN Guidelines for the Prevention and Treatment of Cancer-Related Infections characterize the major pathogens to which patients with cancer are susceptible, with a focus on the prevention, diagnosis, and treatment of major common and opportunistic infections. The guidelines are largely divided into 4 sections comprising discussions on the following: 1) risk factors for infection (major host factors that predispose patients to infectious diseases); 2) prevention of infectious complications (including the use of antimicrobial prophylaxis and preemptive therapy); 3) management

of neutropenic fever; and 4) management of site-specific infections (eg, pneumonia, abdominal infections, catheter-associated infections). These guidelines provide a framework for prevention and treatment of infections that should be applied in conjunction with careful, individual patient evaluation and with an understanding of both the host factors that predispose patients to specific infectious diseases and antimicrobial susceptibility patterns. Additionally, the guidelines are based primarily on studies with adult patients and application of these recommendations to pediatric patients may differ. Consultation with an infectious disease expert is highly recommended.

Literature Search Criteria and Guidelines Update Methodology

Prior to the update of this version of the NCCN Guidelines for Prevention and Treatment of Cancer-Related Infections, an electronic search of the PubMed database was performed to obtain key literature published between August 29, 2016 and June 1, 2017, using the following search terms: cancer related infections OR cancer infections OR cancer induced infections OR prevention of cancer related infections OR cancer and virus OR cancer and bacterial OR cancer and fungal OR cancer and microbial OR cancer and hepatitis OR cancer and influenza OR cancer and candida OR cancer and aspergillus OR cancer and clostridium OR cancer and staphylococcus OR cancer and pseudomonas OR cancer and clostridium OR cancer and pneumocystis OR cancer and herpes OR cancer and varicella zoster OR cancer and HIV. The PubMed database was chosen as it remains the most widely used resource for medical literature and indexes only peer-reviewed biomedical literature.⁹

The search results were narrowed by selecting studies in humans published in English. Results were confined to the following article types: Clinical Trial, Guideline, Meta-Analysis, Randomized Controlled Trial, Systematic Reviews, Validation Studies, and Practice Guidelines.

The PubMed search resulted in 246 citations and their potential relevance was examined. The data from key PubMed articles as well as articles from additional sources deemed as relevant to these guidelines and discussed by the panel have been included in this version of the Discussion section

(eg, e-publications ahead of print, meeting abstracts). Recommendations for which high-level evidence is lacking are based on the panel's review of lower-level evidence and expert opinion.

The complete details of the Development and Update of the NCCN Guidelines are available on the NCCN [webpage](#).

Host Factors That Predispose Patients to Infectious Complications

Immunodeficiencies Associated with Primary Malignancy

Certain malignancies are inherently associated with immune deficits. Patients with hematologic malignancies (eg, chronic and acute leukemias, non-Hodgkin's lymphomas [NHL], myelodysplastic syndromes [MDS]) may be leukopenic due to infiltration of the marrow with malignant cells or due to a dysfunctional marrow. Patients with chronic lymphocytic leukemia (CLL) frequently have hypogammaglobulinemia leading to increased susceptibility to encapsulated bacteria, principally *Streptococcus pneumoniae*.¹⁰ Such patients may have recurrent sinopulmonary infections and septicemia. Patients with multiple myeloma are often functionally hypogammaglobulinemic; the total level of immunoglobulin production may be elevated, but the repertoire of antibody production is restricted. Savage et al¹¹ noted a biphasic pattern of infection among patients with multiple myeloma. Infections by *Streptococcus pneumoniae* and *Haemophilus influenzae* occurred early in the disease and in patients with disease that responds to chemotherapy, whereas infections by *Staphylococcus aureus* and gram-negative pathogens occurred more commonly in advanced disease and during neutropenia.

Patients with advanced or refractory malignancy have a greater risk of infectious complications than those on earlier lines of therapy. Refractory hematologic malignancies can be associated with marrow failure caused by the underlying disease or from the multiple lines of prior cytotoxic therapy or IST. Patients with CLL who receive multiple chemotherapeutic regimens are at a significantly increased risk for developing severe infections.¹² A retrospective study showed that nearly 90% of heavily pretreated patients (median number of prior regimens, 3; range, 1–8) with fludarabine-

refractory CLL experienced serious infectious complications requiring hospitalization.¹³ These infections resulted from bacterial, viral, fungal, and opportunistic pathogens, including *Pneumocystis jirovecii* (formerly called *Pneumocystis carinii*).¹³

Solid tumors may predispose patients to infection because of anatomic factors. Tumors that overgrow their blood supply become necrotic, thus forming a nidus for infection. Endobronchial tumors may cause recurrent postobstructive pneumonias. Abdominal tumors may obstruct the genitourinary or hepatobiliary tracts, predisposing patients to pyelonephritis and cholangitis, respectively. Direct invasion through the colonic mucosa is associated with local abscess formation and sepsis by enteric flora. Patients undergoing surgery for malignancies may be at high risk for infectious complications as a result of the type of surgery (eg, esophagectomy, hepatobiliary reconstruction), the extent of tumor burden, their preoperative performance status, and any previous surgery, chemotherapy, or radiation therapy. Patients with advanced malignancy are also commonly malnourished, which further increases the risk of infection.

Neutropenia

Factors that predispose the neutropenic patient to infection include the absence of granulocytes; the disruption of the integumentary, mucosal, and mucociliary barriers; and the inherent microbial flora shifts that accompany severe illness and antimicrobial usage. The signs and symptoms of infection are often absent or muted in the absence of neutrophils, but fever remains an early, although nonspecific, sign.² Approximately 50% to 60% of patients who become febrile have an established or occult infection.¹⁴ Roughly 10% to 20% of patients with neutrophil counts less than 100 cells/mL will develop a bloodstream infection.¹⁵ Primary sites of infection are the alimentary tract (ie, mouth, pharynx, esophagus, large and small bowel, rectum), sinuses, lungs, and skin.

Initial infections early in the course of fever and neutropenia are primarily bacterial, whereas antibiotic-resistant bacteria, yeast, other fungi, and viruses are common causes of subsequent infections.^{16,17} Coagulase-negative staphylococci, *S aureus*, viridans group streptococci, and enterococci are the major gram-positive pathogens. Coliforms



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(eg, *Escherichia coli*, *Klebsiella* species, *Enterobacter* species) and *Pseudomonas aeruginosa* are the most common gram-negative infections complicating neutropenia.¹⁶ Herpes simplex virus (HSV), respiratory syncytial virus (RSV), parainfluenza, and influenza A and B are occasionally initial pathogens.¹⁷ Infections due to *Candida* species may occur later in the course of neutropenia, particularly as a consequence of gastrointestinal (GI) mucositis. *Aspergillus* species and other filamentous fungi are important causes of morbidity and mortality in patients with severe and prolonged neutropenia.^{16,18} Deaths resulting from infections identified at the onset of fever during neutropenia remain uncommon, and most infection-associated deaths result from subsequent infections during the course of neutropenia.

A seminal study demonstrated that as the neutrophil count decreases below 500 cells/mcL (defined as *neutropenia*), the susceptibility to infection increases.¹⁹ The frequency and severity of infection are inversely proportional to the neutrophil count. The risks of severe infection and bloodstream infection are greatest when the neutrophil count is less than 100 cells/mcL. The rate of decline of the neutrophil count and the duration of neutropenia are also critical factors that measure bone marrow reserve and are highly correlated with the severity of infection and clinical outcome.

Disruption of Mucosal Barriers

The mucosal linings of the GI, sinopulmonary, and genitourinary tracts constitute the first line of host defense against a variety of pathogens. Mucosal immunity is impaired by chemotherapy and radiation therapy. When the physical protective barrier conferred by the epithelial lining is compromised, local flora may invade. Furthermore, neutropenia and loss of the epithelial cell anatomic barrier may predispose patients to typhlitis (neutropenic enterocolitis). Chemotherapy-related GI mucositis predisposes patients to blood stream infections by viridans group streptococci,²⁰⁻²³ gram-negative rods, and *Candida* species.^{24,25}

Splenectomy and Functional Asplenia

In the spleen, rapid antigen presentation occurs, which leads to the production of opsonizing antibodies by B cells. The removal of non-opsonized bacteria protects against encapsulated bacteria to which the patient is not yet immune. Splenic irradiation results in functional asplenia, which predisposes patients to pneumococcal sepsis. Functional asplenia is also a late complication of severe GVHD.²⁶ Thus, in allogeneic HCT recipients, fever in the late transplant period must be evaluated promptly (similar to patients with asplenia) because of the risk of overwhelming infection by encapsulated pathogens.

Overwhelming sepsis by encapsulated bacteria is also the principal risk factor for infection in asplenic patients. The most common pathogen is *Streptococcus pneumoniae*, but other pathogens include *H influenzae* and *Neisseria meningitidis*. The NCCN Guidelines provide recommendations for immunization with the pneumococcal polysaccharide and meningococcal vaccines (see *Vaccination*).

Corticosteroids and Other Immunosuppressive Agents

While many agents administered to patients with cancer can cause some degree of immunosuppression, certain agents (detailed in this section) are more likely to put patients at a risk for serious infection. When assessing a possible infection, it is important to note that many of the newer immunotherapies (eg, nivolumab, ipilimumab, pembrolizumab) can cause inflammation-related side effects that may be mistaken for infection.

Corticosteroids

High-dose corticosteroids (>20 mg prednisone daily) have profound effects on the distribution and function of neutrophils, monocytes, and lymphocytes. In patients with cancer, corticosteroids are seldom the only immunosuppressive agents administered, and it is therefore difficult to delineate the degree of impairment in host defense elicited by the corticosteroid regimen alone. The risk of infections is a function of the dose and duration of corticosteroids, coexisting immunodeficiencies (such as neutropenia and use of other immunosuppressive agents), and the status of the malignancy. Corticosteroids blunt fever and local signs of infection, such as peritonitis.

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Purine Analogue Therapies

Purine analogues (including fludarabine, clofarabine, nelarabine, and cladribine) are used to treat a variety of hematologic malignancies. These therapies are lymphocytotoxic, primarily affecting CD4+ lymphocytes. In previously treated patients with CLL, fludarabine treatment (especially in combination with other IST) was associated with infections such as listeriosis, mycobacterial infections, and opportunistic fungal and viral infections.²⁷ Additionally, fludarabine was associated with infections caused by *Pneumocystis jirovecii*, which is the causative agent of pneumocystis pneumonia (PCP), also known as pneumocystosis. When used alone, purine analogs are associated with an increased risk for infection; risk of infection is further escalated when purine analogs are combined with other immunosuppressive or cytotoxic agents.²⁸ The combination of fludarabine and corticosteroids is more immunosuppressive than either agent alone.²⁹ Fludarabine plus prednisone results in a uniform depression of CD4+ cells that may persist for several months after completion of therapy.³⁰ In one series, 14 of 264 patients (5%) with CLL developed either PCP or listeriosis, and 3 cases occurred more than 1 year after therapy in patients who were in remission.³⁰

Alemtuzumab

An increasing number of allogeneic HCT recipients and patients with hematologic malignancies are being treated with novel monoclonal antibodies that cause a depletion of lymphocyte subsets. Alemtuzumab is a humanized monoclonal antibody that targets CD52, which is abundantly expressed on most normal and malignant B and T lymphocytes. This agent has been used most extensively in patients with CLL who have disease that has failed fludarabine therapy. Alemtuzumab has been associated with grade 3 or 4 neutropenia in about 40% of patients with previously untreated CLL and in 56% to 78% of patients with fludarabine-refractory disease.³¹⁻³⁴ Alemtuzumab is associated with prolonged and severe lymphopenia in most patients. Prescribing information indicates that 4 weeks after initiation of alemtuzumab, the median CD4+ count was 0 cells/mcL and 6 months after discontinuation, the count was 238 cells/mcL in previously untreated patients.³¹ The CD8+ cell counts changed in a similar manner. In previously treated patients receiving alemtuzumab, CD4+ and CD8+ counts may not recover to baseline levels until more than 1 year

after completion of therapy.³¹ Infections pose a concern for morbidity and/or mortality in alemtuzumab recipients, particularly for patients with heavily pretreated, fludarabine-refractory disease.^{13,33,35} Bacterial, viral, fungal, mycobacterial, and *Pneumocystis jirovecii* infections have been reported with alemtuzumab.^{33,35,36}

Anti-infective prophylaxis against herpes viruses and PCP is recommended in patients receiving alemtuzumab treatment (see *Antiviral Prophylaxis and Preemptive Antiviral Therapy and Prophylaxis for Pneumocystis jirovecii*).³¹ Several studies have shown that patients treated with alemtuzumab have increased susceptibility to cytomegalovirus (CMV) reactivation and disease.^{31-33,37-39} In the absence of a large randomized controlled trial, the Infectious Diseases Working Party of the German Society of Hematology and Medical Oncology does not currently recommend CMV surveillance in alemtuzumab recipients.⁴⁰ Conversely, both the Working Group of the UK CLL Forum on behalf of the British Committee for Standards in Haematology and the International Workshop on CLL on behalf of the National Cancer Institute (NCI) recommend routine monitoring for CMV in patients with CLL who have therapies associated with the potential for CMV reactivation (eg, alemtuzumab or HCT).^{41,42} The NCCN Panel recommends that surveillance for CMV reactivation is conducted at least weekly using polymerase chain reaction (PCR) in alemtuzumab recipients (see *Antiviral Prophylaxis and Preemptive Antiviral Therapy: Cytomegalovirus*). Other compounds known to cause lymphopenia (eg, proteasome inhibitors) are associated with an increased risk of herpes zoster reactivation; therefore, prophylaxis with acyclovir, famciclovir, or valacyclovir is recommended.

Anti-CD20 Monoclonal Antibodies

Anti-CD20 monoclonal antibodies (eg, rituximab, ofatumumab) are widely used in the treatment of patients with B-cell lymphoid malignancies.^{43,44} The use of these monoclonal antibodies has been associated with increased risks for hepatitis B virus (HBV) reactivation, which can lead to fulminant hepatitis, liver failure, and/or death.⁴⁴⁻⁵¹ Antiviral prophylaxis is generally recommended for patients who test positive for HBV surface antigen (see *Antiviral Prophylaxis and Preemptive Antiviral Therapy: Hepatitis B virus*).

The use of anti-CD20 monoclonal antibodies in patients with B-cell malignancies has been associated with rare instances of progressive

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multifocal leukoencephalopathy (PML).^{44,45} PML is a demyelinating disease of the central nervous system (CNS) resulting from reactivation of the John Cunningham (JC) virus, and occurs in severely immunocompromised individuals. Though rare, PML is most often fatal. In reports of PML potentially associated with rituximab treatment in patients with B-cell malignancies, rituximab was typically given in combination with chemotherapy regimens or in patients who had received prior immunosuppressive regimens.⁵²⁻⁵⁹ Moreover, patients who developed PML often presented with low CD4+ counts or abnormal (low) CD4+/CD8+ ratio,^{52,54,57,59} which points to a critical role of T-cell immunity in suppressing reactivation of the JC virus.

Other Immunosuppressive Therapies

In addition to the agents mentioned above, there are other immunosuppressive therapies associated with a greater risk of infection in patients with cancer. For example, temozolomide (often administered in conjunction with radiation therapy) is associated with an increased risk of infection, particularly with *Pneumocystis jirovecii*, the causative agent for PCP.⁶⁰ Likewise, idelalisib with or without rituximab is associated with an increased risk of infections including *Pneumocystis jirovecii*.⁶¹ Treatment with other therapies, including ibrutinib and bendamustine, have also been reported to increase susceptibility to infection, including *Pneumocystis jirovecii*.^{62,63}

Hematopoietic Cell Transplantation

Autologous HCT

Autologous HCT recipients generally have fewer infectious complications than allogeneic transplant recipients. Most infections in autologous HCT recipients occur during neutropenia or within the first few months after transplantation before reconstitution of cellular immunity. However, compared to unmanipulated autologous HCTs, CD34+ cell enrichment leads to a substantial reduction in T cells, natural killer cells, and monocytes, which delays immune reconstitution.⁶⁴ Recipients of CD34+ cell-enriched autologous HCT appear to have a similar level of risk as allogeneic HCT recipients for contracting CMV and other opportunistic infections.⁶⁴ Severe or ulcerative mucositis, which develops as a result of

myeloablative high-dose therapy administered prior to HCT, is associated with the occurrence of bacteremia in autologous HCT recipients.⁶⁵⁻⁶⁷

A multicenter prospective study evaluated the potential role of granulocyte-colony stimulating factor (G-CSF) responsiveness in predicting the occurrence of infections in patients with hematologic malignancies undergoing high-dose therapy and autologous HCT.⁶⁸ Responsiveness to G-CSF was determined by the administration of a single dose of G-CSF after completion of high-dose therapy (but prior to HCT), and measuring the induced leukocyte peak occurring 12 to 14 hours after the G-CSF dose. G-CSF responsiveness showed a significant inverse correlation with incidences of febrile neutropenia and infections (ie, higher responsiveness associated with lower infection rates), and was shown to be the only independent predictor of infections based on multivariate analysis.⁶⁸

Allogeneic HCT

The spectrum of pathogens to which allogeneic HCT recipients are most susceptible follows a timeline corresponding to the predominant immune defects. In the first month after allogeneic HCT (pre-engraftment period), neutropenia and breakdown of the mucocutaneous barrier comprise the principal host defense defect, which predisposes patients to bacterial and fungal infections.^{69,70} In addition, reactivation of HSV can often occur during this period. After myeloid engraftment, qualitative dysfunction of phagocytes persists due to corticosteroid and other immunosuppressive agents. The risk of infection by opportunistic viruses and filamentous fungi (molds) during this period is strongly associated with the severity of GVHD and with the requirement for potent immunosuppressive regimens.

Susceptibility to infections during the early post-engraftment period is primarily due to defects in cell-mediated immunity that can persist for several months even in uncomplicated allogeneic HCT recipients, predisposing them to common bacterial and viral infections and to multiple opportunistic infections (eg, molds, viruses, atypical bacteria). In particular, the dominant pathogens during this early post-engraftment period can include herpes viruses (especially CMV), *Pneumocystis jirovecii*, and invasive molds such as *Aspergillus*.^{69,70} Prophylaxis against pneumococcal infection is advised in allogeneic HCT recipients (see *Prophylaxis for Pneumococcal Infection*).

Allografts from human leukocyte antigen (HLA)–matched unrelated donors, partially mismatched related donors, and cord blood are associated with a higher risk of GVHD. T-cell depletion delays immune reconstitution and, consequently, carries a greater risk of infectious complications, most notably by opportunistic viral⁷¹ and fungal⁷²⁻⁷⁴ pathogens. Cord blood transplant recipients may have a higher risk of infections than other allograft recipients during the early transplant period because of slower myeloid engraftment.

Guidelines from the Centers for Disease Control and Prevention (CDC) recommend that allogeneic HCT recipients with severe hypogammaglobulinemia (IgG <400 mg/dL) and with recurrent infections receive intravenous immunoglobulin (IVIG) prophylaxis; IVIG is not routinely recommended in other patient groups or in autologous HCT recipients.⁸ The 2009 guidelines on the prevention of infections in HCT recipients (jointly sponsored by the CDC, Infectious Diseases Society of America [IDSA], American Society for Blood and Marrow Transplantation, and European Society for Blood and Marrow Transplantation, among other organizations) reported similar recommendations on the use of IVIG.⁷⁰

Chronic GVHD

Whereas mature and cooperative T- and B-cell functions are usually reconstituted by 1 to 2 years following engraftment, chronic GVHD is associated with persistently depressed cell-mediated and humoral immunity. Defective reconstitution of humoral immunity is a major factor contributing to increased infection susceptibility in the late post-engraftment transplant period. Winston et al⁷⁵ noted a high frequency of pneumococcal infections between 7 and 36 months after transplantation, associated with serum opsonic deficiency for *Streptococcus pneumoniae*. Kulkarni et al⁷⁶ reported that pneumococcal sepsis occurred a median of 10 months after transplant (range, 3–187 months) and was significantly more frequent in patients with chronic GVHD.

NCCN Recommendations for Categories of Infection Risk

The panel acknowledges that there are multiple definitions of risk related to infection in patients with cancer.^{36,77,78} This section is specific to the overall risk of developing infection and recommendations for prophylaxis are based on this risk characterization. The NCCN Guidelines provide a summary of infection risk categories (low, intermediate, and high risk) in patients with cancer, which are based on factors such as the underlying malignancy, disease status (eg, active disease or disease in remission), duration of neutropenia, prior exposure to chemotherapy, and intensity of IST. Development of the categories of risk was further based on the expert opinion of the panel. An overview of the antimicrobial recommendations based on risk for infection is presented below. For more details, refer to the *Prevention of Infectious Diseases* section in the discussion and *Antimicrobial Prophylaxis* in the algorithm.

Briefly, patients with solid tumors receiving standard chemotherapy regimens and who have an anticipated duration of neutropenia shorter than 7 days are generally considered at low risk for infectious complications; thus, antimicrobial prophylaxis is not routinely recommended in these patients.¹⁶ For patients with HSV-positive serology who are otherwise at low risk for infections, prophylaxis with antivirals can be considered.

Patients with an anticipated duration of neutropenia of 7 to 10 days are considered to be at intermediate risk for infections. In addition, patients with lymphoma, multiple myeloma, CLL, autologous HCT recipients, or those receiving treatment with purine analog-containing regimens (most often for hematologic malignancies such as NHL or CLL) are also considered to be at intermediate risk. For the intermediate-risk patients, prophylaxis with antibacterials (eg, fluoroquinolones) should be considered during neutropenia. Antivirals should be given during periods of neutropenia, and for autologous HCT recipients, until at least 30 days following transplant (however, consider antiviral prophylaxis for varicella zoster virus [VZV] for at least 6–12 months after HCT). Antifungals should be considered during periods of neutropenia and for anticipated mucositis (with the latter pertaining to autologous HCT) for intermediate-risk patients. PCP prophylaxis should be considered in patients with intermediate risk.

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Patients with anticipated duration of neutropenia longer than 10 days, those undergoing intensive induction/consolidation therapy for acute leukemias (ie, acute lymphoblastic leukemia [ALL] or acute myeloid leukemia [AML]), patients undergoing treatment with alemtuzumab-containing regimens, allogeneic HCT recipients, and those with GVHD following allogeneic HCT are considered at high risk for infectious complications. Patients with NHL (in particular, for T-cell malignancy subtypes) or CLL treated with alemtuzumab-containing regimens are considered at high risk for infections. For these high-risk patients, prophylaxis with antibacterials (eg, fluoroquinolones) should be considered during neutropenia. These patients should receive antiviral prophylaxis during periods of neutropenia, and antiviral prophylaxis for VZV for at least 1 year after HCT. In addition, prophylaxis with antifungals can be considered for patients with ALL and for neutropenic patients with AML/MDS.¹⁶ For allogeneic HCT recipients or those with chronic GVHD receiving IST, antifungal prophylaxis can also be considered during periods of neutropenia and until resolution of GVHD. PCP prophylaxis should be considered in high-risk patients.

Prevention of Infectious Diseases

Preventive measures against infections in patients with cancer include upfront prophylaxis or preemptive therapy using broad-spectrum antimicrobial agents directed against the most common infecting pathogens (including bacterial, viral, and fungal) in high-risk patients. Vaccination and minimization of potential exposures to opportunistic pathogens that may be harmful to patients who are immunocompromised due to cancer are additional components of infectious disease prevention.

Antibacterial Prophylaxis

During Neutropenia

Patients with cancer and chemotherapy-induced neutropenia are at risk for severe bacterial infections. Fluoroquinolones are the most commonly used prophylactic antibacterial agents in adults with chemotherapy-induced neutropenia. In a meta-analysis that evaluated 18 trials (N = 1408) in which fluoroquinolones were compared to either placebo or trimethoprim-sulfamethoxazole (TMP/SMX), fluoroquinolone prophylaxis significantly reduced the incidence of gram-negative infections by about 80% compared

with trials without prophylaxis (relative risk [RR], 0.21; 95% CI, 0.12–0.37), leading to an overall reduction in total infections.⁷⁹ The reduction in fever was small, and in blinded trials was not significant. Fluoroquinolone prophylaxis did not affect infection-related mortality rates in this meta-analysis. Moreover, the rate of gram-positive infections and fungal infections was not significantly affected by fluoroquinolone prophylaxis.⁷⁹ This is an important consideration given the increased rate of gram-positive infections in some trials of fluoroquinolone prophylaxis.⁸⁰ Viridans group streptococcal bacteremia breakthroughs have been associated with quinolone prophylaxis,^{20,81,82} which poses a concern due to the potential for substantial morbidity and mortality associated with this pathogen in neutropenic patients.

In a single-center randomized study in patients undergoing high-dose therapy followed by autologous HCT (N = 157), patients were randomized to receive prophylaxis (with 500 mg oral ciprofloxacin twice daily and 1000 mg intravenous [IV] vancomycin once daily) or no prophylaxis; all patients received antifungal prophylaxis with fluconazole.⁸³ Empiric therapy (comprising amikacin, ceftazidime, and full-dose vancomycin) was initiated when neutropenic fever developed. The use of antibacterial prophylaxis significantly reduced the incidences of neutropenic fever (56% vs. 91%; $P < .001$) and bacteremia (6% vs. 35%; $P = .005$) compared with no prophylaxis, but at the expense of decreased response to first-line empiric therapy (66% vs. 84%; $P = .025$).⁸³ Among the patients who received prophylaxis and developed neutropenic fever, 34% required second-line therapy that included a carbapenem, suggesting that these patients developed infections resistant to the prophylactic regimen. Duration of hospitalization and overall survival rates were similar between study arms. These results led the study investigators to conclude that routine antibacterial prophylaxis was not recommended in patients undergoing high-dose therapy and autologous HCT.⁸³ It should be noted, however, that the prophylactic regimen in this study included vancomycin (albeit at a lower dose), which is not supported by the NCCN or IDSA panels for use as either antimicrobial prophylaxis or initial empiric therapy for fever and neutropenia.¹⁶

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Gafter-Gvili et al⁸⁴ conducted a meta-analysis of 95 randomized controlled trials comparing antibiotic prophylaxis with placebo, no intervention, or prevention with another antibiotic in afebrile neutropenic patients.⁸⁴ Antibiotic prophylaxis significantly decreased the risk for all-cause death when compared with placebo or no treatment (RR, 0.67; 95% CI, 0.55–0.81); significant risk reductions were also observed for infection-related mortality, fever, clinically and microbiologically documented infections, gram-positive and gram-negative infections, and bacteremia. Similar results were obtained when the analysis was restricted to prophylaxis with fluoroquinolones. Fluoroquinolone prophylaxis significantly reduced the risk of all-cause mortality (RR, 0.52; 95% CI, 0.35–0.77), as well as for all secondary measures indicated above.⁸⁴ Most of the trials involved hospitalized patients with hematologic malignancies, and data were inadequate to assess the relationship between duration and degree of neutropenia and relative risk of mortality. No significant increase was observed in fluoroquinolone-resistant bacterial infections, although the length of observation may have been too short to detect the emergence of resistant bacteria.⁸⁴

A subsequent systematic review and meta-analysis conducted by the same group of investigators evaluated the risks associated with colonization and infections by fluoroquinolone-resistant bacteria.⁸⁵ Most of the studies (48 of 56 trials) included patients with hematologic malignancies or HCT recipients. Results of the analysis (based on 56 trials, N = 7878 patients; data on colonization by resistant bacteria based on 27 trials) showed that quinolone prophylaxis was associated with an increase (although not statistically significant) in colonization with quinolone-resistant organisms compared with placebo or no intervention (RR, 1.68; 95% CI, 0.71–4.00). However, no difference was observed in the incidence of infections caused by quinolone-resistant organisms (RR, 1.04; 95% CI, 0.73–1.50), regardless of whether these were resistant gram-negative or gram-positive bacteria.⁸⁵ Moreover, in an analysis of trials comparing quinolones with TMP/SMX (11 trials), prophylaxis with quinolones was associated with fewer incidents of colonization and infections by resistant bacteria (those resistant to the prophylactic agents) compared with the use of TMP/SMX.⁸⁵ This analysis suggests that prophylaxis with quinolones does not appear to increase the rate of infections by resistant organisms.

In a systematic review and meta-analysis (based on 109 trials, N = 13,579 patients) comparing antibacterial prophylaxis with placebo, no intervention, or prevention with another agent in afebrile neutropenic patients, the use of antibacterial prophylaxis was found to significantly reduce the risk of all-cause mortality (risk ratio, 0.66; 95% CI, 0.55–0.79) as well as infection-related deaths (risk ratio, 0.61; 95% CI, 0.48–0.77) compared with placebo or no intervention.⁸⁶ The use of prophylaxis also significantly reduced the incidence of fever and clinically or microbiologically documented infections. Although no significant differences in all-cause or infection-related mortality were seen between prophylactic quinolones or TMP/SMX, the use of quinolones was associated with decreased drug resistance and fewer adverse events that subsequently reduced the incidence of drug discontinuation.⁸⁶

Two large, randomized, placebo-controlled studies showed the benefit of levofloxacin prophylaxis in neutropenic patients at different levels of risk for infectious complications.^{87,88} Levofloxacin has similar activity against gram-negative pathogens compared to ciprofloxacin and ofloxacin; however, levofloxacin has improved activity against certain gram-positive pathogens, including streptococci. Bucaneve et al⁸⁷ evaluated levofloxacin prophylaxis in adult patients with cancer in whom chemotherapy-induced neutropenia (less than 1000 neutrophils/mcL) was expected to occur for more than 7 days. This protocol intentionally excluded patients anticipated to have a short duration of neutropenia who would generally be candidates for outpatient management of neutropenic fever. Levofloxacin recipients had a lower rate of microbiologically documented infections, bacteremias, and single-agent gram-negative bacteremias than did placebo recipients.⁸⁷ The effects of prophylaxis were also similar between patients with acute leukemia and those with solid tumors or lymphoma. Mortality and tolerability were similar between the 2 groups.⁸⁷

Conversely, Cullen et al⁸⁸ evaluated levofloxacin prophylaxis after chemotherapy for patients with solid tumors and lymphomas who were anticipated to have brief durations of neutropenia. The primary outcome was the incidence of clinically documented febrile episodes (temperature more than 38°C) attributed to infection. Secondary outcomes included the incidence of all probable infections, severe infections, and hospitalization.

A total of 1565 patients, 87% with solid tumors and 13% with lymphoma, were randomized to receive either levofloxacin or the placebo. During the entire chemotherapy course, 10.8% of levofloxacin recipients had at least one febrile episode compared with 15.2% of placebo recipients ($P = .01$).⁸⁸ Hospitalization was required for the treatment of infection (suspected and documented) in 15.7% of patients in the levofloxacin group and in 21.6% of patients in the placebo group ($P = .004$). The incidence of severe infections, infection-related mortality, and overall mortality were similar between both groups.⁸⁸

The main advantage of levofloxacin prophylaxis in intermediate and higher risk patients with chemotherapy-induced neutropenia was a reduction in clinically significant bacterial infections, including gram-negative rod bacteremia.⁸⁷ In contrast, the main advantage of prophylaxis in lower risk neutropenic patients was a small, but statistically significant, reduction in fever and hospitalization for neutropenic fever.⁸⁸ Neither study conducted a systematic long-term evaluation of antimicrobial resistance. The NCCN Guidelines Panel considers that reduction in the incidence of significant infections is a more clinically meaningful endpoint than reduction in the incidence of neutropenic fever. Using prevention of neutropenic fever as the primary endpoint in this study by Cullen et al,⁸⁸ 1000 hypothetical low-risk patients would have to receive prophylaxis during each cycle of chemotherapy-induced neutropenia to benefit only 44 patients.

An important consideration for low-risk patients with short durations of neutropenia is whether fluoroquinolone prophylaxis is of greater benefit than outpatient fluoroquinolone treatment for fever and neutropenia, should it occur. Both the NCCN Guidelines and IDSA¹⁶ panels recommend oral fluoroquinolone-based regimens as outpatient empiric therapy for neutropenic fever in adults who meet criteria for a low risk of complications. Fluoroquinolone prophylaxis may preclude its subsequent use as empiric therapy for neutropenic fever in the same patient. The modest difference in rates of hospitalization for suspected infection in levofloxacin compared to placebo recipients (15.7% vs. 21.6%, respectively) may be offset by exclusion of outpatient oral empiric therapy in patients receiving fluoroquinolone prophylaxis. To limit antibacterial use, Cullen et al⁸⁹ have suggested prophylaxis with levofloxacin on cycle 1 of myelosuppressive

cancer chemotherapy and only in subsequent cycles if a febrile episode occurs.⁸⁹

The NCCN panel recommends oral fluoroquinolone-based regimens as outpatient empiric therapy for neutropenic fever in adults who have a low risk of complications as a single agent or in combination with a daily long-acting IV agent. IV antibiotics may also be used as a single-agent therapy (see *Outpatient Therapy for Low-Risk Patients* in the algorithm). The decision whether to use antibacterial prophylaxis and the selection of the specific agent requires a balance between expected benefit and risk. The concept of risk applies to immediate adverse effects of the drug (eg, rash, GI intolerance), the potential for selection for resistant pathogens that can harm the individual receiving prophylaxis, and the risk of resistant organisms to a specific population of patients (eg, those being treated at a cancer center). The link between fluoroquinolone use and severe *Clostridium difficile* as well as methicillin-resistant *S aureus* (MRSA) infections provides an additional cautionary note regarding excess use of fluoroquinolones.⁹⁰⁻⁹³

NCCN Recommendations for Antibacterial Prophylaxis

Antibacterial prophylaxis is not recommended for patients with a low risk of overall infection. In patients with neutropenia who are at lower risk of infectious complications (a category that includes most patients with solid tumor malignancies), the main benefit of antibacterial prophylaxis is a reduction in fever rather than in documented infections. In patients with neutropenia expected to last less than 7 days who are not receiving immunosuppressive regimens (eg, systemic corticosteroids), the panel suggests no antibiotic prophylaxis.¹⁶ In patients deemed at intermediate or high risk, the NCCN Guidelines Panel advises that fluoroquinolone prophylaxis (levofloxacin is preferred) be considered in patients with an expected duration of neutropenia (absolute neutrophil count [ANC] <1000 neutrophils/mcL) for more than 7 days. This is in agreement with the recommendations of the IDSA guidelines for the use of antimicrobial agents in neutropenic patients with cancer.¹⁶ For patients who are intolerant to fluoroquinolone, TMP/SMX or an oral third-generation cephalosporin may be considered.

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Prophylaxis for Pneumococcal Infection

Prophylaxis against pneumococcal infection is advised in allogeneic HCT recipients. Patients undergoing allogeneic HCT are at an increased risk for pneumococcal sepsis due to functional asplenia and impaired B-cell immunity. Pneumococcal sepsis is most common in the late transplant period, between 3 months to years after HCT.^{76,94} IST for GVHD delays reconstitution of B-cell immunity and significantly increases the risk of post-transplant pneumococcal sepsis.^{76,95}

The NCCN Guidelines Panel advises that penicillin prophylaxis be initiated at 3 months after HCT and be continued until at least 1 year following transplant. Patients should receive prophylaxis regardless of prior administration of pneumococcal vaccines.⁹⁶ Prophylaxis should be continued in patients with chronic GVHD until IST has been discontinued. Post-transplant pneumococcal infection is generally community-acquired, and the frequency of resistance to antibiotics reflects regional susceptibility patterns. In some regions as many as 35% of pneumococcal isolates have intermediate- or high-level resistance to penicillin,⁹⁷ and cross-resistance to other classes of antibiotics is common. Breakthrough pneumococcal sepsis in HCT recipients receiving penicillin prophylaxis is well described.⁹⁸ Thus, in areas with a significantly higher frequency of penicillin-resistant pneumococcal isolates, alternative agents should be considered based on local susceptibility patterns. Daily TMP/SMX used as prophylaxis for PCP is likely to be protective against pneumococcal disease. In high-risk patients (eg, allogeneic HCT recipients with GVHD), prophylaxis with penicillin and TMP/SMX should be considered. Vaccination with the polysaccharide pneumococcal vaccine is also strongly recommended (see *Vaccination*) 6 to 12 months after cessation of immunosuppression in HCT patients with revaccination after 5 years.^{96,99}

Antifungal Prophylaxis

Antifungal prophylaxis should not be used routinely in all patients with neutropenia. The rationale for antifungal prophylaxis is to prevent fungal infections in a targeted group of high-risk patients, especially those with longer durations of neutropenia or with GVHD after allogeneic HCT.¹⁶ Selection of an antifungal agent is determined by the disease or therapy and includes azoles, amphotericin B products, and echinocandins.

Azoles

Azoles are among the most commonly used medications for the prevention and treatment of fungal infections. Early-generation azoles such as ketoconazole and itraconazole are used less commonly now because of toxicity, drug interactions, and limited spectrum of activity. The “first-generation” triazoles (ie, fluconazole) are used widely due to their low cost and minimal toxicity but are limited by increasing resistance among *Candida* species and lack of activity against most molds. Several “second-generation” triazoles have been subsequently developed. These drugs extend the spectrum of activity of triazoles to include potent activity against many molds (importantly, activity differs within the class) but can also have complicated drug interactions and distinct toxicities and remain extremely costly with extended use.

Fluconazole prophylaxis has been shown to effectively decrease fungal colonization, invasive infection, and fungal infection-related mortality in nontransplant patients with leukemia and in autologous HCT recipients in a placebo-controlled trial.¹⁰⁰ The benefit of fluconazole prophylaxis was greatest in autologous HCT recipients not receiving colony-stimulating growth factor support and in patients with leukemia receiving mucotoxic regimens consisting of cytarabine plus anthracycline.¹⁰⁰ In neutropenic allogeneic HCT recipients, prophylactic fluconazole controlled yeast colonization and also decreased the rate of mucosal candidiasis and invasive *Candida* infections.^{101,102} A decrease in mortality was noted in one study in which most of the patients were allograft recipients.¹⁰² Fluconazole conferred significant long-term improvement in survival, possibly by decreasing *Candida* antigen-induced GI tract GVHD.¹⁰³ Other studies of nontransplant patients with acute leukemia showed no significant benefit of fluconazole in preventing invasive fungal infections, reducing mortality, or reducing the requirement for amphotericin B.^{104,105}

Prophylaxis with voriconazole was compared with fluconazole in a large, randomized, double-blind study that included serum galactomannan surveillance in allogeneic HCT recipients (N = 600).¹⁰⁶ Patients were randomized to receive study drugs for 100 days or for 180 days in the higher-risk cohort of patients. No difference was noted in the primary endpoint (invasive fungal infection-free survival rate at 180 days) between

the fluconazole and voriconazole prophylaxis arms (75% vs. 78%, respectively), but a trend for reduced incidence of *Aspergillus* infections (17% vs. 9%), reduced incidence of invasive fungal infections (11% vs. 7%), and less frequent use of empiric antifungal treatment (30% vs. 24%) was noted in the voriconazole arm, although the differences were not statistically significant. No differences in relapse-free and overall survival rates, nor incidence of severe adverse events were seen between treatment arms.¹⁰⁶

Posaconazole is equally effective compared to fluconazole as primary therapy for oropharyngeal candidiasis¹⁰⁷ but has not been evaluated as primary therapy for invasive fungal infections. In a multicenter randomized trial, prophylaxis with posaconazole in neutropenic patients with AML or MDS receiving induction or re-induction chemotherapy significantly reduced the rate of invasive fungal infections during the treatment period (2% vs. 8%; $P < .001$) and during the 100 days following randomization (5% vs. 11%; $P = .003$). Posaconazole prophylaxis also reduced the incidence of invasive aspergillosis (1% vs. 7%; $P < .001$) and was associated with a significant survival benefit ($P = .04$) compared with the fluconazole/itraconazole arm.¹⁰⁸ Data from a prospective, randomized study showed that posaconazole was as effective as prophylaxis in allogeneic HCT recipients with severe GVHD and reported reduced incidence of invasive aspergillosis and overall invasive fungal infections compared to patients receiving fluconazole.¹⁰⁹

Isavuconazonium sulfate is a second-generation azole that was approved in March 2015 for the treatment of invasive aspergillosis and invasive mucormycosis.¹¹⁰ (see *Invasive Aspergillosis* and *Mucormycosis* and *Other Invasive Mold Infections*). Isavuconazonium sulfate is not currently recommended for prophylaxis.

Toxicities and Drug-Drug Interactions of Azoles

Experience to date suggests that fluconazole and posaconazole are generally well-tolerated and serious adverse events, primarily liver toxicity, are rare. Toxicities for voriconazole include neurologic and ophthalmic adverse events that may be associated with renal toxicity due to the accumulation of the solvent vehicle sulphobutylether beta cyclodextrin sodium contained within the IV formulation. Data suggest that long-term

use of voriconazole may be associated with severe photosensitivity and other adverse events including cutaneous malignancies, elevated serum fluoride levels, and periosteitis.¹¹¹⁻¹¹⁵ Itraconazole may be associated with hepatic toxicity and GI intolerance¹¹⁶ and is contraindicated in patients with a decreased cardiac ejection fraction or a history of congestive heart failure based on its negative inotropic properties. It can also increase cyclophosphamide metabolites, which in turn are associated with hyperbilirubinemia and nephrotoxicity during the early transplant period.¹¹⁷ Fluconazole, itraconazole, posaconazole, and voriconazole may cause QTc prolongation. Conversely, isavuconazonium sulfate has been associated with dose-dependent QTc shortening in healthy individuals.¹¹⁰ In a clinical trial treating patients with invasive mold infections with isavuconazonium sulfate, 7.5% (17 out of 257) of patients showed QTc shortening.¹¹⁸

Azole-associated drug-drug interactions are common clinical occurrences. Both the addition and withdrawal of azoles can result in either increased uptake of these other drugs or sub-therapeutic exposure and potential transplant rejection or GVHD. Several studies demonstrate the interaction of azoles with hepatic enzymatic pathways. Administration of itraconazole with medications that are metabolized by the 3A4 isoenzyme can increase plasma concentrations causing QTc prolongation and ventricular tachyarrhythmias.^{119,120} These findings reinforce a note of caution about itraconazole (and by extension, fluconazole, voriconazole, isavuconazonium sulfate, and posaconazole), with regard to potential serious drug-drug interactions through inhibition of the cytochrome P450 3A4 isoenzyme. Additionally, fluconazole and voriconazole have demonstrated inhibition of CYP2C9 and CYP2C19 enzymes and high interpatient variability of genetic CYP2C19 polymorphisms that may also affect dosing.

The potential for QTc prolongation is a concern exacerbated by the combination of azoles and other drugs (eg, fluoroquinolones, macrolides, ondansetron) and with some chemotherapies (eg, nilotinib for CML, panobinostat for myeloma). Itraconazole and posaconazole are also known inhibitors of gastric P-glycoprotein, which can increase systemic levels of drugs that are affected by this transport system. The list of drug-drug interactions is expansive and continues to grow. While azoles may

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be necessary for antifungal therapy, they should only be incorporated into treatment following consultation with an infectious diseases expert.

Therapeutic Drug Monitoring of Azoles

Therapeutic drug monitoring (TDM) for the pharmacokinetic evaluation of antifungal agents provides guidance for achieving adequate plasma drug concentration while reducing toxicity. This is an area of active research, though clinical use is limited by the need for optimization of methods and training of personnel regarding interpretation of results. As a result, these tests generally require sending samples to a reference laboratory thereby increasing turn-around time for results. The support of an infectious diseases consultant is recommended to address the multiple variables that may affect TDM.

TDM should be considered for patients receiving triazoles; there is no current evidence to support the use of TDM for the evaluation of polyenes or echinocandins. Fluconazole and isavuconazonium sulfate are the two triazoles that do not require TDM. Fluconazole has linear pharmacokinetics that eliminate the need for TDM,¹²¹⁻¹²⁵ though patients in renal failure should receive a modified dose.¹²⁶ Studies intended to define a therapeutic range for isavuconazonium sulfate have not been performed; thus, TDM is not currently recommended for isavuconazonium sulfate. TDM should be considered for posaconazole, itraconazole, and voriconazole. Variability of therapeutic drug levels may be affected by the route of drug administration, timing of monitoring, location of the infection, and intrinsic patient factors (ie, age, weight).

There are 3 formulations of posaconazole: oral suspension, delayed-release tablet, and IV solution. Pharmacokinetic studies with the oral suspension of posaconazole in healthy individuals showed that administration with or after a high-fat meal, or with any meal or nutritional supplement, greatly enhanced its absorption up to 400%.^{127,128} The plasma concentration of posaconazole can be reduced by proton pump inhibitors (PPIs) due to the increase in gastric pH when given orally.¹²⁷ Subtherapeutic concentrations and breakthrough fungal infections have been reported.^{129,130} As reviewed by Brüggemann et al,¹³¹ a substantial list of drug interactions with azole antifungal drugs can result in subtherapeutic effects or toxicity. The 2013 approval of the tablet

formulation of posaconazole has improved absorption and demonstrates a more predictable bioavailability.¹²⁸ Gastric pH does not affect plasma concentration of extended-release posaconazole,¹³² nor does it have the same interaction with PPIs or metoclopramide.¹³³ The IV formulation has also demonstrated similar pharmacokinetics and safety compared with the extended-release tablet.¹³⁴ A target concentration of posaconazole for prophylactic TDM of greater than 0.7 mcg/mL is supported by individual studies^{130,135,136} as well as two phase III studies;^{108,109} however, doses as low as 0.5 mcg/mL have also been reported as effective.^{130,136-140} TDM may not be necessary when using either the extended-release tablet or IV formulation in the prophylactic setting as data indicate that a dose of 300 mg/d results in at least 0.5 ug/mL in greater than 95% of patients. Treatment of an established infection is recommended to have a trough concentration greater than 1 mcg/mL with potentially higher doses based on the pathogen resistance.^{141,142}

Studies of itraconazole demonstrate a significant rate of breakthrough infections when plasma drug concentrations are below 1 mcg/mL;^{143,144} however, increased mortality was observed at plasma drug concentrations greater than 0.5 mcg/mL.^{145,146} Targeting a lower itraconazole plasma concentration for prophylaxis and a higher dose if an active infection is being treated may be beneficial. Studies suggest that trough concentrations of itraconazole between 1 and 2 mcg/mL have shown the best therapeutic responses for invasive infections,¹⁴⁷⁻¹⁵⁰ while a trough concentration of greater than 0.5 mcg/mL may be sufficient for prophylaxis. Currently, an upper limit of 17 mcg/mL measured by bioassay has been suggested,¹⁵¹ but studies for the upper limit have not been extensive. Itraconazole should be given either 1 hour before or 1 hour after meals based on the 43% increase in bioavailability in patients who fasted.¹⁵²

Target voriconazole trough values between 0.5 and 2 mcg/mL have been proposed in clinical studies.¹⁵³⁻¹⁶⁰ While 0.5 mcg/mL is a suggested target for prophylaxis, a higher range of 1 to 2 mcg/mL may be necessary for active disease and for patients with disease that has a poor prognosis. Higher concentrations may also benefit immunocompromised patients by reducing breakthrough infection.^{161,162} Trough concentrations greater than or equal to 4 mcg/mL have correlated with toxicity in various

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studies.^{153,157,160,163-167} Voriconazole bioavailability was lowered by about 22% when taken with food and by 34% when given with a high-fat meal.^{168,169} Therefore, voriconazole should be given either 1 hour before or 1 hour after meals.

Studies have shown a general consensus regarding a minimal level of plasma concentration necessary for the triazoles, though the lack of prospective studies has limited the adoption of formal monitoring standards. The British Society for Medical Mycology has published its guidelines for the use of TDM of antifungal agents based on available literature.¹⁷⁰ These guidelines provide similar recommendations as those proposed in an earlier review by Andes et al.¹⁷¹ Consideration of TDM is recommended by the NCCN panel in conjunction with involvement of an infectious diseases expert.

Amphotericin B Formulations

Amphotericin B formulations are broad-spectrum antifungal agents that have activity through disruption of the fungal cell wall synthesis and subsequent development of pores in the membrane leading to cell death. The original formulation, amphotericin B deoxycholate, was associated with dose-limiting toxicities including infusion-related reactions and nephrotoxicity. Three lipid-associated formulations, amphotericin B lipid complex (ABLC), liposomal amphotericin B (L-AmB), and amphotericin B colloidal dispersion (ABCD), have since been developed to have reduced toxicity.

Low-dose amphotericin B formulations have been studied in high-risk patients and have been shown to provide protection against invasive molds, although no survival benefit in randomized studies was seen when compared with fluconazole.^{116,172,173} Based on the toxicity of amphotericin B products and the availability of safer and equally effective alternative agents, amphotericin B products are considered a category 2B recommendation for prophylaxis. If an amphotericin B product is used, a lipid formulation is generally preferred because of less infusional and renal toxicity compared to conventional amphotericin B. Use of the lipid formulation is particularly important for patients at high risk for renal failure, such as patients with pre-existing renal disease, HCT recipients, and patients who are concurrently receiving other nephrotoxic agents.^{174,175}

Aerosolized delivery of amphotericin B products has been considered for several years with the advantage of local delivery to the lungs while simultaneously avoiding systemic toxicity. A randomized, placebo-controlled trial found that aerosolized L-AmB was useful for preventing invasive pulmonary aspergillosis in patients with prolonged neutropenia.¹⁷⁶ Limitations to the use of aerosolized amphotericin B for prophylaxis relate to the variability of this treatment due to different nebulizers and amphotericin B formulations, the lack of dosing optimization, and a dearth of direct comparative data with systemically administered mold-active azoles or echinocandins.¹⁷⁷

Echinocandins

Echinocandins are a class of antifungal agents that disrupt the integrity of the fungal cell wall through noncompetitive inhibition of β -(1,3)-D-glucan synthase, a component specific to the cell wall of many fungi. Echinocandins have fungicidal activity against *Candida* species and are fungistatic towards *Aspergillus* species. Combination therapy with amphotericin B or triazoles has been proposed to improve activity against molds; however, clinical evidence for this remains quite limited. Advantages of this family of antifungals are the relatively low toxicity profiles and limited drug-drug interactions. Though echinocandins demonstrate activity against *Candida* species that are resistant to other antifungal agents,¹⁷⁸ there is limited or no activity against dimorphic fungi. Three echinocandins are approved for use: caspofungin, micafungin, and anidulafungin. All three agents are approved for the treatment of esophageal candidiasis. Caspofungin and anidulafungin have additional indications for the treatment of candidemia and other infections caused by *Candida* species. Caspofungin is indicated for treatment of candidal pleural space infections, empiric treatment of fungal infections in neutropenic patients, and treatment of invasive aspergillosis in patients who are refractory to or intolerant of other antifungal agents. Micafungin has the additional indication for prophylaxis of candidal infections in patients receiving HCT.

Caspofungin was evaluated in a double-blind study including 128 patients with esophageal candidiasis.¹⁷⁹ Patients received either caspofungin or amphotericin B deoxycholate. Two doses of caspofungin were evaluated (50 mg or 70 mg IV once daily) with a greater response in the patients

given the higher dose (96% vs. 85%). Both groups treated with caspofungin had a better response than patients receiving amphotericin B (78%). At the two-week follow-up, a greater percentage of patients remained negative for candidiasis with the caspofungin treatment (89% in the 70 mg group, 74% in the 50 mg group, and 63% in the amphotericin B group). Furthermore, drug-related adverse events were lower with caspofungin (7%, 4%, and 24%, respectively). Several studies have evaluated the role of caspofungin in the treatment of invasive aspergillosis in patients refractory to or intolerant of other antifungals, supporting its recommendation in this capacity.^{180,181}

Micafungin is an echinocandin approved for prophylaxis against *Candida* infections in patients undergoing HCT.¹⁸² In a randomized, double-blind trial of autologous and allogeneic HCT recipients, the success rate with micafungin was superior to fluconazole (80% vs. 73.5%; absolute difference +6.5%; 95% CI, 0.9–12%; $P = .03$) based on pre-specified criteria for treatment success (absence of suspected, proven, or probable invasive fungal infections during treatment period and absence of proven or probable infection during the 4-week period after treatment).¹⁸³ The duration of this study encompassed the neutropenic period, but not the period after neutrophil recovery when GVHD would be expected to occur. The frequency of breakthrough candidemia was similar in both arms, but there was a trend to fewer episodes of invasive aspergillosis in allogeneic HCT recipients receiving micafungin. Survival and drug-related toxicity were similar between treatment arms.¹⁸³ Micafungin has shown activity in the treatment of aspergillosis in patients refractory to or intolerant of other antifungal agents.^{184–186}

Anidulafungin has been shown to be an effective antifungal agent against *Candida* infection in several studies. A randomized double-blind study in 601 patients with esophageal candidiasis demonstrated noninferiority of IV anidulafungin to oral fluconazole (97.2% vs. 98.8%, respectively) and lower adverse effects (9.3% vs. 12.0%) and recurring infections at the 2-week follow-up (64.4% vs. 89.5%).¹⁸⁷ In a smaller study of 19 patients with triazole-refractory mucosal candidiasis, anidulafungin treatment resolved infection in 18 of the patients.¹⁸⁸ A larger phase III trial similarly showed superiority of anidulafungin compared to fluconazole in the treatment of

candidemia and invasive candidiasis (75.6% vs. 60.2%).¹⁸⁹ The response at 2-week follow-up was 64.6% in the anidulafungin group versus 49.2% in the fluconazole group.

NCCN Recommendations for Antifungal Prophylaxis

CYP3A4 inhibition by azoles can lead to toxicity when administered with several classes of drugs used in cancer therapy, including proteasome inhibitors, tyrosine kinase inhibitors, and vinca alkaloids.¹⁹⁰ Thus, mold-active azoles should be stopped several days before the potential interacting drug is given. These azoles should also not be started until the other agent has been discontinued and sufficient time has elapsed for the drug to be eliminated. Due to variations in drug pharmacokinetics, firm recommendations regarding a minimum time from drug discontinuation to azole administration cannot be made, though some institutions consider waiting at least 10 days following administration of these classes of drugs. Use of echinocandin prophylaxis may be considered in the place of azoles. Consultation with pharmacology and infectious diseases experts is recommended.

The NCCN Guidelines Panel recommends posaconazole (category 1) for antifungal prophylaxis in neutropenic patients with AML and MDS receiving induction or re-induction chemotherapy (see *Overall Infection Risk in Patients with Cancer* in the algorithm).¹⁶ The role of antifungal prophylaxis in patients with acute leukemia receiving consolidation chemotherapy has not been adequately evaluated. Voriconazole, fluconazole, micafungin, or amphotericin B products are all category 2B recommendations in this disease setting. Antifungal prophylaxis should be continued until resolution of neutropenia.

In patients receiving autologous HCT with mucositis, antifungal prophylaxis with fluconazole or micafungin (both category 1) is recommended until resolution of neutropenia. No prophylaxis is recommended in autologous HCT recipients without mucositis.

The NCCN Guidelines Panel recognizes that strong evidence exists for the use of fluconazole or micafungin as prophylaxis in neutropenic allogeneic HCT recipients (category 1) (see *Overall Infection Risk in Patients with Cancer* in the algorithm).¹⁶ However, it should be noted that fluconazole

use can predispose patients to colonization and bloodstream infection by fluconazole-resistant *Candida* strains.^{73,191} Posaconazole as prophylaxis has not been evaluated during the neutropenic period following conditioning in allogeneic HCT recipients; thus, the safety of this approach is unknown. Drug-drug interactions during conditioning for HCT, specifically with posaconazole or voriconazole, complicate treatment of fungal infections in these patients. Prophylaxis may need to be tailored following consultation with an infectious diseases expert. Posaconazole, voriconazole, and amphotericin B products are all considered category 2B recommendations. Antifungal prophylaxis should be considered until at least day 75 after allogeneic HCT (see *Overall Infection Risk in Patients with Cancer* in the algorithm).^{16,103}

Although many centers reasonably use antifungal prophylaxis in non-neutropenic allogeneic HCT recipients with GVHD, this practice was only evaluated in a single, properly designed study. In the prospective, randomized, double-blind study, posaconazole was compared with fluconazole as prophylaxis in allogeneic HCT recipients with severe GVHD requiring intensive IST.¹⁰⁹ Inclusion criteria included grade II to IV GVHD, chronic extensive GVHD, or intensive IST consisting of either high-dose corticosteroids, antithymocyte globulin, or a combination of 2 or more immunosuppressive agents or types of treatment. Prophylaxis with posaconazole resulted in reduced incidences of invasive aspergillosis, total invasive fungal infections while on treatment, and deaths attributed to fungal infection.¹⁰⁹ Posaconazole is recommended (category 1) as prophylaxis in patients with GVHD receiving intensive IST, as defined by the inclusion criteria in this trial. Prophylactic posaconazole can be considered in all patients with GVHD receiving IST (category 1), although the benefit/risk ratio of mold-active prophylaxis in patients receiving less intensive IST has not been established. Voriconazole, echinocandins, and amphotericin B products are all category 2B recommendations.

Patients with chronic severe neutropenia (ANC <500 neutrophils/mcL) due to the underlying disease (such as aplastic anemia) are at substantial risk for invasive aspergillosis.¹⁹² Although this population has not been evaluated in clinical trials of antifungal prophylaxis, some panel members

advise the use of a prophylactic mold-active agent (eg, posaconazole or voriconazole).

Secondary antifungal prophylaxis is defined as administration of antifungal therapy in a patient with a prior fungal infection to prevent recrudescence. The panel recommends secondary prophylaxis with an appropriate antifungal agent in patients with prior chronic disseminated candidiasis¹⁹³ or with invasive filamentous fungal infection¹⁹⁴ during subsequent cycles of chemotherapy or HCT. In patients with invasive aspergillosis before HCT, antifungal therapy for more than a month and resolution of radiologic abnormalities correlate with a lower likelihood of post-transplant recurrence of infection.¹⁹⁵ Secondary prophylaxis with a mold-active agent is advised for the entire period of immunosuppression.

Prophylaxis for *Pneumocystis jirovecii*

TMP/SMX prophylaxis for *Pneumocystis jirovecii* is highly effective in preventing PCP.¹⁹⁶⁻¹⁹⁹ In a systematic review and meta-analysis of 12 randomized studies (N = 1245; primarily in patients with acute leukemias or in HCT recipients), prophylaxis with TMP/SMX resulted in a significant reduction in PCP occurrence by 91% compared with placebo, no treatment, or treatment with non-PCP antibiotics (RR, 0.09; 95% CI, 0.02–0.32). In addition, TMP/SMX prophylaxis significantly reduced PCP-related mortality (RR, 0.17; 95% CI, 0.03–0.94).¹⁹⁶ TMP/SMX has the potential advantage of activity against other infectious complications (such as common bacterial infections, listeriosis, nocardiosis, and toxoplasmosis) that may afflict patients with severe T-cell depletion or impairment.²⁰⁰ TMP/SMX is considered the treatment of choice for PCP prophylaxis (preferred, category 1; see *Antipneumocystis Prophylaxis* in the algorithm). In cases of intolerance, TMP/SMX desensitization should be considered. Daily dapsone and aerosolized pentamidine are alternatives to TMP/SMX. Although early data suggested that these agents may be inferior when used prophylactically in allogeneic HCT recipients,²⁰¹⁻²⁰⁴ more recent studies have suggested that these agents are a safe and effective alternative.²⁰⁵⁻²⁰⁷ For patients receiving dapsone, measurement of G6PD levels is recommended prior to the initiation of therapy. Patients who are G6PD deficient may have an increased risk for hemolytic adverse reactions.²⁰⁸ Atovaquone appears to be equivalent to dapsone in HIV patients who cannot tolerate TMP/

SMX.²⁰⁹ In pediatric patients with acute leukemias who were intolerant of TMP/SMX, atovaquone was reported to be an effective strategy for PCP prophylaxis.²¹⁰

Prophylaxis against PCP should be used in allogeneic HCT recipients (category 1) for at least 6 months and while receiving IST and in patients with ALL (category 1) throughout anti-leukemic therapy.^{211,212} Patients should receive prophylaxis against PCP for a minimum of 2 months after alemtuzumab and until the CD4 count is greater than 200 cells/mcL.³¹ Other patients who should receive PCP prophylaxis at least through active treatment include: 1) those receiving treatment with idelalisib +/- rituximab; 2) patients with neoplastic diseases receiving intensive corticosteroid treatment (eg, the equivalent of 20 mg or more of prednisone daily for 4 weeks or more, also depending on the patient's overall immunologic status); and 3) patients receiving concomitant temozolomide and radiotherapy (see *Antipneumocystis Prophylaxis* in the algorithm).^{61,212-215} Panel members advise prophylaxis against PCP (category 2B) for patients receiving purine analog therapy (eg, fludarabine, cladribine [2-CdA]) and other T-cell-depleting agents until CD4 count is greater than 200 cells/mcL and for autologous HCT recipients until 3 to 6 months post-transplant.

Antiviral Prophylaxis and Preemptive Antiviral Therapy

Herpes Simplex Virus

HSV is an important pathogen in patients who develop neutropenia and mucositis. HSV infections primarily result from reactivation of latent virus. The presence of latent HSV can be determined by pretreatment HSV serology. Reactivation and infection with HSV occur in 60% to 80% of HCT recipients and patients (without prophylaxis) with acute leukemia undergoing induction or re-induction therapy who are seropositive for HSV.²¹⁶⁻²¹⁸ Among allogeneic HCT recipients, HSV disease is most likely to occur within the first month post-transplant, but may occur in later stages during intense immunosuppression.^{69,70} Although disseminated HSV infection is uncommon, infection from viral reactivation is frequently associated with increased mucosal damage, resulting in increased pain, limited ability to maintain oral hydration and nutrition, and an increased risk of bacterial and fungal superinfections.

NCCN Recommendations for HSV Prophylaxis

Antiviral prophylaxis against HSV is advised during the period of neutropenia in HSV-seropositive patients who are receiving chemotherapy (induction or consolidation) for acute leukemia, and during neutropenia and possibly longer in allogeneic and autologous HCT recipients depending on the degree of immunosuppression (see *Overall Infection Risk in Patients with Cancer* in the algorithm). A longer period of prophylaxis should be considered in allogeneic HCT recipients with GVHD or with frequent HSV reactivations before transplantation.⁸ Acyclovir, famciclovir, or valacyclovir are the initial agents of choice for HSV prophylaxis.^{16,219} Foscarnet is typically reserved for patients with acyclovir-resistant HSV infection.^{16,219} In patients receiving antiviral prophylaxis with ganciclovir or foscarnet for prevention of CMV reactivation, additional prophylaxis with acyclovir is not necessary given that these agents are active against HSV.²¹⁹

HSV and herpes zoster infections are common in patients with CLL treated with the CD52 monoclonal antibody alemtuzumab. For these patients, antiviral prophylaxis is advised until at least 2 months after completion of alemtuzumab therapy and until CD4+ cell counts are 200 cells/mcL or more.^{31,220}

Prophylaxis against HSV should be considered in other patients at intermediate risk for HSV reactivation, including those with hematologic malignancies with prolonged neutropenia or those receiving high-dose corticosteroids or T-cell-depleting agents (eg, fludarabine). Once a patient has had HSV reactivation requiring treatment, the panel recommends HSV prophylaxis for that patient during all future episodes of neutropenia induced by cytotoxic therapy. HSV prophylaxis is indicated in seropositive children only.

Varicella Zoster Virus

Impaired cellular immunity is the principal risk factor for VZV disease. In allogeneic HCT recipients with a history of VZV infection, about 30% have reactivation of VZV disease without antiviral prophylaxis.²²¹ In patients with a history of chicken pox, oral acyclovir administered from 1 to 2 months until 1 year after allogeneic HCT significantly decreased the incidence of VZV disease compared to placebo (5% vs. 26%, respectively).²²¹ The



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frequency of VZV disease in the post-prophylactic period was similar between the groups and predominantly occurred in patients who required systemic immunosuppression. This prolonged course of acyclovir prophylaxis is likely to also prevent HSV reactivations. Subsequent studies have consistently demonstrated the benefit of long-term antiviral prophylaxis against VZV disease in recipients of allogeneic HCT. Patients who received anti-VZV prophylaxis with acyclovir or valacyclovir for 1 year post-HCT had significantly reduced VZV disease compared with those who did not receive long-term prophylaxis (9% vs. 25%; $P < .001$); no evidence of rebound VZV disease was observed.²²² Long-term (1 year post-allogeneic HCT) prophylaxis with lower doses of acyclovir or valacyclovir was associated with a 19% to 35% cumulative incidence of VZV reactivation, but successfully prevented the occurrence of severe VZV disease comprising visceral involvement or serious complications.^{223,224}

NCCN Recommendations for VZV Prophylaxis

The NCCN Guidelines Panel recommends prophylaxis against VZV for at least 1 year after allogeneic HCT in patients seropositive for VZV pretransplant (see *Overall Infection Risk in Patients with Cancer* in the algorithm), and recommends considering the extension of prophylaxis in patients who continue to receive systemic IST. Although higher doses are necessary, the same agents used as HSV prophylaxis are also active against VZV. For pediatric patients, prophylaxis for VZV should not be routinely given unless there is a history of recurrent zoster infections or incidence of first zoster infection while on myelosuppressive therapy, even if they are seropositive or vaccinated.

Among autologous HCT recipients, HSV reactivation is more likely to occur in the early neutropenic phase, whereas the risk of VZV reactivation extends through the first year.²²⁵ Thus, VZV prophylaxis for at least 6 to 12 months post-transplant should be considered in autologous HCT recipients. Prophylaxis against VZV should be considered in other patients at intermediate risk for viral reactivation, including patients with hematologic malignancies with prolonged neutropenia or those receiving T-cell-depleting agents (eg, fludarabine, alemtuzumab). Bortezomib is associated with an increased risk of VZV reactivation during active therapy²²⁶⁻²²⁹; carfilzomib may also be associated with VZV reactivation.²³⁰ Prophylaxis

with acyclovir, valacyclovir, or famciclovir should be protective and can be considered in these settings.²³⁰⁻²³² As previously discussed, among patients with CLL receiving alemtuzumab treatment, antiviral prophylaxis is recommended until 2 months after completion of treatment and until the CD4+ cell counts reach 200 cells/mL or more (see *Overall Infection Risk in Patients with Cancer* in the algorithm).^{31,220}

Cytomegalovirus

CMV infections most frequently occur in patients with cancer who undergo allogeneic HCT or who receive alemtuzumab therapy. CMV is a common cause of opportunistic infections during the early post-engraftment phase following allogeneic HCT, but can also occur in the late post-engraftment phase (particularly for patients with GVHD during the latter phase).^{69,70} Infection can result from viral reactivation (in immunocompromised CMV-seropositive patients) or primary infection (in CMV-seronegative patients). The risk for CMV reactivation and disease is highest among HCT recipients with CMV-seropositive status prior to transplant.²³³ Among CMV-seropositive patients undergoing allogeneic HCT (with graft sources from peripheral blood, bone marrow, or umbilical cord blood), the incidence of CMV reactivation ranged from 50% to 60% (with CMV disease in about 10%–30% of seropositive recipients) even with routine surveillance and antiviral prophylaxis or preemptive therapy.²³³⁻²³⁶

In two randomized studies, prophylaxis with acyclovir was associated with increased survival in allogeneic HCT recipients, but the rates of CMV reactivation and disease were fairly high.^{237,238} Oral valacyclovir (a valine esterified analogue of acyclovir with high oral bioavailability) was compared with acyclovir as prophylaxis in allogeneic HCT recipients in whom either the donor or recipient was CMV seropositive.²³⁹ All patients received initial IV acyclovir until day 28 after transplantation or until discharge, and then either oral valacyclovir or acyclovir until week 18. Valacyclovir was more effective than acyclovir in preventing CMV infection (28% vs. 40%; hazard ratio [HR], 0.59; 95% CI, 0.46–0.76; $P < .0001$); no differences were observed in CMV disease, adverse events, or overall survival.²³⁹ In another study, acyclovir and valacyclovir were demonstrated to be acceptable agents for CMV prophylaxis, but surveillance and preemptive therapy with ganciclovir or foscarnet was still necessary.²¹⁹ The poor sensitivity of CMV

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to acyclovir is likely due to the lack of a CMV-encoded thymidine kinase and lower activity of acyclovir against the CMV DNA polymerase. Routine use of acyclovir or valacyclovir for primary prophylaxis of CMV infection is not recommended.

Valganciclovir and ganciclovir are the agents of choice for first-line preemptive therapy; foscarnet is more commonly used for patients who cannot tolerate ganciclovir or for second-line preemptive therapy.²¹⁹ Foscarnet and ganciclovir had similar efficacy as preemptive CMV therapies in allogeneic HCT recipients, but ganciclovir was associated with a higher rate of early discontinuation because of neutropenia or thrombocytopenia.²⁴⁰ Although ganciclovir had a higher rate of early discontinuation, there remains a paucity of data to recommend foscarnet as first-line treatment for CMV. Additionally, breakthrough CMV infection and disease with foscarnet have been reported.²⁴¹⁻²⁴³

Pharmacokinetic studies have demonstrated the feasibility and safety of using oral valganciclovir, a pro-drug of ganciclovir, in place of ganciclovir in patients who underwent allogeneic HCT.^{244,245} Oral valganciclovir used as preemptive anti-CMV therapy was shown to have acceptable oral bioavailability and was safe and effective in controlling CMV infection in allogeneic HCT recipients, including patients with grades I and II GI GVHD.^{244,246-248} Thus, valganciclovir is a highly acceptable oral option for preemptive therapy for CMV in the absence of substantial GI GVHD. Reports of higher rates of CMV disease with oral valganciclovir compared to IV ganciclovir in patients with hepatic dysfunction restricted approval for solid tumor transplant patients by specifically excluding liver transplant patients.²⁴⁹⁻²⁵¹ It is postulated that hepatic dysfunction allows bioabsorption of valganciclovir but decreases cleavage of the valine ester, thereby limiting conversion to the active form.²⁵⁰

Cidofovir has been evaluated as both primary and secondary preemptive therapy in allogeneic HCT recipients.²⁵²⁻²⁵⁵ In a retrospective study of allogeneic HCT recipients (N = 82) treated for CMV disease (n = 20), primary preemptive therapy (n = 24) or secondary preemptive therapy (n = 38) with cidofovir demonstrated an observed response in 50% of patients treated for CMV disease (mainly CMV pneumonia) and in 62% of patients treated with primary preemptive therapy.²⁵⁴ Moreover, secondary

preemptive therapy with cidofovir resulted in a response rate of 66% in patients where treatment failed or relapse occurred (defined as continued presence or recurrence of pp65 antigenemia or viral DNA after at least 1 week of antivirals) following initial preemptive therapy with ganciclovir, foscarnet, or the combination of these agents.²⁵⁴

Late CMV disease, defined as occurring after day 100 of HCT, remains a persistent problem in the era of CMV prophylaxis and preemptive therapy. In one series, 92% of patients with late CMV pneumonia had chronic GVHD or had received T-cell-depleted transplants.²⁵⁶ Results of T-cell reconstitution at 3 months after allogeneic HCT appear to be useful in risk stratification for late CMV disease. CD4+ T-cell counts less than 50 cells/mcL, total lymphocyte counts less than 100 cells/mcL, undetectable CMV-specific T-cell responses, and GVHD were all associated with late CMV disease or death in CMV-seropositive allogeneic HCT recipients.²⁵⁷ In addition, a CD4+ cell count less than 100 cells/mcL, a CD8+ count less than 50 cells/mcL, and use of high-dose steroids (2 mg/kg/d or greater) were significantly predictive of delayed recovery of CMV-specific immunity at 3 months after allogeneic HCT; use of steroids impaired both CD4+ and CD8+ T-cell function in a dose-dependent manner.²⁵⁸ In patients who did not receive high-dose steroids and received CMV prophylaxis with ganciclovir, subclinical CMV antigenemia appeared to stimulate functional recovery of both CD4+ and CD8+ cells. This finding may have implications for investigating potential CMV vaccine strategies in this clinical setting.

CMV reactivation is common among patients with lymphoproliferative malignancies (most commonly, CLL) receiving alemtuzumab therapy, and occurs most frequently between 3 to 6 weeks after initiation of therapy when T-cell counts reach a nadir.^{33,37-39} Several studies of alemtuzumab in patients with CLL have demonstrated the effectiveness of using routine CMV monitoring coupled with preemptive anti-CMV therapy with ganciclovir in preventing overt CMV disease.^{33,37,38,259} A small randomized study in patients with lymphoproliferative disease treated with alemtuzumab-containing regimens (N = 40) showed that upfront CMV prophylaxis with oral valganciclovir significantly reduced the incidence of CMV reactivation compared with oral valacyclovir (0% vs. 35%; *P* = .004).³⁹

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NCCN Recommendations for CMV Prophylaxis

Based on the available data that predict the risk of CMV disease, the NCCN Guidelines Panel recommends routine CMV surveillance after allogeneic HCT, together with preemptive anti-CMV therapy with oral valganciclovir or IV ganciclovir. In cases of ganciclovir-resistant CMV or when ganciclovir is not tolerated (eg, ganciclovir-induced myelosuppression), IV foscarnet or IV cidofovir may be used (see *Prevention of Cytomegalovirus Reactivation or Disease* in the algorithm). Surveillance should typically occur for at least 1 to 6 months post-transplant and during chronic GVHD requiring IST. Higher-risk transplant subgroups may exist and require different management strategies. Note that the CD4+ count will be reduced by systemic corticosteroids and by other lymphocyte-depleting agents. The majority of cases of late CMV disease occur within the first year of transplant and less than 5% occur after the second year.²⁵⁶ Therefore, the value of CMV surveillance beyond 2 years after HCT is unknown but can be considered in patients with significant chronic GVHD. There is debate about how to treat patients after a negative test for CMV. There are not enough data to determine whether patients should be transitioned to surveillance or continue with chronic maintenance therapy, and if so, for how long. The benefits must be weighed against the potential toxicity associated with long-term antiviral use. Ganciclovir and valganciclovir are associated with bone marrow suppression that may increase the risk of common opportunistic infections. Foscarnet can cause nephrotoxicity and electrolyte abnormalities but is tolerated.^{240,260,261} Cidofovir can be associated with substantial nephrotoxicity^{254,255}; although less frequent, ocular toxicity has been reported.²⁶² Acyclovir and valacyclovir have excellent safety profiles but are only weakly active against CMV and are not recommended as prophylaxis or treatment of CMV infection.

The NCCN Guidelines Panel recommends routine surveillance for CMV reactivation consisting of weekly monitoring by PCR during alemtuzumab therapy and at least 2 months after completion of treatment.^{31,263} Upon confirmation of CMV viremia (defined as PCR positivity for CMV in ≥ 2 consecutive samples obtained 1 week apart³¹), the panel recommends preemptive therapy with oral valganciclovir or IV ganciclovir for 2 weeks and until CMV is no longer detectable (see *Prevention of Cytomegalovirus Reactivation or Disease* in the algorithm). IV foscarnet or IV cidofovir

should be used for cases of ganciclovir-resistant CMV or when ganciclovir is not tolerated (eg, ganciclovir-induced myelosuppression). Following a negative test of CMV, there are not enough data to determine whether patients should continue with chronic maintenance therapy and, if so, for how long, or move to surveillance.

For the prevention and treatment of CMV, adjunctive IVIG can be administered; however, IVIG is generally not recommended for prophylactic use except in limited situations due to cost and the limited evidence of activity of this treatment. Although no optimal dosing regimen has been determined, IVIG is commonly administered every other day for 3 to 5 doses. CMV-specific IVIG has not been shown to be any more efficacious than standard IVIG.

Hepatitis B Virus

The risk factors for HBV infection include personal or parental history of an intermediate to high prevalence of HBV infection in one's birthplace (defined as a prevalence of hepatitis B surface antigen [HBsAg] positivity in greater than 2% of the population); household and sexual contact with HBsAg+ persons; individuals with multiple sexual partners or history of sexually transmitted diseases; individuals who have been inmates of correctional facilities; patients with chronically elevated AST or ALT levels; patients with a history of injection drug use; men who have sex with other men; and patients positive for hepatitis C virus (HCV) or HIV.

A positive HBsAg is associated with active infection or a window period before the development of protective immunity in a patient exposed to HBV. An individual who has been vaccinated for HBV typically has the following serology: negative HBsAg, positive hepatitis B surface antibody (HBsAb), and negative hepatitis B core antibody (HBcAb).²⁶⁴ False-negative HBsAg results may occur in patients with chronic liver disease.²⁶⁵ HBsAb positivity is generally equated with protective immunity, although reactivated HBV disease may occur in the setting of significant immunosuppression in HBcAb-positive individuals.²⁶⁶ A patient with resolved hepatitis B infection will be HBcAb positive but HBsAg negative. As mentioned above, some patients with cancer are at increased risk for HBV reactivation due to profound immunosuppression stemming from cytotoxic regimens, high-dose corticosteroids, tyrosine kinase inhibitors, anti-CD20/CD52

monoclonal antibodies, and/or the underlying malignancy (eg, leukemia, lymphoma).

Patients with malignancies who are HBsAg positive and/or HBcAb positive are at risk for HBV reactivation with cytotoxic chemotherapy. Approximately 20% to 50% of patients with HBsAg positivity and 3% to 45% with HBcAb positivity develop HBV reactivation.^{49,264,267-275} The risk of HBV reactivation for patients who are HBsAg negative, HBcAb positive varies widely based on the virological profile, disease, and immunosuppressive regimen. Serum HBV DNA testing prior to the initiation of therapy may help define their risk of reactivation. If viremic, they may receive similar prophylaxis as patients who are HBsAg positive.²⁷⁶ Complications of HBV reactivation can range from self-limited hepatitis to fulminant hepatic failure and death.^{275,277-281}

HBV reactivation can lead to early discontinuation or delayed initiation of treatment.^{282,283} In patients with B-cell lymphoid malignancies treated with rituximab-containing regimens, HBV reactivation was observed in patients with HBcAb positivity (with or without HBsAb positivity), even among those who were HBsAg negative prior to initiation of treatment.^{49,269,275} In a meta-analysis and evaluation of the U.S. Food and Drug Administration (FDA) safety reports, it was reported that HBcAb positivity correlated with increased incidence of rituximab-associated HBV reactivation.²⁶⁸

A retrospective study showed that allogeneic HCT recipients who were HBsAg negative but HBcAb positive had a high risk of seroconversion to HBsAg positivity and HBV reactivation (subsequently leading to hepatitis) following allogeneic HCT.²⁸⁴ After allogeneic HCT, loss of HBV-specific immunity may occur (ie, loss of HBsAb and development of HBsAg and HBV PCR positivity). This has been observed in up to 40% of susceptible individuals in one report²⁸⁵ and may be confused with hepatic GVHD.

There are several nucleos(t)ide analogs approved by the FDA for the prevention and treatment of HBV. Historically, data supporting the use of these analogues have been based on lamivudine, a reverse transcriptase inhibitor. Antiviral prophylaxis with lamivudine has been shown to reduce the risks for HBV reactivation in HBsAg-positive patients with hematologic malignancies treated with IST.²⁸⁶⁻²⁸⁸ In a meta-analysis of clinical trials evaluating lamivudine prophylaxis in HBsAg-positive lymphoma patients treated with IST, prophylaxis resulted in a significant reduction in HBV

reactivation (risk ratio, 0.21; 95% CI, 0.13–0.35) and a trend for reduced HBV-related deaths (risk ratio, 0.68; 95% CI, 0.19–2.49) compared with no prophylaxis.²⁸⁸ In allogeneic HCT recipients considered at high risk for HBV reactivation (ie, HBsAg-positive recipient or donor, or HBsAg-negative/HBcAb-positive recipient), antiviral prophylaxis with lamivudine demonstrated effective control of HBV reactivation and reduced the risk for developing hepatitis.^{273,289} However, despite its initial effectiveness, virologic breakthrough was high, with reports of resistance in 80% of patients after 5 years of therapy.²⁹⁰ Thus, lamivudine monotherapy has fallen out of favor. Studies suggest one of the newer agents (such as entecavir or tenofovir) may be preferable or combination therapy may have a possible role for patients with lamivudine-resistant HBV infections.²⁹¹⁻²⁹³

As of 2015, tenofovir is available in 2 different pro-drug forms, tenofovir disoproxil fumarate (DF) and tenofovir alafenamide (AF). Tenofovir AF has greater plasma stability than tenofovir DF, allowing use of a lower dose and lesser systemic exposure to the drug.²⁹⁴ Tenofovir DF has demonstrated superior antiviral efficacy compared with adefovir in a phase III randomized double-blind study in patients with chronic HBV infection, making tenofovir preferred over adefovir in this setting.²⁹⁵ Two randomized, phase III, double-blind studies comparing tenofovir AF to tenofovir DF in patients with HBeAg-negative²⁹⁶ or HBeAg-positive²⁹⁷ chronic HBV infection showed that the efficacy of tenofovir AF was non-inferior to tenofovir DF, with better bone and renal safety for tenofovir AF. While these data support the use of tenofovir for HBV infection, limited data are available regarding its use in patient populations with cancer. No detectable resistance to tenofovir DF was reported in patients with chronic hepatitis B after 6 years of treatment.²⁹⁸ In another study, sequencing of the HBV polymerase/reverse transcriptase indicated sequence changes at polymorphic sites, though none resulted in drug resistance.²⁹⁹ In total, there were only 16 cases of virologic breakthrough, 12 of which were associated with nonadherence to study medication. Resistance for tenofovir DF remained undetectable throughout a 5-year span. By comparison, lamivudine resistance was calculated to be 24% in the first year, and this number steeply climbed to 70% by year 5.²⁹⁹

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Entecavir and telbivudine have shown improved antiviral activity compared to adefovir in randomized open-label studies in patients with chronic hepatitis B.^{300,301} A few small case studies have evaluated entecavir in the prevention³⁰² or treatment of HBV in patients with cancer (reviewed by Liu et al³⁰³). Entecavir had a low drug resistance of 1.2% at 5 years³⁰⁴ compared to adefovir, which had an intermediate resistance that increased from 0% in the first year to 29% by year 5.^{295,305,306} Conversely, telbivudine had a higher resistance, reaching 17% in the second year.²⁷⁶ Greater than 10% of patients in a phase III clinical trial who did not have genotypic resistance after 2 years and continued to receive telbivudine developed resistance after 4 years.³⁰⁷

In addition to drug resistance, the safety profile of the nucleos(t)ide analogues should affect drug selection. Nephrotoxicity has been seen with adefovir^{308,309} and tenofovir,³¹⁰ while myopathy and neuropathy are more commonly associated with telbivudine.^{311,312} No significant side effects have been reported with lamivudine or entecavir; however, it is recommended that all patients be monitored for lactic acidosis and severe hepatomegaly with steatosis.

NCCN Recommendations for HBV Prophylaxis

Risk-based screening is recommended by the American Society of Clinical Oncology (ASCO)³¹³ and the American Association for the Study of Liver Disease (AASLD).³¹⁴ Although it is possible that risk-based screening may be more cost-effective than universal screening, there are currently no validated risk tools that could easily be implemented into clinical practice. Furthermore, less than 60% of patients with HBV infection may have obvious risk factors,³¹⁵ and only 10% to 35% of infected patients may be aware of their own HBV infection.^{316,317} Therefore, any patient expected to receive IST or chemotherapy should be screened. Implementation of universal screening, as recommended by the CDC, should be considered.³¹⁸

In patients undergoing intensive IST, including HCT, both patient and donor should be screened for HBV, HCV, and HIV prior to treatment.^{319,320} Evaluation of HBsAg, HBeAb, and HBsAb should be considered at baseline.^{219,264,320} Vaccination against HBV should be strongly considered in HBV-naïve patients (ie, negative for HBsAg, HBsAb, and HBeAb) (see

Vaccination).^{219,264} In HBV-naïve patients undergoing allogeneic HCT, grafts from HBsAg-positive or HBV DNA-positive donors should be avoided wherever possible. Donors who have not been exposed to HBV should be considered for HBV vaccination before hematopoietic cell collection.

In HBsAg-positive or HBeAb-positive individuals, baseline quantitative PCR for HBV DNA should be obtained. In allogeneic HCT candidates with evidence of active HBV infection (chronic hepatitis based on biopsy or positive HBsAg or high levels of HBV DNA), transplant procedure should be delayed when possible, and antiviral therapy should be given for 3 to 6 months prior to conditioning.²¹⁹ In HCT candidates who are HBsAg-positive or HBeAb-positive but without evidence of active HBV replication, antiviral prophylaxis should be considered (starting shortly before the transplant procedure). All allogeneic HCT recipients should continue surveillance for at least 6 to 12 months after transplant or during GVHD.

Similarly, the NCCN Guidelines for B-cell Lymphomas recommend HBsAg and HBeAb testing for all patients with B-cell NHL planned for treatment with anti-CD20 monoclonal antibody-containing regimens (see [NCCN Guidelines for B-cell Lymphomas](#)).^{321,322} The panel recommends that baseline quantitative PCR for HBV DNA be obtained to determine viral load in patients who test positive for HBsAg and/or HBeAb. For patients undergoing anti-tumor therapy, the B-cell Lymphomas panel suggests prophylactic antiviral therapy (for cases of HBsAg positivity; also preferred for HBsAg-negative/HBeAb-positive cases) or preemptive antivirals upon detection of increasing viral load (an option for HBsAg-negative/HBeAb-positive cases with concurrent high levels of HBsAb).^{321,322} During anti-tumor therapy, HBV viral load should be monitored via PCR monthly, then every 3 months after treatment completion. Prophylaxis with antivirals should be continued (for up to 12 months after completion of anti-tumor therapy) if viral load remains undetectable.^{321,322}

The optimal choice of antiviral agents for prophylaxis (or preemptive approaches) will primarily be driven by institutional standards. The NCCN panel recommends consultation with an expert in hepatitis treatment to determine appropriate antiviral prophylaxis for patients who test positive for HBV. Preferred agents for HBV prophylaxis are entecavir and tenofovir. Although data were originally obtained with lamivudine, entecavir and

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tenofovir are preferred, especially when treating patients with active HBV infections due to the low threshold of resistance with lamivudine. Monitoring of viral load and transaminases should be considered for patients without active HBV infection who are not receiving prophylaxis.

Hepatitis C Virus

Studies for HCV reactivation in patients with cancer are not as expansive as studies for hepatitis B; however, an increase in mortality was reported in patients with cancer who had HCV infection compared to patients with cancer who were HCV negative.³²³ A review by Yazici et al³²⁴ summarized studies of HCV reactivation in patients receiving targeted therapies and the data correlated an increase in HCV reactivation with these therapies.³²⁴ Differences in outcomes between patients who are HCV positive with cancer versus HCV positive without cancer were reported to include higher occurrence of occult infection, higher risk of developing early cirrhosis, higher rate of fibrosis progression, development of viral reactivation, and poorer virologic outcomes (reviewed by Borchardt et al).³²⁵ The guidelines from the joint IDSA and AASLD panels for the testing, management, and treatment of hepatitis C recommend that treatment for HCV be considered for patients with chronic HCV with a life expectancy of greater than 12 months.³²⁶

NCCN Recommendations for HCV Screening and Management

All patients who are expected to receive chemotherapy or IST should be screened for HCV. The data are limited regarding the treatment of HCV in patients with cancer, but it is generally not recommended that HCV treatment and cancer therapy be given concurrently.³²⁵ The IDSA/AASLD guidelines can provide additional guidance for antiviral therapy, but an infectious diseases consult is necessary to evaluate the use of concomitant or sequential anti-HCV and cancer therapy.³²⁶ Monitoring of ALT levels and HCV viral load monthly, or as clinically indicated, should be initiated as part of surveillance. The NCCN Guidelines for B-cell Lymphomas address the management of HCV infection in patients with HCV-associated lymphomas (see [NCCN Guidelines for B-cell Lymphomas](#)).³²¹

Human Immunodeficiency Virus

The CDC surveillance report estimates that 1.1 million persons are living with HIV in the United States. This includes the estimated 166,000 persons whose infection has not yet been diagnosed.³²⁷ There is support for HIV testing in all patients treated for cancer.³²⁸ Patients who are HIV-positive and have cancer are classified as having either AIDS-defining cancer (ADC) or non-AIDS-defining cancer (NADC). ADC includes Kaposi sarcoma, NHL, and cervical cancer. There is a higher incidence of these cancers in HIV-positive patients than in HIV-negative patients.³²⁹

The incidence of NADC is increasing, likely due to the longer life expectancy of HIV-positive patients resulting from the advancement of treatment options.³³⁰ HIV-positive patients with NADC were shown to have an overall worse cancer outcome when compared to HIV-negative patients with the same cancer.³³¹ However, improvement in outcome was seen when HIV-positive patients received highly active antiretroviral therapy (HAART).³³² There should be caution regarding the concomitant administration of select antiretroviral therapies (including the protease inhibitors and non-nucleoside reverse transcriptase inhibitors) with cancer therapy as adverse events through cytochrome P450 3A4 have been documented.³³³ A publication from MD Anderson Cancer Center retrospectively evaluated the use of HIV screening in patients prior to systemic cancer therapy.³³⁴ Out of the 18,874 patients in this study, there were 3514 patients who tested positive for HIV at the initiation of systemic cancer therapy. Patient histories indicated a higher incidence in patients with sexually transmitted disease (37.7% vs. 18.5%; $P < .001$) or a history of illegal drug use (46.2% vs. 18.6%; $P < .001$). Patients screened for HIV included 12.1% of patients with NADC and 9.4% of patients with cervical cancer. Interestingly, a significantly higher percentage (88.4%) of patients with NHL were screened for HIV, which may be partially attributed to clinician education of the role of HIV in these patients.³³⁴

NCCN Recommendations for HIV Screening

In 2006, the CDC published recommendations for routine HIV testing in all patients (13–64 years of age) in the health care setting.³³⁵ The testing is intended to be voluntary and conducted only with consent from patients. Under these guidelines, patients are informed either verbally or in written

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format that HIV testing will be conducted unless the patient declines testing (opt-out screening). The CDC recommends that patients at high risk for HIV infection be screened at least annually.³³⁵ The implementation of these guidelines is largely dependent upon institutional practices and the prevalence of undiagnosed HIV infections in specific institutions. However, the NCCN panel strongly encourages concordance with the CDC recommendations.

In addition to the CDC recommendations, the NCCN panel emphasizes that all patients receiving chemotherapy or IST be screened for HIV.³²⁸ Patients co-infected with hepatitis pose an additional complication. Select antiretroviral therapies including the integrase-strand inhibitors and nucleoside/nucleotide reverse transcriptase inhibitors have demonstrated fewer drug-drug interactions compared with the protease inhibitors and non-nucleoside reverse transcriptase inhibitors. However, consultation with an infectious disease expert is necessary for treatment of HIV in patients with cancer as therapies continuously evolve. HIV viral load should be monitored monthly during therapy and then as clinically indicated.

Screening for Other Viruses

Rapid PCR panels should be considered for detection of respiratory viruses including RSV, influenza, parainfluenza virus, adenovirus, rhinovirus, and metapneumovirus in patients with cough and/or shortness of breath that might indicate a viral infection (see *Site-Specific Evaluation and Treatment of Infections: Lung Infections* for discussion on non-viral causes). Ribavirin and IVIG have been proposed as antiviral therapies,³³⁶⁻³⁴⁰ however, data are not sufficient to provide recommendations.

RSV is a major cause of severe infection in the immunocompromised, with mortality rates up to 80% in HCT recipients.^{341,342} Progression of RSV to the lower respiratory tract occurs in up to half of patients receiving HCT or chemotherapy.³⁴³⁻³⁴⁵ The virulent nature of RSV requires hospitalization for treatment. Treatment options are limited to ribavirin and adjunctive IVIG. There is a diversity of practice among the institutions for the treatment of RSV disease. Based on limited data^{346,347} and strong panel disagreement regarding the use of ribavirin and the best method of delivery, ribavirin was designated a category 3 recommendation. Recommendations for inhaled versus oral ribavirin should be based on the individual institution.

Rapid screening tests are available for detection of influenza. Clinical benefit is highest when treatment is initiated within the first 48 hours of influenza symptoms, although benefits can still be seen when initiated after the 48-hour window.³⁴⁸ During the influenza season, consider empiric antiviral therapy for patients within 48 hours after symptoms develop that are suggestive of influenza (eg, high fever, coryza, myalgia, dry cough), especially during community outbreaks. Both the IDSA (2007) and CDC guidelines (2011) recommend antiviral treatment with the neuraminidase inhibitors oseltamivir or zanamivir, which are active against both influenza A and B viruses.^{349,350} Both agents are approved by the FDA for the treatment of influenza within 48 hours of symptomatic onset; the indicated duration of treatment is 5 days.^{351,352} However, longer courses of treatment (eg, 10 days) and treatment until resolution of symptoms can be considered in immunocompromised patients, though this is controversial. Some centers have used higher doses (eg, 150 mg BID) of oseltamivir in these patients with mixed results. Pandemic influenza does not have a predictable seasonal pattern, and may spread in the community concurrently with a seasonal influenza strain. Antiviral susceptibility of influenza strains is variable and cannot be predicted based on previous influenza outbreaks. In cases of seasonal influenza and pandemic strains, it is necessary to be familiar with susceptibility patterns and guidelines on appropriate antiviral treatment.³⁵³ There are some data on the activity of peramivir; however, the activity has been uneven across studies.³⁵⁴ Peramivir, available only as an IV injection, can be considered for patients who cannot absorb oral oseltamivir or tolerate oseltamivir or inhaled zanamivir³⁵⁵ (see *Site-specific Evaluation and Treatment of Infections: Lung Infections*).

BK virus is a common polyomavirus that remains dormant in the kidney and urinary tract. In immunosuppressed individuals, BK virus can reactivate. Patients undergoing allogeneic HCT are particularly vulnerable to BK virus and the development of hemorrhagic cystitis.^{356,357} While cidofovir demonstrates effectiveness as a treatment option for BK virus, renal toxicity is a significant complication.³⁵⁸ There is currently a lack of data to support recommendations on the treatment of BK virus.



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Vaccination

Vaccination in patients with cancer can reduce the morbidity and mortality associated with infection. In general, patients with hematologic malignancies have a greater risk for infection than patients with solid tumors. HCT patients may lose immunity to pathogens post-transplant. Therefore, the vaccination recommendations for these patients are more expansive than the recommendations for the general population of patients with cancer. In any immunocompromised patient, live vaccines, including the live attenuated influenza vaccine (LAIV), have the potential to cause disease and should not be administered during chemotherapy or periods of significant immunosuppression such as treatment for GVHD. The safety of vaccines for patients receiving immunostimulatory drugs has not been established. Inactivated vaccines can often be safely administered to patients with cancer. Although the immunogenicity of the vaccines may be reduced in immunocompromised patients, the potential for protection conferred by antigen-derived vaccines, even if incomplete, is better than no protection if the vaccine is withheld. While guidelines may provide general recommendations for vaccination schedules, the efficacy and safety of each vaccine should be evaluated to optimize the schedule on a case-by-case basis. For more information on vaccination in cancer survivors, see the [NCCN Guidelines for Survivorship](#).

Influenza Vaccine

Influenza infections cause significant morbidity and mortality in patients with cancer. Among bone marrow transplant recipients, influenza accounts for about 10% to 40% of all community-acquired viral respiratory infections.³⁵⁹⁻³⁶¹ An increase in both the incidence and duration of influenza infections has been observed in patients with cancer who are immunosuppressed compared to healthy controls.^{362,363} During community outbreaks, influenza infections may represent a significant proportion of fever and neutropenia episodes.³⁶⁴ Influenza infections in patients with cancer who are severely immunocompromised are often associated with hospitalizations, delays in potentially life-saving chemotherapy, and occasionally death.³⁶²⁻³⁶⁴ As a result, annual vaccination against influenza with the inactivated influenza virus is recommended for all individuals at increased risk due to immunosuppression.³⁶⁵ A randomized study of 97

patients receiving cytotoxic chemotherapy (3-week cycles) for solid tumors found that the immunogenicity of the influenza vaccine was similar when administered at the time of chemotherapy administration (day 1) or within the cytopenic period (day 11).³⁶⁶ The Advisory Committee on Immunization Practices (ACIP) for the CDC guidelines includes health care professionals and household members or caregivers in their target group for annual immunization to prevent transmission of influenza to high-risk patients.³⁶⁵

The intranasal vaccine should be avoided in patients with immunosuppression, because a LAIV is still capable of replication, which could theoretically lead to infection in immunocompromised individuals.^{365,367} Because no data are available assessing the risk for person-to-person transmission of the LAIV from vaccine recipients to immunosuppressed contacts, the CDC recommends that inactivated influenza vaccine should be used in household contacts, health care workers, and others who have close contact with severely immunocompromised patients (ie, persons requiring a protected environment). Persons with close contact to patients with a lesser degree of immunosuppression (eg, patients receiving chemotherapy or corticosteroids, HIV-positive patients) may receive the LAIV.^{365,367}

There are not yet sufficient data for the panel to recommend the high-dose influenza vaccine over the standard-dose influenza vaccine. Preliminary data have shown that the high-dose influenza vaccine is safe for patients with cancer and may show more immunogenicity compared to the standard-dose influenza vaccine for this patient population.^{368,369} Further data are needed to assess whether the high-dose influenza vaccine confers a clinical benefit compared to the standard-dose vaccine for patients with cancer.

Pneumococcal Vaccine

The pneumococcal conjugate vaccine can be given in newly diagnosed adults with hematologic or solid tumor malignancies following assessment of their immune status. The conjugate pneumococcal vaccine (PCV13) should be administered to newly diagnosed adults with cancer who are pneumococcal vaccine-naïve, followed by the polysaccharide pneumococcal vaccine (PPSV23) at least 8 weeks later. Subsequent doses of PPSV23 should follow current PPSV23 recommendations for adults at

high risk.³⁷⁰ For patients who have previously received PPSV23, the PCV13 dose should be given at least 1 year after the last PPSV23 dose. For those who require additional doses of PPSV23, the first such dose should be given no sooner than 8 weeks after the PCV13 dose.

Vaccination with the conjugated 13-valent vaccine 6 to 12 months after HCT followed by the polysaccharide pneumococcal vaccine at least 1 year after cessation of immunosuppression in HCT is recommended with revaccination with the polysaccharide pneumococcal vaccine after 5 years.^{96,99} Patients with asplenia should receive the pneumococcal vaccine. The pneumococcal vaccine should be administered at least 2 weeks before elective splenectomy.³⁷¹ Penicillin prophylaxis is advised in asplenic patients to prevent pneumococcal disease.^{372,373}

Meningococcal Conjugate Vaccine

The meningococcal vaccine is recommended for patients with increased risk for meningococcal disease including patients with persistent complement component deficiency, patients taking eculizumab, and patients with anatomic or functional asplenia. The ACIP recommends that asplenic persons be immunized with the meningococcal vaccine.³⁷⁴ The meningococcal vaccine should be administered at least 2 weeks before elective splenectomy.³⁷¹ The conjugated meningococcal vaccine (MCV4) is preferred in adults 55 years of age or younger, because it confers longer lasting immunity than the polysaccharide vaccine. Re-vaccination for the meningococcal vaccine with MCV4 after 5 years is recommended for functional asplenic patients who received MCV4 or MPSV4.³⁷⁴ The meningococcal vaccine is also recommended 6 to 12 months after HCT.

Human Papillomavirus Vaccine

The human papillomavirus (HPV) vaccine is a recombinant 3-dose vaccine that can be given to patients up to 26 years of age. The lower age limit for this vaccine is 9 years of age. There is no evidence to suggest that this vaccine is helpful for patients who are already HPV positive at the time of vaccination.

Haemophilus Influenzae Type b Vaccine

Immunization of adults with the pediatric *H influenzae* type b (Hib) vaccine is considered optional because of limited data on efficacy in older children and adults, although studies suggest good immunogenicity in immunocompromised patients. The Hib vaccine is recommended 6 to 12 months post-HCT. For patients with planned splenectomy, immunization is ideally performed at least 2 weeks in advance. If this is not feasible, immunization is advisable after splenectomy, because such patients are still capable of mounting a protective antibody response.

Varicella/Zoster Vaccines

The varicella/zoster vaccines are live vaccines and should be given no earlier than 24 months following HCT. The varicella vaccine may be administered to HCT recipients who are seronegative for varicella, and who do not have GVHD or ongoing immunosuppression. Because of limited data in using the varicella vaccine among HCT recipients, physicians should assess the immune status of each recipient on a case-by-case basis and determine the risk for infection before using the vaccine. For patients who are 60 years of age or older and seropositive for varicella, the zoster vaccine may be advisable (category 3). Because of insufficient data for the safety and efficacy of the zoster vaccine among HCT recipients, physicians should assess the immune status of each recipient and assess the potential benefit before using the vaccine. Specific antivirals (ie, acyclovir, famciclovir, valacyclovir) cannot be given within the 24 hours before vaccination nor during the 14 days after vaccination.

Travel Vaccines

Vaccines have variable risk and efficacy in patients receiving cancer care; therefore, the panel recommends consultation with an infectious disease expert prior to the administration of travel vaccines (eg, typhoid, yellow fever).

Vaccine Summary

Although efficacy data are lacking for the use of vaccines in patients with cancer, recommendations for their use are based on the principles of immunization and safety data. Persons receiving chemotherapy or radiation therapy for malignancies should not receive live vaccines for at

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least 3 months after cessation of therapy and until they are presumed to be immunocompetent.³⁷¹ Data indicate a reduced response to vaccination in patients receiving IST. In patients receiving blinatumomab, suppressed immunoglobulin levels were measured that persisted through the first year following the conclusion of treatment.³⁷⁵ Similarly, anti-CD20 therapy has correlated with decreased serum immunoglobulins.³⁷⁶⁻³⁸² Live vaccines are contraindicated during treatment and for a period of at least 6 to 12 months in patients who are receiving IST (eg, blinatumomab, CAR T cells, monoclonal antibodies). These patients may also have a blunted response to inactivated vaccines. Certain live vaccines can be safely administered to household members of severely immunocompromised patients (eg, measles, mumps, rubella [MMR]), whereas others cannot (eg, smallpox vaccine) because of the potential risk of transmission. The package insert for the vaccine should be reviewed prior to administration. The NCCN panel recommends that all household members be up to date on vaccinations.

Ideally, patients should be vaccinated at least 2 weeks before receiving cytotoxic therapy or IST; however, this timing is often not feasible in patients with cancer. In general, vaccination should not be given on the same day as cytotoxic therapy as cytotoxic therapy may reduce the proliferative lymphocytic responses required for protective immunity. In patients receiving chemotherapy, immunization between cytotoxic chemotherapy courses is likely to be associated with higher response rates than during chemotherapy administration.^{383,384} Patients vaccinated less than 2 weeks before starting cytotoxic therapy or IST or while receiving these agents may have a limited response to vaccination. These patients should be revaccinated at least 3 months after therapy is discontinued and once immune competence has been restored.³⁷¹

In summary, the NCCN panel recommends that patients with cancer receive the influenza, pneumococcal, meningococcal, and HPV vaccines. HCT recipients should also receive the inactivated vaccines for diphtheria/tetanus/acellular pertussis (DTaP), Hib, hepatitis A and B, and polio. The live vaccine for MMR may be given if no GVHD or ongoing immunosuppression is seen two years post-transplant in patients who are seronegative. The live varicella vaccine may also be given 2 years post-transplant if the patient is seronegative. There remains disagreement

among the panel about the zoster vaccine. Consultation with an infectious disease expert is recommended prior to administration of travel vaccines.

Protected Environments

Although well-designed clinical trials have not validated the use of high-efficiency particulate air (HEPA) filtration, the CDC recommends that allogeneic HCT recipients be placed in rooms with HEPA filters.⁸ It is also reasonable to use HEPA filtration in nontransplant patients with prolonged neutropenia. The principal benefit of HEPA filtration is likely to be related to the prevention of mold infections. In a retrospective analysis, HEPA filters were protective in highly immunocompromised patients with hematologic malignancies in the setting of an outbreak of aspergillosis.³⁸⁵ The value of laminar airflow in preventing infections is unclear and generally is not recommended.

Management of Neutropenic Patients with Fever

The definitions of fever and neutropenia in the NCCN Guidelines are consistent with those developed by the IDSA and FDA for evaluating antimicrobial therapy for fever and neutropenia.¹ *Fever* is defined as a single oral temperature of 38.3°C (or equivalent) or higher or 38.0°C or higher over 1 hour in the absence of an obvious cause. Axillary or rectal temperature measurements should be avoided.¹⁶ Although uncommon, a patient with neutropenia and signs or symptoms of infection (eg, abdominal pain, severe mucositis, perirectal pain) without fever should be considered to have an active infection. The concomitant administration of corticosteroids may blunt fever response and any localized signs of infection. The NCCN Guidelines define *neutropenia* as either 1) an ANC less than 500 neutrophils/mcL, or 2) an ANC less than 1000 neutrophils/mcL and a predicted decline to 500 neutrophils/mcL or less over the next 48 hours.

Initial Evaluation

The initial evaluation should focus on determining the potential sites and causative organisms of infection and on assessing the patient's risk of developing an infection-related complication. A site-specific history and physical examination should be performed promptly, cultures should

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be obtained, and empiric antibiotics should be started soon after the time of presentation (see *Initial Evaluation of Fever and Neutropenia* in the algorithm). The common sites of infection for patients with fever and neutropenia (such as the alimentary tract, skin, lungs, sinus, ears, perivaginal/perirectal, urologic, neurologic, and intravascular access device sites) should be thoroughly assessed with special attention to any devices. Other important factors in patient history to consider include major comorbid illness, medications, time since last chemotherapy administration, recent antibiotic therapy, and previously documented infections. Other epidemiologically relevant exposures that should be considered include marijuana use, cigarette smoking, infections from household members, pets, travel, and recent blood product administration (see *Initial Evaluation of Fever and Neutropenia* in the algorithm).

Initial laboratory/radiology evaluation should include a complete blood count with differential analysis and blood chemistry tests to assess liver function (eg, total bilirubin, albumin, alanine aminotransferase [ALT], aspartate aminotransferase [AST]) and renal function (eg, blood urea nitrogen [BUN], creatinine, electrolytes). Oxygen saturation and urinalysis should be considered, depending on symptoms. Chest radiographs should be done for all patients with respiratory signs or symptoms; however, radiographic findings may be absent in neutropenic patients with pulmonary infection.³⁸⁶

Cultures

Culture specimens should be collected during or immediately after completing the examination. Two blood samples should be cultured. When obtaining blood cultures, there are 3 options: 1) one set can be obtained peripherally and one can be obtained from a central venous catheter (preferred); 2) both sets can be obtained peripherally; or 3) both sets can be obtained through the catheter (see *Initial Evaluation of Fever and Neutropenia* in the algorithm). The positive predictive value (PPV) of a catheter culture is less than of a peripheral culture. Obtaining blood for culture from both the central venous catheter and peripherally may help determine whether the venous access device (VAD) is the source of a bloodstream infection based on the differential time to positivity (DTP).³⁸⁷ However, some experts recommend that only blood from the VAD needs to

be obtained for culture, without the requirement for a peripheral vein blood culture.³⁸⁷ A meta-analysis has shown little clinical use for two-site culturing in patients with cancer who have a VAD, and poor patient acceptance of peripheral venipunctures when a VAD is in place.³⁸⁸ The panel consensus is that the volume of blood for culture is the most important aspect of blood culturing; however, the panel recommends obtaining one peripheral and one catheter culture for distinguishing between catheter-related infections and from secondary sources.

In the absence of lesions or clinical signs and symptoms, routine cultures of the anterior nares, oropharynx, urine, stool, and rectum are rarely helpful. Diarrheal stools suggestive of infection should be tested for the presence of *C difficile*.³⁸⁹ In patients with diarrhea, consider screening for enteric pathogens including rotavirus and norovirus in winter months and during outbreaks. Symptoms of urinary tract infection should be evaluated with a urinalysis and culture. Vascular access site inflammation or drainage should be cultured. Biopsy with microbiologic and pathologic evaluation should be considered for new or undiagnosed skin lesions (see *Initial Evaluation of Fever and Neutropenia* in the algorithm). Viral cultures of vesicular or ulcerated mucosal or cutaneous lesions may identify HSV infections. In patients with symptoms of respiratory viral infection, viral cultures and rapid viral antigen testing of the nasopharyngeal secretions can be useful during local outbreaks of such infections.^{390,391} However, note that rapid immunofluorescent viral antigen tests may still result in a false negative for H1N1 (swine flu).

Initial Empiric Antibiotic Therapy

The foundation of infection management is to administer empiric antibiotics in patients with fever and neutropenia. This approach is necessary, because currently available diagnostic tests are not sufficiently rapid, sensitive, or specific to identify or exclude microbial causes of fever from other noninfectious causes. All neutropenic patients should be treated empirically with broad-spectrum antibiotics promptly at the first sign of infection (ie, fever). This is done to avoid the mortality associated with a delay in treatment in patients with a serious infection.^{1,392} Many highly effective antibiotic regimens are available, and are recommended based on data from randomized clinical trials.

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Selection of initial therapy should consider the following:

- The patient's infection risk assessment;
- The antimicrobial susceptibilities of pathogens isolated locally;
- The most common potentially infecting organisms, including antibiotic-resistant pathogens, such as extended spectrum beta-lactamase-producing gram-negative rods, vancomycin-resistant enterococcus (VRE), and colonization with or previous infection with MRSA;
- The potential sites of infection;
- The importance of a broad-spectrum bactericidal antibiotic regimen that includes antipseudomonal coverage;
- Clinical instability (eg, hypotension, organ dysfunction);
- Drug allergy;
- Recent antibiotic use (including prophylaxis); and
- Bactericidal nature of the antibiotic.

Recommended Approaches

The panel recommends the following approaches to initial empiric management of febrile neutropenia to be appropriate based on the results of large, randomized, controlled clinical trials (see *Initial Empiric Therapy for Fever and Neutropenia* in the algorithm).^{1,2,392}

For select, low-risk patients with fever and neutropenia, one approach is IV antibiotic monotherapy (all category 1 except where noted) with imipenem/cilastatin, meropenem, piperacillin/tazobactam, or an extended-spectrum antipseudomonal cephalosporin (cefepime [category 1] or ceftazidime [category 2B]).³⁹³⁻³⁹⁷ Local institutional bacterial susceptibilities should be considered when selecting empiric antibiotic therapy. In hospitals where infections caused by antibiotic-resistant bacteria (eg, MRSA or drug-resistant gram-negative rods) are commonly observed, policies on initial empiric therapy of neutropenic fever may need to be tailored accordingly.

Meta-analyses of randomized trials have reported that cefepime was associated with increased all-cause mortality when used as empiric therapy for neutropenic fever, although no increase in infection-related mortality was noted.³⁹⁸⁻⁴⁰⁰ However, a meta-analysis by the FDA, using additional data, did not find a statistically significant increase in mortality for cefepime-treated patients compared with controls. Thus, the FDA

concluded that cefepime remains an appropriate therapy for its approved indications.⁴⁰¹ A randomized, dual-center study of 105 patients treated with piperacillin/tazobactam or imipenem/cilastatin as empiric therapy for febrile neutropenia reported imipenem/cilastatin to have superior efficacy, although this area of research requires further investigation.⁴⁰²

Another approach for initial empiric therapy for low-risk patients with fever and neutropenia is oral antibiotic therapy (see *Initial Empiric Therapy for Fever and Neutropenia* in the algorithm). Ciprofloxacin plus amoxicillin/clavulanate (category 1) is an option for oral antibiotic therapy, with the alternative of ciprofloxacin plus clindamycin for patients allergic to penicillin. Moxifloxacin (category 1) or levofloxacin (category 2A) are other recommended options for this approach. Fluoroquinolone regimens should not be administered in patients receiving antimicrobial prophylaxis with a fluoroquinolone. Additionally, while data support the use of fluoroquinolones for prophylaxis, the risks and benefits should be evaluated for empiric therapy or other clinical scenarios. In particular, the side effects of fluoroquinolones should be taken into consideration. In 2016, the FDA issued a warning that fluoroquinolones are associated with disabling side effects involving tendons, muscles, joints, nerves, and the CNS.⁴⁰³

IV antibiotic monotherapy is the preferred treatment option for intermediate- or high-risk patients with fever and neutropenia. However, IV antibiotic combination therapy, though not routinely recommended, may be considered in higher-risk or resistant cases. In such situations, an aminoglycoside combined with an antipseudomonal agent can be considered.⁴⁰⁴⁻⁴⁰⁶ Aminoglycoside use carries the inherent risk of renal and otic toxicity. Avoiding these toxicities requires careful monitoring and necessitates frequent reassessment, but once-daily aminoglycoside dosing is associated with less renal toxicity than shorter interval dosing.⁴⁰⁷ Once-daily aminoglycoside dosing should probably not be used for treating meningitis or endocarditis based on inadequate clinical data. The use of vancomycin, linezolid, daptomycin, or quinupristin/dalfopristin is not routinely recommended. Although published studies exist regarding the use of some of these agents in neutropenic patients, the panel strongly recommends that these agents not be used routinely as initial empiric therapy because of concerns for resistance and breakthrough infections.

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For patients at high risk for *Pseudomonas* infections (eg, history of previous *Pseudomonas* infections, presence of ecthyma gangrenosum), initial combination therapy with the most active antipseudomonal agents available in the local setting should be considered.

For specific indications, the addition of IV vancomycin either to IV monotherapy or to combination therapy (see *Empiric Addition of Vancomycin*) may be considered. Support for the judicious use of vancomycin has developed because of the increased frequency of beta-lactam-resistant gram-positive infections caused by MRSA, most coagulase-negative staphylococci, penicillin-resistant viridans group streptococci and enterococci, and *Corynebacterium jeikeium*. Vancomycin should be reserved for specific indications and should not be considered as a routine component of initial therapy for fever and neutropenia.

Empiric Addition of Vancomycin

Considerable debate has occurred about the use of empiric vancomycin in patients with fever and neutropenia, as the uncontrolled use of vancomycin has facilitated the dissemination of vancomycin-resistant organisms, especially enterococci.^{408,409} The clinical concern is that a portion of infections caused by gram-positive pathogens can be fulminant and lead to rapid death in patients who are not treated promptly with appropriate antibiotics. However, a large, prospective, randomized trial from the European Organization for Research and Treatment of Cancer (EORTC) failed to show true clinical advantages for empiric vancomycin in adults.⁴¹⁰ This study reported that empiric vancomycin decreased the number of days the patients had fever but did not improve survival. The study also showed that empiric vancomycin was associated with an increased incidence of nephrotoxicity and hepatotoxicity.⁴¹⁰ A prospective randomized trial of fever and neutropenia in children has reported benefit for empiric vancomycin;⁴¹¹ however, another randomized study in children failed to show a benefit for the addition of vancomycin.⁴¹²

In addition to the occurrence of VRE, there are other vancomycin-resistant pathogens of note. Reports of vancomycin-resistant and vancomycin-intermediate sensitive *S aureus* are currently rare but are of key concern, and they underscore the need for judicious vancomycin use.^{413,414} The increase in vancomycin resistance has been associated with use of

vancomycin among hospitalized patients. The NCCN Guidelines Panel advises practitioners to adopt the recommendation of the Hospital Infection Control Practices Advisory Committee (HICPAC) of the CDC for preventing the spread of vancomycin resistance.^{415,416} Because of the increased risk for vancomycin-resistant organisms, empiric vancomycin use should be considered only in patients at high risk for serious gram-positive infection, and should not be considered as a routine component of initial therapy for fever and neutropenia. Vancomycin should be considered in the following clinical situations:

- Clinically apparent, serious IV catheter-related infection (to cover coagulase-negative staphylococcal isolates, which are usually beta-lactam antibiotic-resistant and MRSA);^{417,418}
- Blood cultures positive for gram-positive bacteria before final identification and susceptibility testing;
- Known colonization with penicillin/cephalosporin-resistant pneumococci or MRSA;
- Clinical instability (eg, hypotension or shock), pending the results of cultures;^{419,420} and
- Soft tissue infection (particularly in regions where MRSA infection is common).⁴²¹

If empiric vancomycin (or other agents for gram-positive resistant infection) is initiated in any of these situations, its use should be reassessed within 2 to 3 days of initiation. If a resistant gram-positive pathogen (eg, MRSA) is not identified, the panel recommends discontinuing the agent. Authoritative guidelines have been published on the dosing and therapeutic monitoring of vancomycin.⁴²² For management of complicated cases of *C difficile* infections, oral vancomycin can be considered (see *Site-Specific Evaluation and Treatment of Infections: Abdominal, Rectal, and Liver Infections: Clostridium difficile Colitis*).

In patients with acute leukemia receiving mucotoxic regimens, prophylaxis with ciprofloxacin and TMP/SMX have been associated with an increased risk of viridans group streptococcal infections.^{81,423,424} The broad-spectrum, gram-negative bacillary coverage and limited gram-positive pathogen activity of these drugs likely predispose patients to GI colonization and subsequent infection with such organisms.^{425,426} One study has reported

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an increased risk of breakthrough viridans group streptococcal infection following prophylaxis with levofloxacin,⁴²⁷ which has increased activity against gram-positive bacteria compared to ciprofloxacin; however, this is a single report and more data will be necessary to fully evaluate the use of newer-generation fluoroquinolones.

Although bloodstream infections by viridans group streptococci resistant to all beta-lactams are observed in patients with cancer, cefepime, imipenem/cilastatin, meropenem, and piperacillin-tazobactam have more reliable activity than ceftazidime against viridans group streptococci.⁴²⁸ The addition of vancomycin provided no benefit compared to placebo with regard to defervescence, episodes of gram-positive bacteremia, or use of empiric antifungal therapy in patients with hematologic malignancies with neutropenic fever of unknown etiology that persisted for 48 to 60 hours after initial empiric piperacillin-tazobactam.^{429,430} In patients with neutropenic fever and severe mucositis who are receiving imipenem/cilastatin, meropenem, or piperacillin/tazobactam (ie, antibiotics with activity against oral flora), it does not appear that the addition of vancomycin is advantageous. Thus, the NCCN Guidelines Panel strongly recommends that vancomycin should not be routinely added to an empiric regimen solely based on persistent neutropenic fever of unknown etiology.

Agents with Broad-Spectrum Activity Against Gram-Positive Pathogens

Decreased susceptibility to vancomycin is an increasing concern. If decreased susceptibility is found on minimum inhibitory concentration (MIC) assessment, other treatment options for resistant gram-positive infections should be considered. Linezolid, daptomycin, and quinupristin/dalfopristin are active against the majority of gram-positive organisms, including beta-lactam-resistant and vancomycin-resistant pathogens.⁴³¹⁻⁴³⁶ Resistance of gram-positive organisms to linezolid is infrequent, but this agent should be administered with caution in patients with compromised bone marrow function because of the marrow toxicity associated with its long-term use. Thrombocytopenia is most common (0.3%–10%) and increases with the duration of linezolid treatment, typically with duration of treatment greater than 2 weeks. In neutropenic patients with cancer, myeloid recovery does not seem to be delayed with short courses of linezolid;^{437,438} however,

experience with long durations of therapy (eg, more than 14 days) is limited in patients with cancer.

Vancomycin or linezolid should be used for the treatment of MRSA pneumonia in ventilated patients.⁴³⁹⁻⁴⁴² The FDA issued an alert about linezolid indicating that it is not approved for treatment of catheter-related infections, catheter-site infections, or gram-negative infections.⁴⁴³ In an open-label randomized study, patients treated with linezolid had a higher chance of death compared with those receiving vancomycin, oxacillin, or dicloxacillin for intravascular catheter-related infections with: 1) gram-negative agents alone; 2) both gram-positive and gram-negative organisms; or 3) no infection. No mortality difference by treatment was found among those who had gram-positive infections alone.⁴⁴³

Daptomycin is effective against most gram-positive pathogens, but it should not be used for the treatment of pneumonia, because it is inactivated by pulmonary surfactant.^{444,445} Daptomycin is indicated for the treatment of complicated skin and skin structure infections caused by susceptible strains of certain gram-positive microorganisms.⁴⁴⁶⁻⁴⁴⁸ A pharmacokinetic study of daptomycin in febrile neutropenic patients with cancer showed that this agent was active and well tolerated in this population (N = 29) with a median time to defervescence of 3 days following the start of treatment.⁴⁴⁹ A randomized study showed similar efficacy of daptomycin compared with vancomycin or anti-staphylococcal beta-lactams as therapy for *S aureus* bacteremia and endocarditis.⁴⁵⁰ In a prospective study in patients with cancer who were treated with daptomycin for gram-positive catheter-related bloodstream infections (N = 40), the rates of symptoms resolution at 48 hours (76% vs. 53%) and microbial eradication at 48 hours (78% vs. 34%) were higher with daptomycin compared with historical vancomycin treatment in matched-control patients.⁴⁵¹ In addition, the overall response rate was higher with daptomycin (68% vs. 32%), and the incidence of nephrotoxicity was lower. The treatment groups were comparable with regards to the rate of neutropenia, complications, adverse events, length of hospital stay, and deaths.⁴⁵¹

Quinupristin/dalfopristin is active against *S aureus* (including MRSA) and *Enterococcus faecium* (including vancomycin-resistant strains) but is inactive against *Enterococcus faecalis*. Use of quinupristin/dalfopristin has

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been limited because of the high frequency of substantial musculoskeletal symptoms.⁴⁵²

Optimal therapy for VRE infections is not well defined. Linezolid, quinupristin/dalfopristin (active against *E. faecium*, but not *E. faecalis*), and daptomycin have been used with variable success in the treatment of patients with VRE bloodstream infections.^{432,436,438,452} Removal of an infected catheter should always be strongly considered. In the absence of more definitive data, therapy with one of these agents is advised for VRE bacteremia.

Telavancin, ceftaroline, oritavancin, and dalbavancin have been approved for the treatment of complicated skin and skin structure infections caused by gram-positive pathogens, including MRSA.⁴⁵³⁻⁴⁵⁶ Ceftaroline is also indicated for the treatment of community-acquired bacterial pneumonia caused by susceptible gram-negative and gram-positive (except for MRSA) pathogens; this agent is not active against *Enterococcus faecalis*.⁴⁵⁴ There are no directive data on the use of these agents in the oncologic setting. Therefore, these agents are not currently recommended as first-line therapy.

The panel recommends that the use of linezolid, daptomycin, and quinupristin/dalfopristin be limited to specific situations involving infections caused by documented vancomycin-resistant organisms, or for patients in whom vancomycin is not an option. Although studies have been published in patients with neutropenia, the NCCN Guidelines Panel strongly recommends that these agents not be used as routine empiric therapy for neutropenic fever because of concerns about the emergence of resistance and toxicity.

Initial Empiric Therapy for Patients Who Are Clinically Unstable

Sepsis is suggested by signs of clinical instability including hypotension, tachypnea, new or worsening tachycardia, mental status changes, decreased urine output, and organ dysfunction. Initial therapy for sepsis should broadly cover pathogens that are likely to cause sepsis while minimizing the potential for inadequate treatment.⁴¹⁹ Unlike the stable patient with neutropenic fever, modifying antibiotics based on culture data may not be possible for the patient with sepsis if the initial regimen does

not provide adequate coverage. The antibiotic regimen should be modified, if necessary, after culture results and susceptibility are known.

The initial empiric regimen for the neutropenic patient with clinical instability may include a broad-spectrum beta-lactam (eg, imipenem/cilastatin, meropenem, piperacillin-tazobactam) plus an aminoglycoside and vancomycin. Addition of fluconazole or an echinocandin should be strongly considered in patients not receiving antifungal prophylaxis. Local susceptibility patterns and recent antibiotic use should be taken into account when devising the antibiotic regimen.⁴¹⁹ In hospitals where infections by antibiotic-resistant bacteria (eg, MRSA or drug-resistant gram-negative rods) are commonly observed, policies on initial empiric therapy of neutropenic fever may need to be tailored accordingly. Some experts also suggest that patients who have a history of *P aeruginosa* colonization or of invasive disease should receive combination therapy with an antipseudomonal beta-lactam plus an aminoglycoside or ciprofloxacin.

For cases of septic shock, rapid interventions are needed. Fluid resuscitation, oxygen, invasive hemodynamic monitoring, and vasopressor agents may be required. Stress doses of hydrocortisone (IV 50 mg every 6 hours with or without fludrocortisone oral 50 mcg daily) have been associated with decreased mortality in patients with septic shock and with insufficient adrenal reserve.⁴⁵⁷⁻⁴⁶¹ Stress-dose corticosteroids are recommended for patients with septic shock who require vasopressor support.^{419,462,463} High-dose corticosteroids have not shown any benefit in the setting of septic shock or severe sepsis, and may be associated with increased risks for secondary infections.⁴⁶⁴⁻⁴⁶⁷

Outpatient Management of Patients with Neutropenic Fever

Initial Evaluation of Risk

Patients with neutropenia may be categorized into either a high- or low-risk group using criteria derived either from validated clinical prediction rules based on risk models or from clinical trial eligibility criteria.^{3,4,78,468-471} Risk assessment attempts to predict the probability that a neutropenic patient will experience serious complications during a febrile episode. This assessment helps to determine whether a patient at low risk for serious

complications could safely receive treatment outside of the hospital and which initial empiric therapy with oral antibiotics is appropriate.

Prospective trials have indicated that febrile neutropenic patients can be initially evaluated in the hospital, ambulatory clinic, or home and then treated effectively with broad-spectrum IV therapy, sequential IV then oral therapy, or oral therapy.^{470,472,473} Only centers with the necessary infrastructure should treat low-risk patients in an outpatient setting, preferably in an investigational context.

Risk assessment should be performed as part of the initial evaluation (see *Initial Risk Assessment for Febrile Neutropenic Patients* in the algorithm). A widely used and validated prediction rule to assess risk was developed by the Multinational Association of Supportive Care in Cancer (MASCC). The MASCC risk index is derived from a model that includes weighted scores based on burden of illness (eg, extent of febrile neutropenia), evidence of clinical instability or comorbid conditions (eg, hypotension, chronic obstructive pulmonary disease, dehydration), history of prior fungal infections, site of medical care (eg, inpatient, outpatient), and age (cut off of 60 years); patients with MASCC risk index scores less than 21 are considered at high risk for developing infectious complications (see *Risk Assessment Resources* in the algorithm).⁴⁷⁴⁻⁴⁷⁷ It is also acceptable to employ risk assessment criteria that have been identified in large clinical trials to distinguish between patients at low and high risk for complications during the course of neutropenia. It is important to note that risk stratification generally, as well as the MASCC risk index specifically, were validated in adults. No generalizable, cross-validated, risk-stratified management exists for pediatric patients with febrile neutropenia.

The MASCC prediction rule does not consider the duration of neutropenia to be a deciding factor that influences the clinical course of treatment;⁴⁷⁶ however, the panel acknowledges that the duration of anticipated neutropenia may be helpful in risk assessment. A patient with severe neutropenia (ANC \leq 100 neutrophils/mcL) anticipated to last greater than or equal to 7 days may be considered at high risk, regardless of the MASCC risk index score or other risk factors listed in the guidelines. This recommendation is also in agreement with those of the current IDSA guidelines on the management of neutropenic patients with cancer.¹⁶

Duration of Neutropenia and Risk

For decades, clinicians have regarded depth and duration of neutropenia as critical determinants of a patient's risk for infection. Once the relationship between the ANC and incidence of infections was demonstrated, the importance of increased neutrophil counts for improved outcomes was evident. In the original study by Bodey et al,¹⁹ the fatality rate was highest (80%) among patients with initial neutrophil counts less than 100 cells/mcL that did not change during the first week of infection compared to the lower rate (27%) seen in patients with initial neutrophil counts less than 1000 cells/mcL that rose to greater than 1000 cells/mcL with treatment.¹⁹ Subsequently, clinical trials have reported that response rates to antibiotic regimens are highly influenced by trends in the neutrophil count during febrile episodes. In one study, the overall response rate was 73% when the initial neutrophil count increased compared to 43% when it decreased or remained unchanged ($P < .0001$). The response rate in patients who recovered from neutropenia was 67%, compared to only 32% in patients who remained severely neutropenic ($P < .0001$).

In 1988, Rubin et al⁴⁷⁸ examined the influence of the duration of neutropenia on the response to empiric antimicrobial therapy in patients with fever of undetermined origin.⁴⁷⁸ Patients with fewer than 7 days of neutropenia had a 95% response rate to initial antimicrobial therapy, compared to a 32% response rate in patients with more than 14 days of neutropenia ($P < .001$); however, intermediate durations between 7 and 14 days had response rates of 79%.⁴⁷⁸

Bone marrow recovery is an important factor that influences outcome during the febrile neutropenic episode. Delayed bone marrow recovery might be anticipated in certain patient subsets (eg, patients who have received multiple cycles of myelosuppressive chemotherapy, HCT recipients, patients with known bone marrow metastases, patients who have received radiation therapy to the pelvis, spine, or long bones). Most patients with solid tumors have neutropenia lasting less than 7 days and are generally lower risk. Several studies have demonstrated the ability of clinicians to predict a patient's anticipated duration of neutropenia. In prospective studies of patients identified as low risk for morbidity and mortality from febrile neutropenia, the expected duration of neutropenia

was used as an eligibility criterion. Clinicians were correctly able to identify patients with an expected short duration of neutropenia (ie, fewer than 7–10 days) in more than 80% of the cases,^{472,473,479} indicating that the duration of neutropenia can be one of several factors in selecting patients for outpatient management of neutropenic fever.

Evaluation of Patients for Outpatient Therapy for Neutropenic Fever

Outpatient therapy has become a common practice in low-risk patients with neutropenic fever. Several single-center clinical trials generally support the shift in care for low-risk patients to the outpatient setting; the hospital is not necessarily a safer place for low-risk patients, given the documented hazards of hospitalization.^{480,481} However, not all centers are equipped to manage outpatient treatment, and some patients with fever are not appropriate candidates. Early success with this type of therapy has been predicated on the ability to accurately determine an individual patient's risk of developing complications associated with infection and on the presence of an adequate infrastructure for treatment and monitoring.

Once a level of risk has been identified, it can then be used to determine the appropriate site of care and route of broad-spectrum antibiotics administration. The panel recommends that all high-risk patients receive hospital care with broad-spectrum IV therapy (see *Initial Risk Assessment for Febrile Neutropenic Patients* in the algorithm). Low-risk patients may be treated in the hospital with oral or IV antibiotics, in an ambulatory clinic, or at home if adequate follow-up care can be provided (ie, 24 hours per day, 7 days per week). Outpatient therapy should be considered only for low-risk patients who consent to home care, have a telephone, have access to emergency facilities, have an adequate and supportive home environment, and are within 1-hour travel time of a medical center or physician's office. Outpatient therapy requires a period of early assessment and an observation period of 2 to 12 hours (category 2B) (see *Outpatient Therapy for Low-Risk Patients* in the algorithm). The assessment requires a careful examination, review of laboratory results, review of social criteria for home therapy (as described above), and assessment of whether oral antibiotics are feasible. The observation period is used to confirm that the patient is at low risk and to ensure the clinical stability of the patient; to administer the first dose of antibiotics and monitor for any reactions; to organize discharge

plans for home and follow-up care; and to provide patient education. A telephone follow-up should be performed within 12 to 24 hours. This assessment and observation can be performed during a short hospital stay or in an ambulatory facility or office staffed with qualified health care professionals. Providers who perform the early assessment and follow-up should be well trained (eg, a physician, nurse, physician assistant, and/or nurse practitioner) and should have experience and expertise in managing patients with fever and neutropenia.

Outpatient Regimens

Outpatient antimicrobial treatment may consist of broad-spectrum IV antibiotics given at home or in the clinic, or an oral regimen for carefully selected patients.⁴⁸² For selected low-risk patients, the combination of ciprofloxacin with amoxicillin/clavulanate is considered the oral regimen of choice based on well-designed randomized trials (category 1) (see *Outpatient Therapy for Low-Risk Patients* in the algorithm). Although some of these trials were performed in an inpatient setting, they demonstrate the efficacy of the oral combination compared with standard IV therapy in the low-risk population.^{468,483,484} Ciprofloxacin plus clindamycin is an acceptable alternative for penicillin-allergic patients.^{3,16} However, ciprofloxacin monotherapy is not considered by the panel to be an adequate broad-spectrum agent because of the suboptimal coverage for gram-positive organisms and potential for serious breakthrough infections caused by viridans group streptococci.⁴²⁵ Nonetheless, several small studies have used high-dose oral ciprofloxacin alone in low-risk patients with fever and neutropenia.⁴⁸⁵⁻⁴⁸⁷

Moxifloxacin (category 1) is a newer-generation fluoroquinolone that was shown to be safe in low-risk patients with neutropenic fever.⁴⁸⁸ In a double-blind, randomized trial, single-daily moxifloxacin was compared with twice-daily ciprofloxacin plus amoxicillin/clavulanic acid in the treatment of low-risk febrile neutropenic patients with cancer.⁴⁸⁹ Low risk was defined as an MASCC score greater than 20 that is equivalent to a less than 10% complication rate. Of the 333 patients treated on this trial, 169 were given moxifloxacin, and 169 patients were treated with the ciprofloxacin combination. Therapy success was observed in 80% of patients treated with moxifloxacin compared with 82% of patients given ciprofloxacin

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combination therapy (95% CI, -10%–8%, $P = \text{NS}$). Despite similar therapy success rates, the reasons for failure of the treatment differed between the two groups. Moxifloxacin-treated patients had greater microbial complications including persistent or breakthrough resistance, while patients given the ciprofloxacin combination had mostly drug intolerance or adverse events that resulted in treatment failure. Rates of patients treated with moxifloxacin compared to ciprofloxacin combination with serious adverse events (6% vs. 8%, $P = .23$) or any adverse event (44% vs. 52%; $P = .13$) were similar. Moxifloxacin has a longer half-life, which allows for once-daily dosing. It is more active against gram-negative bacteria but has limited activity against *P aeruginosa* compared to ciprofloxacin. Therefore, both of these treatments are recommended for low-risk patients with febrile neutropenia, but the choice of regimen may be influenced by local resistance and infection patterns.

Two other fluoroquinolones, levofloxacin and ofloxacin, have been tested for the treatment of low-risk patients with febrile neutropenia. Levofloxacin is a category 2A recommendation following studies demonstrating safety and efficacy^{87,88} (see *Antibacterial Prophylaxis*). Data from a 2008 self-administered survey indicated that 50% of oncologists were using levofloxacin as empiric therapy for low-risk patients with febrile neutropenia.⁴⁹⁰ Ofloxacin was safe in low-risk patients with neutropenic fever in a randomized trial, though an early death in a non-hospitalized patient in this trial underscores the need for close monitoring.⁴⁷² Ofloxacin is not currently recommended.

NCCN Recommendations for Outpatient Therapy

The panel feels that outpatient therapy with a fluoroquinolone should be based on reliable gram-negative bacillary activity of the antibiotic that includes *P aeruginosa* and local antibacterial susceptibilities. Ciprofloxacin plus amoxicillin/clavulanate (or ciprofloxacin plus clindamycin in penicillin-allergic patients) is the standard oral outpatient antibiotic regimen for low-risk patients with neutropenic fever. There is also evidence supporting quinolone monotherapy in this setting.

Moxifloxacin (category 1) and levofloxacin (category 2A) are recommended quinolone monotherapies. These recommendations for quinolone-based outpatient regimens for neutropenic fever only apply to low-risk patients

who have not received a quinolone as prophylaxis. Additionally, in order for a low-risk patient to receive oral antibiotics, the patient should not present with nausea or vomiting, and must be able to tolerate oral medications (see *Outpatient Therapy for Low-Risk Patients* in the algorithm). IV therapy may also be used for outpatient treatment of low-risk patients with fever and neutropenia when treatment is given either in the home or day clinic setting (see *Outpatient Therapy for Low-Risk Patients* in the algorithm). Several IV outpatient regimens for low-risk patients have been studied in nonrandomized or small open trials, including IV ceftazidime, imipenem/cilastatin, and aztreonam plus clindamycin.^{3,398,468,470,473,491}

Once-daily ceftriaxone has been used for empiric antibiotic therapy in a few noncomparative studies in centers where *Pseudomonas* is not a common pathogen.⁴⁹² However, most *P aeruginosa* isolates are resistant to ceftriaxone. Although ceftriaxone combined with a once-daily aminoglycoside is a convenient regimen for outpatient IV administration, an aminoglycoside without an antipseudomonal beta-lactam may not be effective against *P aeruginosa*, which remains an infrequent but potentially lethal pathogen. Therefore, the panel cannot recommend ceftriaxone (with or without an aminoglycoside) as empiric therapy for neutropenic fever. If this regimen is used, it should be restricted to low-risk patients at centers where *P aeruginosa* infection is uncommon. In addition to the antimicrobial spectrum, other factors to consider in the choice of an outpatient regimen include stability of the reconstituted drugs, ability to manage IV infusions, and VADs.

Follow-Up of Outpatients with Fever and Neutropenia

Follow-up management can be performed at the patient's home or in the physician's office or clinic. The panel recommends that patients be assessed daily while febrile, although some experts feel that less frequent follow-up may be appropriate after fever defervescence (see *Outpatient Therapy for Low-Risk Patients* in the algorithm). For the first 72 hours after initiation of empiric therapy, the patient should be assessed daily at home or at the clinic for treatment response, signs of toxicity, and treatment compliance. If the disease is responding to the treatment regimen, then daily follow-up by telephone is sufficient. A return to the clinic is recommended for any positive culture, for persistent or recurrent fever at

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3 to 5 days, if serious subsequent infections or adverse events develop, if the patient is unable to continue the prescribed antibiotic regimen (eg, intolerance to the oral regimen), or for infusion of IV antibiotics.

Empiric Antifungal Therapy in Persistent Neutropenic Fever

Empiric antifungal therapy for persistent febrile neutropenia unresponsive to broad-spectrum antibacterial agents is initiated in neutropenic patients known to be at risk for invasive fungal infections, but who do not have early detection of those infections following clinical examination and collection of cultures.^{6,493-496} Traditionally, empiric antifungal therapy is initiated after 4 or more days of empiric antibiotic therapy for fever and neutropenia, in patients who have remained febrile or who have recrudescing fever (see *Results of Daily Monitoring* in the algorithm). The timing to add empiric antifungal therapy varies with the risk of invasive mold infections, but generally ranges between 7 to 10 days of neutropenic fever despite empiric antibiotic therapy. In patients at high risk for mold infections (eg, neutropenia lasting >10 days, allogeneic HCT recipients, treatment with high-dose corticosteroids), the NCCN Guidelines Panel recommends adding empiric antifungal agents after 4 days unless the patient is receiving prophylaxis with mold-active agents. The concept of using empiric antifungal therapy was established in the 1970s and 1980s when about 20% of patients being treated for acute leukemia or undergoing HCT would develop an invasive fungal infection due to *Candida* or *Aspergillus* species by day 20 of neutropenia.⁴⁹⁷ The toxicity of amphotericin B limited its use as routine prophylaxis, which would entail exposing more patients to a toxic drug over a prolonged period compared with empiric therapy. With the widespread use of fluconazole prophylaxis in the 1990s among high-risk patients with acute leukemia and in HCT recipients, the incidence of invasive candidiasis in these patients decreased substantially, although breakthrough candidemia by fluconazole-resistant strains occurred.^{73,103} Empiric antifungal therapy for neutropenic fever principally involved switching from fluconazole to amphotericin B to broaden the antifungal spectrum to include molds such as *Aspergillus*. Subsequently, L-AmB proved to be safer than and as effective as conventional amphotericin B for empiric antifungal therapy.⁴⁹⁸

Amphotericin B products are considered a category 2B recommendation for prophylaxis and an empiric antifungal therapy for persistent or recurrent neutropenic fever of unknown etiology based on their toxicity and the availability of safer and equally effective alternative agents. In cases where there is a stronger clinical suspicion of mold infection than neutropenic fever alone (eg, a new pulmonary nodule in a patient with fever and prolonged neutropenia), use of an amphotericin B formulation (or a mold-active azole or an echinocandin) should be considered pending additional diagnostic evaluation. In general, lipid formulations of amphotericin B are preferred over the conventional formulation because they are less toxic.⁴⁹⁹ This recommendation is stronger in patients with risk factors for acute renal failure, such as pre-existing renal disease, HCT recipients, and coadministration of nephrotoxic agents.^{174,175,500}

Fluconazole has been used successfully as empiric therapy for neutropenic fever in patients not receiving prophylaxis but is limited by lack of activity against molds.^{501,502} IV followed by oral itraconazole solution was as effective as, but less toxic than, conventional amphotericin B when used as empiric therapy in an open, randomized study;⁵⁰³ these results led to FDA approval of oral itraconazole solution for this indication. IV itraconazole is no longer available in the United States. Itraconazole in the capsule formulation has erratic oral bioavailability and is therefore not suitable as empiric antifungal therapy. Additionally, the capsule formulation should be used with caution when concurrent with histamine H2-receptor antagonists and PPIs as these medications can reduce absorption of the itraconazole capsule.¹²⁰ Itraconazole has negative inotropic effects and is contraindicated in patients with evidence of ventricular dysfunction or a history of congestive heart failure.¹²⁰

Voriconazole was compared with L-AmB in an open, randomized study of empiric antifungal therapy (N = 837 patients, 72% with hematologic malignancies).⁵⁰⁴ The overall success rates for preventing invasive fungal infections were 26% with voriconazole and 31% with L-AmB. Empiric voriconazole was associated with fewer breakthrough fungal infections (1.9% vs. 5.0%; $P = .02$), with the greatest protective benefit occurring in pre-specified high-risk patients (relapsed acute leukemia and allogeneic HCT). Because the noninferiority of voriconazole versus L-AmB was not

demonstrated in this study based on prespecified criteria, voriconazole did not receive FDA approval for use as empiric therapy.^{494,505} Voriconazole is an option (category 2B) for empiric therapy in patients at high risk for invasive mold infection.

Echinocandins are active against *Candida* and *Aspergillus* species but have unreliable activity against most other opportunistic fungi. Caspofungin was compared with L-AmB as empiric therapy for fungal infections in a randomized double-blind study in patients with persistent fever and neutropenia (N = 1095).⁵⁰⁶ The overall success rates were 34% in both caspofungin and L-AmB recipients. The proportion of patients who survived at least 7 days after therapy was greater in the caspofungin group (92.6% vs. 89.2%, $P = .05$). The rates of breakthrough fungal infections and resolution of fever during neutropenia were similar between the 2 groups. Among patients with a baseline invasive fungal infection, the success rate was higher with caspofungin versus L-AmB (52% vs. 26%; $P = .04$) and the mortality rate was lower with caspofungin (11% vs. 44% with L-AmB).⁵⁰⁶ Drug-related toxicities and premature withdrawals because of drug-related adverse events were significantly lower in caspofungin recipients. This study supports caspofungin as an option for empiric antifungal therapy. Caspofungin is approved for use as empiric treatment of presumed fungal infection in patients with fever and neutropenia.⁵⁰⁷ Micafungin was compared to voriconazole in a randomized, cooperative group, open-label trial as empiric antifungal therapy in patients with hematologic malignancy and febrile neutropenia. This study found no significant differences in clinical efficacy between the 2 therapies, although discontinuation due to drug-related adverse effects occurred less frequently in patients treated with micafungin.⁵⁰⁸ Another echinocandin, anidulafungin, has not been studied specifically for empiric antifungal therapy; however, some panel members would consider it likely to be effective, based on the data for caspofungin and micafungin.

Posaconazole and isavuconazonium sulfate can be considered for patients who have invasive, refractory infections or who have intolerance to amphotericin B formulations. Neither agent is approved by the FDA as either primary or invasive refractory therapy for invasive fungal infections.

It is unclear whether patients who are already receiving mold-active prophylaxis should subsequently receive empiric antifungal therapy with an additional or different antifungal solely based on persistent neutropenic fever.⁵⁰⁹ One approach has been to evaluate such patients with a high-resolution CT scan of the chest, in search of lesions suspicious for invasive fungal disease. CT scanning in this setting has not been validated but it is a reasonable approach, in concert with careful physical examination and blood cultures, in an effort to identify a source of persistent unexplained fever in patients with neutropenia. Laboratory markers (such as serum galactomannan and beta-glucan) have important limitations, including false-negative results in some patients already receiving prophylactic or empiric antifungals.^{510,511} A meta-analysis showed the sensitivity of the galactomannan test for proven aspergillosis to be only 70% among patients with hematologic malignancies and 82% among HCT recipients.⁵¹² However, these antigen-based assays have a high negative predictive value in the absence of mold-active antifungal therapy.

In patients undergoing chemotherapy for acute leukemias and receiving only yeast-active prophylaxis with fluconazole, 3% to 4% developed invasive fungal infections despite prophylaxis.^{100,105} Empiric antifungal therapy with anti-mold activity would be expected to benefit these few patients without incurring a greater risk of toxicity.

Preemptive antifungal therapy uses characteristic changes in chest or sinus CT scans, laboratory markers, or both to trigger modification of the antifungal regimen, rather than providing empiric antifungals to all persistently febrile neutropenic patients. Maertens and colleagues⁵¹³ evaluated a preemptive strategy of incorporating L-AmB in high-risk neutropenic patients (who received fluconazole prophylaxis) based on such pre-specified triggers, including serially positive serum galactomannan tests, a bronchoalveolar lavage (BAL) showing mold, and/or suggestive chest CT in patients with persistent fever or with signs of invasive fungal infection. A total of 136 treatment episodes (among 88 patients) were evaluated. Among these, neutropenic fever developed in 117 cases, of which 35% would have met the existing criteria for empiric antifungal therapy. Using the preemptive strategy, antifungal therapy was given in 7.7% (9 of 117 episodes of neutropenic fever) of patients rather than up

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to one third of patients who might have received it on the basis of fever alone.⁵¹³ In addition, seropositivity for galactomannan led to early initiation of antifungal therapy in 10 non-febrile episodes. This approach detected all cases of invasive aspergillosis but missed 1 case of invasive fungal infection that involved disseminated zygomycosis resulting in death. Two cases of breakthrough candidemia were detected by conventional culture methods and successfully treated.⁵¹³ In a randomized trial of patients with neutropenic fever, a preemptive strategy was associated with an increased incidence of probable or proven invasive fungal infections (9% vs. 3% in empirically treated group; $P < .05$), although without an increase in overall mortality and ultimately with a decreased cost of antifungal drugs compared to empiric therapy.⁵¹⁴ Taken together, the panel considers the evidence supporting preemptive antifungal therapy to be too preliminary to support its routine use.

Follow-up of Patients with Neutropenic Fever

Daily evaluation by a health care professional who is experienced in treating patients with fever and neutropenia is essential. The daily examination should focus on a site-specific assessment, and an infectious disease consultation should be considered for all complicated cases or progressive infections. Daily follow-up should include an evaluation of response to empiric antimicrobial therapy, both in terms of fever trends and changes in signs and/or symptoms of infections. Time to defervescence ranges from 2 to 7 days (median, 5 days) for febrile patients with cancer with neutropenia who receive appropriate initial antibiotic therapy.⁵¹⁵ This rate of fever response should be considered when assessing the need to adjust initial antibiotics; random additions or changes for persistent fever are discouraged in the absence of clinical or microbiologic evidence. The expected slow defervescence of fever also complicates decisions regarding the need for repeat blood cultures. Although some experts recommend daily blood cultures until the patient becomes afebrile, increasing evidence suggests that daily blood cultures are unnecessary in stable neutropenic patients with persistent fever of unknown etiology.⁵¹⁶ As part of follow-up, patients should also be evaluated for potential drug toxicities by liver and kidney function tests (generally conducted at least twice weekly).

Current bacterial blood culture systems (such as the BACTEC™ continuous-monitoring culture system) can detect 90% to 100% of bacterial bloodstream pathogens within 48 hours of culture. For this reason, routine ordering of additional cultures before obtaining the results from the initial series is discouraged. Daily review of previously obtained cultures is critical, and the panel recommends documenting the clearance of bloodstream bacterial or fungal infections with repeat blood cultures. The overall response to initial empiric antimicrobial therapy should be evaluated 3 to 5 days from initiation of empiric therapy.

Follow-up Therapy in Responding, Clinically Stable Patients

Patients who have infections that respond to empiric therapy should exhibit decreasing fever trends, show stable or improving signs and symptoms of infection, and be hemodynamically stable. For these patients, no change is needed to the initial empiric regimen, and if patients were started appropriately on an agent for Gram-positive resistant infections, they should continue with the course of therapy. If patients received an agent for Gram-positive-resistant infections as part of their initial empiric therapy, but they do not have a pathogen recovered or a site of infection identified justifying such treatment, then treatment should be discontinued. Similarly, the appropriateness of empiric Gram-negative therapy should be reassessed. It is generally recommended that antibiotics be continued until the ANC is 500 cells/mcL or greater, and is increasing (see *Results of Daily Monitoring* in the algorithm).

Patients with fever of unknown origin who become afebrile soon after starting empiric therapy may have empiric antibiotics discontinued with ANC recovery (ANC ≥ 500 neutrophils/mcL) as long as the neutrophil count is likely to continue to increase (patients are often receiving a growth factor). This recommendation assumes that the patient is clinically well and afebrile for at least 24 hours before antibiotic discontinuation. Patients who become afebrile but remain persistently neutropenic (ANC < 500 neutrophils/mcL) should receive a more prolonged course of antibiotic therapy until the neutropenia resolves, although de-escalation to prophylactic antibiotics should be considered⁵¹⁷ (see *Results of Daily Monitoring* in the algorithm). Lower-risk patients can also be switched to oral antibiotics until their

neutropenia resolves (eg, 500 mg ciprofloxacin every 8 hours plus 500 mg of amoxicillin/potassium clavulanate every 8 hours).

Follow-up Therapy in Persistently Febrile but Otherwise Hemodynamically Stable Patients

Patients with recurrent fever should be reassessed promptly to determine the need for either a change in their antibiotic regimen or for the addition of antifungal therapy. The hemodynamically stable patient with persistent fever of unknown etiology may be safely watched without altering the initial antimicrobial therapy. Modifications of initial empiric antibiotic therapy should be based on specific new clinical findings and/or new microbiologic results; fever alone should not prompt changes in antimicrobial therapy. The exception is consideration of empiric antifungal therapy in patients who have persistent or recurrent fever after 4 to 7 days of empiric antibacterial therapy and who are not receiving mold-active prophylaxis (see *Results of Daily Monitoring* in the algorithm). Documented infections are usually treated according to the site, pathogen, and at least until ANC recovery (see *Site-Specific Evaluation and Treatment of Infections*).

Follow-up Therapy in Non-responding, Clinically Unstable Patients

Although fever resolution may be slow during neutropenia, persistent fever may result from a noninfectious etiology, such as drug-induced fever. Persistent fever may also represent an inadequately treated infectious process, such as a nonbacterial infection (fungal or viral), a bacterial infection that is resistant to empiric antibiotics, a venous access or closed space infection, or inadequate antimicrobial serum levels. It is important to recognize that documented deep tissue infections may take longer than fever of unknown etiology to respond to antimicrobial therapy. In these cases, daily assessment of clinical improvement or failure depends on radiographic, culture, and clinical examination data, and on the fever trends. Unusual infections (eg, toxoplasmosis) may complicate neutropenia, particularly if immunosuppressive agents (eg, high-dose corticosteroids) are also used. The panel strongly recommends an infectious disease consultation for these patients.

Patients who remain persistently or intermittently febrile, show no improvement in signs/symptoms of infections, have persistent positive

blood cultures, and/or may be hemodynamically unstable should be considered non-responsive to initial empiric antimicrobial therapy. These patients pose a serious management challenge and are at increased risk of infection-associated morbidity and mortality. For such patients, antimicrobial coverage should be broadened to include anaerobes, resistant gram-negative rods, and resistant gram-positive organisms, as clinically indicated. Antifungal therapy with activity against molds may be considered for patients with fever continuing for 4 or more days following initiation of empiric antibiotic therapy (see *Results of Daily Monitoring* in the algorithm). The lack of response may suggest an infection with a pathogen resistant to the antimicrobial therapy being used, inadequate serum or tissue levels of the antibiotic(s), infection at a vascular site (ie, catheter or “closed space” infection), or emergence of a second infection. Some documented infections fail to respond to appropriate therapy because of associated profound neutropenia. If possible, treatment should be optimized using broad-spectrum antibiotic combinations that minimize other organ toxicity.

Both NCCN and ASCO⁵¹⁸ have guidelines for the use of prophylactic colony-stimulating factors (CSFs) in neutropenic patients (see [NCCN Guidelines for Myeloid Growth Factors](#)). It is not clear whether these agents are useful as adjunctive therapy for established infectious events. Although the data supporting their use are limited, adjunctive therapy with G-CSF or granulocyte-macrophage CSF (GM-CSF) should be considered (category 2B) in neutropenic patients with serious infectious complications such as pneumonia, invasive fungal infections, or any type of progressive infection.

Deescalation and Duration of Therapy for Patients with Documented Infections

Targeted treatment of documented infections should be continued for patients whose infections are responding to therapy. The need to continue empiric Gram-negative therapy may be reassessed in these patients, discontinuing Gram-negative therapy if appropriate.⁵¹⁹ The duration and deescalation of antimicrobial therapy is dictated by the 1) underlying site of infection; 2) causative organism(s); and 3) patient's clinical condition, response to treatment, and neutrophil recovery (see *Follow-up Therapy*

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for *Responding Disease* in the algorithm). For example, most skin and soft tissue infections can be treated with 7 to 14 days of therapy. For most bacterial bloodstream infections, 7 to 14 days of therapy is usually adequate, with longer durations (10–14 days) recommended for gram-negative or more complicated bacteremias. For all *S aureus* bloodstream infections, treatment should be continued for at least 4 weeks after documentation of a first negative blood culture. In cases of endovascular involvement, treatment may need to be prolonged. Treatment for bloodstream infections caused by yeast should be continued for at least two weeks after the first negative blood culture is obtained. Catheter removal is recommended for septic phlebitis, tunnel infection, or port pocket infection and if bloodstream infection is caused by *Candida*, *S aureus*, *Pseudomonas aeruginosa*, *Corynebacterium jeikeium*, *Acinetobacter*, *Bacillus* organisms, atypical mycobacteria, yeasts, molds, VRE, *Stenotrophomonas maltophilia*, and other multi-drug resistant organisms. A duration of treatment lasting 7 to 14 days is usually indicated for infections of the lungs (eg, bacterial pneumonia) or sinuses.⁵²⁰ Complex intra-abdominal infections, such as typhlitis, should be treated until all evidence of infection has resolved and the patient has recovered from neutropenia. For fungal infections with *Candida*, treatment should be continued for at least 2 weeks after documentation of a first negative blood culture. Invasive mold infections (eg, aspergillosis) generally require treatment for a minimum of 12 weeks.

The duration of treatment for HSV (uncomplicated, localized disease to the skin) and VZV (uncomplicated, localized disease to a single dermatome) infections is typically 7 to 10 days.⁵²¹⁻⁵²³ Life-threatening infections, such as invasive fungi or CMV, require individualized courses of therapy that are often prolonged. The duration of anti-infective therapy may need to be extended if further chemotherapy is required while treating a significant infection. This may occur with infections that complicate leukemia or lymphoma treatments in which multiple cycles of intensive chemotherapy are required.

In patients with influenza, oseltamivir is approved for a duration of 5 days in ambulatory patients who are otherwise healthy individuals with intact immune systems. A longer course of treatment (eg, at least 10 days) that

continues until resolution of symptoms should be considered in the highly immunocompromised.

Patients with documented infections who become afebrile after the initiation of the empiric antibiotic regimen and who are at low risk for complications associated with infection may be candidates for outpatient antibiotic therapy. The regimen, whether oral or IV, should be appropriate for neutropenic fever and have activity against the specific infection.

Development of Clinical Instability While Receiving Antibacterial Therapy

It is essential to recognize the early signs of breakthrough infections after the initiation of antibacterial therapy. Although persistent neutropenic fever alone is not an indication to modify the antibacterial regimen, signs of breakthrough infection should prompt additional evaluation and consideration of therapy modification.

New findings suggestive of sepsis (eg, hypotension, tachycardia, mental status changes, organ dysfunction) require the following: 1) repeat physical examination to identify the source of infection; 2) repeat blood cultures; 3) consideration of radiologic studies; and 4) empiric modification of antimicrobial therapy pending culture results.⁴¹⁹ Information about previous use of antibiotics and local sensitivity patterns of gram-negative pathogens should guide empiric changes. Empiric addition of vancomycin is warranted in the unstable patient. In patients receiving ceftazidime, the possibility of breakthrough infections (either from extended spectrum beta-lactamase-producing or from cephalosporinase-producing gram-negative rods) should be considered and switching to imipenem/cilastatin or meropenem is appropriate pending culture results. *Stenotrophomonas maltophilia* or carbapenem-resistant *P aeruginosa* may cause breakthrough sepsis in patients receiving imipenem/cilastatin or meropenem; consider empiric modification to a regimen containing piperacillin-tazobactam, an aminoglycoside, and TMP/SMX. In patients not receiving a systemic antifungal agent, addition of fluconazole or an echinocandin should be strongly considered for possible candidemia. The antibiotic regimen should then be tailored based on culture and radiologic results.

Site-Specific Evaluation and Treatment of Infections

The NCCN Guidelines provide recommendations for site-specific evaluation and therapy for infections of the mouth and esophagus, sinuses, liver, abdomen, rectum, vascular access sites, lungs, skin/soft tissue, urinary tract, and CNS. This section is tailored to patients with neutropenia or those who are otherwise significantly immunocompromised (eg, HCT recipients).

Mouth and Esophageal Infections

The mouth and esophagus are common sites of infection in patients with fever and neutropenia. This site predilection occurs because of the propensity of the mouth and alimentary tract mucosa to be disrupted by cytotoxic therapy, which can cause mucositis. Unfortunately, the characteristics of this disruption are not etiology specific, and important viral and fungal pathogens are often only distinguished by microbiologic culture. Empiric antibiotic therapy must consider the endogenous anaerobic flora and the shift in oral flora, which occur with serious illness or antibiotic use. The increased frequency of HSV reactivation and severity of these infections in patients with cancer are well known and preventable. The incidence of HSV reactivation in immunocompromised patients may approach 50% to 75%, but it is nearly zero in those who receive prophylaxis with appropriate antiviral agents.⁵²⁴ HSV infections are associated with more extensive mucosal damage, increased secondary infections, and significantly prolonged healing time. Baglin et al⁵²⁵ reported that patients with fever and neutropenia who experienced concomitant HSV reactivation and were treated with appropriate antiviral therapy had a significant decrease in the number of days with fever.⁵²⁵ Ulcerations of the oral mucosa may be due to HSV infections or fungal sources. A culture should be obtained to determine the pathogenic organism, and addition of antiviral or systemic antifungal therapy should be considered, pending results. Vesicular lesions are most often caused by herpes virus infections and should be treated with antivirals pending culture (or other diagnostic assays) results (see *Initial Clinical Presentation: Mouth/Mucosal Membrane* in the algorithm).

Systemic or topical antifungal agents can be used to treat thrush. Because of the risk of candidemia, systemic antifungal therapy is advised in

neutropenic patients. Fluconazole is recommended as first-line therapy for thrush (see *Initial Clinical Presentation: Mouth/Mucosal Membrane* in the algorithm). If the infection does not respond, the dose of fluconazole can be increased up to 800 mg daily (in adults with normal renal function).⁵²⁶ Although cross-resistance among azoles may occur, oral voriconazole or posaconazole are reasonable oral options for thrush that is refractory to fluconazole. Echinocandins can be used for patients with azole-refractory mucosal candidiasis. Though amphotericin B formulations are also effective, they are not recommended because of toxicity.

Thrush along with retrosternal burning, chronic nausea, or odynophagia should raise suspicion for *Candida* esophagitis. However, *Candida* esophagitis may occur in the absence of oral thrush, especially in patients receiving oral topical antifungal agents. Definitive diagnosis of esophageal candidiasis is made by endoscopy. Empiric systemic antifungal therapy is often used to treat presumed *Candida* esophagitis.

The presence of thrush favors esophageal candidiasis in patients with symptoms compatible with esophagitis, although the symptoms of HSV and *Candida* esophagitis are similar. Other causes of esophagitis (eg, radiation esophagitis, GVHD of the esophagus or stomach) also produce similar symptoms. A trial of fluconazole and/or acyclovir (5 mg/kg IV every 8 hours in patients with normal renal function) should be considered in neutropenic patients and other highly immunocompromised persons with symptoms that suggest esophagitis. CMV esophagitis is a rare complication of chemotherapy-induced neutropenia and is most commonly observed in allogeneic HCT recipients with GVHD. Negative CMV surveillance results from PCR studies would make CMV disease very unlikely. If CMV esophagitis is diagnosed, treatment with valganciclovir or ganciclovir should be initiated. Foscarnet or cidofovir should be reserved for ganciclovir-resistant CMV or for patients who cannot tolerate ganciclovir. Empiric treatment may be considered in patients at high risk for CMV disease with symptoms suggestive of esophagitis.

For patients with esophagitis that does not respond to empiric therapy with these agents, careful upper endoscopy with platelet support (if required) may be considered to obtain cultures. Tissue biopsies are the gold standard for the diagnosis of invasive esophageal infections. However,

endoscopy and biopsy may be associated with complications in patients who are profoundly neutropenic and/or thrombocytopenic; therefore, the procedure should be performed with caution. Radiographic procedures, such as barium studies, lack sensitivity and add little clinically significant information; therefore, they are not recommended.

Sinus or Nasal Infections

The sinuses are a common site of bacterial infection. Patients with severe and prolonged neutropenia (eg, more than 10 days) and allogeneic HCT recipients with GVHD are particularly susceptible to invasive mold infections. Cytotoxic therapy disrupts the natural cleansing mechanisms in the nasal passages and increases colonization. A preceding chronic infection may also become active in the setting of neutropenia. Sinusitis during the early neutropenic period (less than 7 days) is principally caused by respiratory and gram-negative bacterial pathogens. In patients with longer-duration neutropenia or in patients receiving concomitant high-dose corticosteroid therapy, invasive mold infections are an important concern.

Initial symptoms of sinusitis may be mild. A high-resolution CT scan of the sinuses is the radiographic procedure of choice to evaluate patients with pain or tenderness of the sinuses, nasal erosions, unilateral facial swelling, unilateral eye tearing, or epistaxis. An MRI that includes evaluation of the orbital and cavernous sinuses is useful to evaluate proptosis of the eye or cranial nerve abnormalities (see *Initial Clinical Presentation: Sinus/Nasal* in the algorithm). Bony erosion on CT scan suggests invasive fungal disease. Ear, nose, and throat (ENT) and ophthalmologic examinations should be performed for symptomatic patients with abnormalities on CT scans, with biopsy and culture of any abnormal tissues. Broad-spectrum coverage for aerobes and anaerobes is appropriate for neutropenic and otherwise highly immunocompromised patients with sinus infections. Vancomycin (or another gram-positive active agent) should be added for periorbital cellulitis, which is frequently caused by *S aureus*.

Sinus endoscopy with biopsy and culture are often required to definitively establish the diagnosis and should be pursued aggressively in patients at high risk for mold infection. Invasive fungal sinusitis in patients with hematologic malignancies and with prolonged neutropenia is

principally caused by *Aspergillus* species (*A flavus* and *A fumigatus*) and Zygomycetes. In a case-control study of invasive aspergillosis and zygomycosis in patients with either acute leukemia or who were allogeneic HCT recipients, the risk factors that favored the diagnosis of zygomycosis included fungal sinusitis and use of voriconazole.⁵²⁷ A lipid formulation of amphotericin B should be used for suspected or confirmed invasive sinus mold infection, pending definitive histology and culture results. Isavuconazonium sulfate or posaconazole can be considered for treatment of refractory infection or if there is intolerance to amphotericin B formulations; isavuconazonium sulfate has been approved by the FDA for invasive aspergillosis and mucormycosis;¹¹⁰ however, posaconazole has not been approved for these indications.¹²⁸ Urgent debridement of necrotic tissue should be performed, when feasible.⁵²⁸

Abdominal, Rectal, and Liver Infections

Most infections in the abdomen, rectum, or liver are discovered because of a combination of clinical signs and symptoms (eg, abdominal pain, perirectal pain, diarrhea) and of biochemical abnormalities (eg, abnormal liver function tests). These infections are usually diagnosed and managed based on the radiologic, GI, and surgical expertise of the treating oncology center. Improved imaging techniques (including ultrasonography, CT scans, MRI, and radionuclide and endoscopic procedures) have decreased the need for surgical intervention. The choice of diagnostic studies should be based on the clinical presentation and relative clinical benefit. Antimicrobial therapy for GI infections must take into account the high likelihood of polymicrobial pathogens and the presence of the endogenous anaerobic GI flora. Acceptable therapeutic options in this setting include monotherapy with a carbapenem (imipenem/cilastatin, meropenem, doripenem, or ertapenem), piperacillin/tazobactam, or pairing ceftriaxone with metronidazole. In neutropenic patients, the antibiotic regimen should have antipseudomonal activity. Percutaneous aspiration and drainage should be performed, if feasible, for suspicious infected collections. Cholangitis may complicate obstructive tumors or previous hepatobiliary surgery. If cholangitis is suspected (ie, patients have fever with or without abdominal tenderness and liver enzyme abnormalities compatible with obstruction), a CT scan should be performed to detect biliary tract dilatation and abscess or infected collections. An endoscopic cholangiogram is useful to document

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the level of obstruction; if present, endoscopic stent placement may resolve the obstruction, which is a key component in managing cholangitis.

The GI tract and central venous catheters are the principal portals of entry of systemic candidiasis. *Candida* species are frequently components of the colonic flora in normal adults. Patients are susceptible to candidal bloodstream infection because of the mucosal damage induced with cytotoxic therapy and neutropenia. Breaches in the GI tract after anastomotic leaks also predispose patients to candidal peritonitis and bloodstream infections,⁵²⁹ and antifungal prophylaxis (eg, fluconazole) should be considered.

***Clostridium Difficile* Colitis**

Clostridium difficile colitis is principally a complication of antibiotic therapy and hospitalization, but it is also a complication of neutropenia, occurring in about 7% of patients.⁵³⁰ Diarrhea should be evaluated with at least 2 stool *C difficile* toxin screens. Additionally, depending on clinical circumstances, a GI multiplex panel may be considered for identification of other pathogens, including adenovirus, rotavirus, and norovirus. The rate and severity of *C difficile* colitis in the United States may be increasing, partly because of the emergence of a more virulent strain of *C difficile*. Multi-institutional outbreaks of *C difficile* colitis have been reported that were associated with high morbidity and mortality; these outbreaks were caused by a distinct strain with variations in toxin genes and with resistance to fluoroquinolones.^{92,93} Early reports suggested that metronidazole cured over 90% of cases of *C difficile* colitis, and the rate of recurrence was low.^{531,532} However, Musher et al⁵³³ reported that among patients (N = 207) treated with metronidazole for *C difficile* colitis, only 50% were cured and had no recurrence of disease.

A multicenter, double-blind, randomized trial was conducted to evaluate the efficacy and safety of oral fidaxomicin versus oral vancomycin in patients with *C difficile* infection (N = 629).⁵³⁴ The primary endpoint of this study was clinical cure, defined as the resolution of diarrhea and no further therapy necessary following completion of study treatment. The clinical cure rate with fidaxomicin was noninferior to vancomycin (88.2% vs. 85.8%) in the modified intent-to-treat analysis.⁵³⁴ The frequency and severity of adverse events were similar between treatment arms. In addition, fidaxomicin was

associated with a significantly decreased recurrence rate compared with vancomycin (15.4% vs. 25.3%; $P = .005$) and a significantly higher rate of resolution of diarrhea without recurrence (74.6% vs. 64.1%; $P = .006$).⁵³⁴ A decrease in recurrence of *C difficile* diarrhea was not observed in the treatment of the current epidemic strain, NAP1/BI/027. The investigators postulate that the improved duration of infection resolution with fidaxomicin may be due to its preservation of normal intestinal anaerobic flora, which may help to prevent the reemergence of *C difficile*.⁵³⁴

Another multicenter, double-blind, randomized trial evaluated the efficacy and safety of oral fidaxomicin versus oral vancomycin in adult patients with acute *C difficile* infection (N = 535; n = 509 evaluable).⁵³⁵ The primary endpoint of this study was clinical cure; fidaxomicin was noninferior to vancomycin (87.7% vs. 86.8%) in the modified intent-to-treat analysis. Interestingly, among the subgroup of patients receiving concomitant antibiotics for other infections (n = 96), treatment with fidaxomicin resulted in a higher cure rate compared with vancomycin (90.2% vs. 73.3%; $P = .031$).⁵³⁵ The incidence of treatment-emergent adverse events was similar between treatment arms.

Both of these large randomized controlled studies showed that treatment of *C difficile* infection with fidaxomicin was noninferior to vancomycin. A subgroup analysis combining data from the 2 randomized studies was conducted to evaluate the efficacy of these agents in patients with a cancer diagnosis who had *C difficile* infection.⁵³⁶ Overall, the cure rate was significantly lower among the patients with cancer (n = 183) compared with patients without cancer in these trials (n = 922; 79.2% vs. 88.6%; $P < .001$). In addition, the median time to resolution of diarrhea was delayed among patients with cancer (100 hours vs. 55 hours; $P < .001$). An analysis by treatment regimen showed that among the subgroup of patients with cancer, those treated with fidaxomicin had a more rapid median time to resolution of diarrhea compared with patients treated with vancomycin (74 hours vs. 123 hours; $P = .045$).⁵³⁶ Subtotal colectomy, diverting ileostomy, or colostomy may be required in cases involving toxic dilatation or perforation of the colon.

Multiple recurrences of *C difficile* are a challenge in the patient with cancer and may respond to a prolonged, tapered treatment with oral vancomycin

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dose over several weeks.⁵³⁷ The use of oral vancomycin followed by duodenal infusion of donor feces (fecal microbiota transplant, FMT) may also be an effective strategy for patients with recurrent *C difficile* infection, although there is a lack of data on the safety and efficacy of FMT in patients with cancer. In one randomized study, patients with recurrent *C difficile* infection were assigned to receive treatment with a short course of initial oral vancomycin (500 mg PO 4 times daily for 4 days) followed by bowel lavage and infusion of donor feces (n = 16) or standard oral vancomycin (500 mg PO 4 times daily for 14 days) alone (n = 13) or standard oral vancomycin with bowel lavage (n = 13). Resolution was achieved in 81% of patients in the FMT group compared with 31% in the vancomycin alone group and 23% in the group treated with vancomycin plus bowel lavage ($P < .001$ for both comparisons with the infusion group).⁵³⁸ Another randomized study assigned patients with recurrent *C difficile* infection to receive an initial short course of vancomycin (125 mg PO 4 times daily for 3 days) followed by FMT via colonoscopy (n = 20) or vancomycin (125 mg PO 4 times daily for 10 days, followed by 125-500 mg/day every 2-3 days for at least 3 weeks) alone (n = 19). In this study, resolution was achieved in 90% of patients in the FMT group compared with 26% of patients in the vancomycin group ($P < .0001$).⁵³⁹ While these studies should be interpreted with caution as they excluded patients who had neutropenia or recent chemotherapy, some institutions consider FMT for treatment of refractory *C difficile* infection in select cases.

Another consideration for recurrent *C difficile* is bezlotoxumab, a human monoclonal antibody against *C difficile* toxin B, used in conjunction with antibiotic treatment. Bezlotoxumab was approved by the FDA in 2016 to reduce recurrence for *C difficile* for patients receiving antibacterial treatment and who are at high risk for *C difficile* recurrence.⁵⁴⁰ Two double-blind, randomized, placebo-controlled, phase 3 trials of 2655 patients receiving oral antibiotics for *C difficile* infection studied the efficacy and safety of bezlotoxumab. Both trials showed that the rate of recurrent *C difficile* infection was significantly lower in patients given bezlotoxumab than in those given placebo (MODIFY I: 17% vs. 28%, $P < 0.001$; MODIFY II: 16% vs. 26%, $P < 0.001$). Rates of adverse events were similar between bezlotoxumab and placebo.⁵⁴¹

The NCCN panel recommends vancomycin (preferred in adults), or metronidazole for the treatment of suspected *C difficile* colitis. Oral vancomycin has a similar efficacy rate compared to oral metronidazole and can be considered an option for initial therapy for *C difficile* colitis despite the risk of selection for VRE and the substantial expense. Oral vancomycin should be considered over metronidazole for more complicated cases, such as those associated with severe diarrhea, dehydration, clinical instability, significant comorbidities, or recurrent or refractory *C difficile* colitis. Efforts should be made to deliver vancomycin by the nasogastric route in patients with severe *C difficile* colitis.^{542,543} Limited data suggest that IV metronidazole may be useful in this setting, and it is best used as an adjunct to oral vancomycin.^{544,545} IV vancomycin is not recommended in this setting because of inadequate luminal levels. IV metronidazole should be used in patients who cannot be treated with oral agents (see *Initial Clinical Presentation: Additions to Initial Empiric Regimen* in the algorithm). Fidaxomicin is not generally used as first-line treatment for *C difficile*; however, it can be considered as an alternative treatment for confirmed *C difficile* or for the treatment of recurrent infection.

Enterocolitis

Neutropenic enterocolitis is a serious, potentially life-threatening disease characterized by fever, diarrhea, and abdominal pain.^{546,547} When it occurs in the cecum, it is commonly referred to as typhlitis. The cecum is more vulnerable because of its size and shape, but any portion or the entire colon may be involved. This illness has frequently been associated with acute leukemia, neutropenia, and intensive cytotoxic therapy. CT scanning is the preferred diagnostic test and usually identifies any thickening of the bowel wall. The differential diagnosis for this syndrome includes *C difficile* colitis, CMV enteritis (most common in allogeneic HCT recipients), and GI tract GVHD. Bloodstream infections and sepsis (frequently polymicrobial), bowel perforation, and hemorrhage may occur. The natural history of typhlitis is quite variable, but all patients should be assessed for *C difficile* infection and should be treated with bowel rest and broad-spectrum antibiotics, including coverage for *C difficile*, aerobic pathogens, and anaerobic pathogens. Parenteral nutrition should be considered if clinical signs and symptoms do not resolve promptly. Approximately 5% of patients with typhlitis develop complications requiring surgical intervention (eg,

perforation, uncontrolled sepsis, rectal bleeding).⁵⁴⁸ Consequently, the panel recommends that surgical and other subspecialty consultations be obtained early in the course of treatment.

Lung Infections

Pulmonary infiltrates pose a difficult diagnostic challenge in patients with cancer. Noninfectious causes of pulmonary infiltrates include congestive heart failure, pulmonary edema, hemorrhage, infarction, drug-induced pneumonitis, radiation injury, tumor, bronchiolitis obliterans, and acute respiratory distress syndrome. Common processes can have atypical radiographic appearances, and 2 or more pulmonary processes can exist simultaneously. A careful history should include the time course of respiratory symptoms, sick contacts (eg, community respiratory viral infections, tuberculosis), recent hospitalization, travel, exposure to animals, and exposure to droplets from water distribution systems (*Legionella*). Community outbreaks of specific pathogens (eg, influenza, pertussis) should be considered in the differential diagnosis and should guide initial therapy.

Community-Acquired Pneumonia in the Absence of Neutropenia and Immunosuppressive Therapy

The diagnostic evaluation and initial therapy for community-acquired pneumonia must consider host factors and previous use of antibiotics. The IDSA has published guidelines on community-acquired pneumonia.³⁵⁰ If feasible, sputum and blood cultures should be collected before starting therapy. In patients who are not neutropenic, receiving IST, or requiring hospital admission (based on a validated pneumonia severity index), therapy includes either 1) a respiratory fluoroquinolone (levofloxacin 750 mg/d, moxifloxacin); or 2) a beta-lactam (eg, high-dose amoxicillin or amoxicillin-clavulanate) plus a macrolide (eg, azithromycin).³⁵⁰ These regimens will treat most of the common community-acquired pathogens, including “atypical” pneumonia (*Chlamydia*, *Mycoplasma*, and *Legionella* species). Although daptomycin is effective against most gram-positive pathogens, it should not be used for the treatment of pneumonia, because it is inactivated by pulmonary surfactant.^{444,445}

In patients requiring hospital admission, monotherapy with a respiratory fluoroquinolone or combination therapy with a macrolide plus either ceftriaxone, cefotaxime, or ertapenem is recommended. Ertapenem has gram-positive, gram-negative (excluding *P aeruginosa* and *Acinetobacter* species), and anaerobic activity useful for suspected aspiration or postobstructive pneumonia. In patients with severe community-acquired pneumonia (eg, who require admission to an intensive care unit), the panel advises broad-spectrum coverage with an antipseudomonal beta-lactam plus either a respiratory fluoroquinolone or azithromycin. In patients with previous MRSA infection or known colonization with MRSA, addition of vancomycin or linezolid should be considered for pneumonia requiring hospitalization (see *Additions to Initial Empiric Regimen* in the algorithm).³⁵⁰ A nasopharyngeal wash for respiratory viruses and initiation of empiric antiviral therapy should be considered during peak influenza season in the local area. Antiviral susceptibility of influenza strains is variable and cannot be predicted based on prior influenza outbreaks. In cases of seasonal influenza and pandemic strains (eg, H1N1), it is necessary to be familiar with susceptibility patterns and guidelines on appropriate antiviral treatment. Note that rapid immunofluorescent viral antigen tests may result in a false negative for H1N1 (swine flu). A parapneumonic effusion should be aspirated and submitted for Gram stain, bacterial culture, protein, lactate dehydrogenase, and pH.

Community respiratory viral infections (such as influenza, RSV, adenovirus, rhinoviruses, and metapneumoviruses) have a seasonal pattern (generally November through April); however, parainfluenza viral infections can occur throughout the year. During the influenza season, consider empiric antiviral therapy for patients within 48 hours after symptoms develop that are suggestive of influenza (eg, high fever, coryza, myalgia, dry cough), especially during community outbreaks. Both the IDSA (2007) and CDC guidelines (2011) recommend antiviral treatment with the neuraminidase inhibitors oseltamivir or zanamivir, which are active against both influenza A and B viruses.^{349,350} Both agents are approved by the FDA for the treatment of influenza within 48 hours of symptomatic onset; the indicated duration of treatment is 5 days.^{351,352} However, longer courses of treatment (eg, 10 days) and treatment until resolution of symptoms should be considered in immunocompromised patients; some centers have used higher doses

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(eg, 150 mg BID) of oseltamivir in these patients with mixed results (see *Suggested Minimum Duration of Therapy for Documented Infection* in the algorithm). Pandemic influenza does not have a predictable seasonal pattern, and may spread in the community concurrently with a seasonal influenza strain. Antiviral susceptibility of influenza strains is variable and cannot be predicted based on previous influenza outbreaks. In cases of seasonal influenza and pandemic strains, it is necessary to be familiar with susceptibility patterns and guidelines on appropriate antiviral treatment.³⁵³ Peramivir has been shown to have similar clinical outcomes as oral oseltamivir³⁵⁴ and can be considered for patients who cannot have oral oseltamivir or inhaled zanamivir, though it is available only as an IV injection.³⁵⁵

Hospital-Acquired Pneumonia

Guidelines on the management of adults with hospital-acquired pneumonia from the American Thoracic Society (ATS) emphasize that the time of onset is an important risk factor for specific pathogens that may be resistant to antibiotics.⁵⁴⁹ Early-onset hospital-acquired pneumonia (occurring within the first 4 days of hospitalization) is likely to be caused by antibiotic-sensitive bacteria and usually carries a better prognosis. However, patients with cancer may be at risk for acquisition of antibiotic-resistant bacteria based on prior hospitalizations, prior antibiotic use, and impaired immune status regardless of when pneumonia begins in the course of the current hospitalization. The ATS guidelines define the following as risk factors for multidrug-resistant pathogens in patients with health care-associated pneumonia: 1) received antibiotics in the preceding 90 days; 2) hospitalization for 2 or more days in the preceding 90 days; 3) resident in nursing home or extended care facility; 4) chronic dialysis within 30 days; 5) home wound care; and 6) family member with a multidrug-resistant pathogen.⁵⁴⁹ Late-onset hospital-acquired pneumonia (occurring after 5 or more days of hospitalization) is more likely to be caused by multidrug-resistant pathogens, and is associated with greater morbidity and mortality.

The population of multidrug-resistant bacteria (notably, MRSA and antibiotic-resistant gram-negative pathogens) varies among different hospitals and geographic distributions. Therefore, the selection of initial therapy for hospital-acquired pneumonia requires knowledge of the local

patterns of antibiotic susceptibility. For example, at some centers, a high frequency of extended-spectrum beta lactamase-producing gram-negative bacterial infections may make a carbapenem the drug of choice as initial therapy for pneumonia. At other centers, carbapenem-resistant gram-negative infections are an increasing problem, and an alternative class of antibiotics may be preferred based on prior local susceptibility results.⁵⁵⁰

In patients with late-onset hospital-associated pneumonia or risk factors for multi-drug-resistant pathogens regardless of when pneumonia developed in relation to hospitalization, a broad-spectrum antibiotic regimen is recommended. An antipseudomonal beta-lactam (eg, ceftazidime, cefepime, imipenem/cilastatin, meropenem, doripenem, piperacillin/tazobactam) plus an antipseudomonal fluoroquinolone (eg, ciprofloxacin or levofloxacin) or aminoglycoside, plus either linezolid or vancomycin (to cover MRSA) is a reasonable initial regimen (aim for vancomycin trough level of 15–20 mcg/mL).⁵⁴⁹ If *Legionella* is suspected, a quinolone (ciprofloxacin, levofloxacin, or moxifloxacin) should be used instead of an aminoglycoside. The antibiotic regimen should be subsequently tailored based on culture results.

Pulmonary Infiltrates in Neutropenic Patients

In patients with neutropenia for fewer than 7 days, pulmonary infections are likely to be caused by Enterobacteriaceae (eg, *E coli*, *Klebsiella* species), *P aeruginosa*, *S aureus*, and pathogens encountered in non-immunocompromised persons (as previously described). Because of the neutropenia, consolidation and sputum production may be absent.⁵⁵¹ Blood cultures, a chest radiograph, and, if possible, a sputum sample for Gram stain and culture should be obtained. In suspected acute bacterial pneumonia, appropriate empiric antibiotic therapy must be initiated promptly and the response must be closely monitored in an inpatient setting. The therapeutic regimen depends on several variables, including recent use of antibiotics, community or nosocomial pneumonia, and the local antibiotic sensitivity data.

If community-acquired pneumonia is suspected (ie, pneumonia is present before admission or develops within 3 to 4 days of hospitalization), addition of a macrolide or fluoroquinolone to an antipseudomonal beta-lactam is warranted to treat atypical pathogens. For nosocomial pneumonia,

therapy with an antipseudomonal beta-lactam is advised, and addition of an aminoglycoside or fluoroquinolone should be considered. For cases of nosocomial pneumonia in which hospital-acquired legionellosis is suspected, empiric addition of a macrolide or fluoroquinolone is also warranted. Vancomycin or linezolid should be added for pneumonia in patients colonized with MRSA and for nosocomial pneumonia at centers in which MRSA is common. Community respiratory viruses should also be considered, especially during winter months. RSV, parainfluenza, and influenza are significant pathogens during neutropenia in patients receiving chemotherapy for acute leukemia and in HCT recipients.

If clinical improvement occurs within 48 to 72 hours of therapy, no further diagnostic measures are necessary; antibiotic therapy should be continued until neutropenia resolves and for at least 7 to 14 days thereafter. Once neutropenia resolves, an appropriate oral antibiotic regimen can be administered for the remainder of the course.

In cases of refractory pneumonia, bacterial infection resistant to the initial antibiotic regimen and nonbacterial pathogens should be considered, particularly filamentous fungi.⁵⁵¹ A CT scan of the chest is useful in defining the location and morphology of the lesions, and in guiding diagnostic procedures. A “halo sign” in a persistently febrile neutropenic patient is highly suggestive of invasive aspergillosis;⁵⁵² however, angioinvasive infections including other filamentous fungi and *P aeruginosa* may produce similar findings.

A new or progressive infiltrate developing in patients with prolonged neutropenia (eg, more than 10 days) receiving broad-spectrum antibacterial agents suggests invasive aspergillosis or infection with other molds.⁵⁵¹ Consider adding voriconazole or a lipid formulation of amphotericin B while waiting for diagnostic results. Empiric modification of the antibacterial regimen based on the predominant local hospital pathogens (eg, MRSA, antibiotic-resistant gram-negative bacteria) is also warranted in patients with rapidly progressive pneumonia.

Pulmonary Infiltrates in Patients with Impaired Cellular Immunity

Patients with impaired cellular immunity are at increased risk for common bacterial infections and opportunistic infections, including fungi (eg, *Aspergillus* and other filamentous fungi, *Cryptococcus neoformans*, dimorphic fungi), *Legionella*, *Pneumocystis jirovecii*, *M tuberculosis*, nontuberculous mycobacteria, *Nocardia* species, and viral pathogens.

In patients with clinical and radiographic findings suggestive of acute bacterial pneumonia (eg, acute onset fever, respiratory symptoms, focal infiltrate), the diagnosis and management are similar to the treatment of neutropenic patients. An antipseudomonal beta-lactam plus either a respiratory fluoroquinolone or azithromycin is a reasonable initial regimen in patients with pneumonia requiring hospitalization. In allogeneic HCT recipients with GVHD not receiving mold-active prophylaxis, addition of a mold-active drug (eg, voriconazole) should be considered. Particularly among the most highly immunocompromised patients (eg, chronic GVHD), the differential diagnosis is very broad, and an initial empiric regimen cannot have activity against all possible pathogens. It is critical to establish a definitive diagnosis in patients with negative diagnostic results who are deteriorating clinically after a 2- to 3-day trial of broad-spectrum antibiotics.

Diffuse infiltrates have a broad differential diagnosis,⁵⁵¹ including PCP, viral infections, hemorrhage, and drug-induced pneumonitis. A diagnosis of PCP should be considered in patients with significantly impaired cellular immunity not receiving PCP prophylaxis who present with diffuse pulmonary infiltrates. BAL is the standard approach for diagnosing PCP. In patients with substantial respiratory disease (eg, labored breathing, requiring supplemental oxygen), empiric therapy should be initiated before BAL. Pending BAL results, an initial regimen can include a respiratory fluoroquinolone against community-acquired pathogens and TMP/SMX (TMP component: 5 mg/kg every 8 hours) against possible PCP. Based on studies of patients with AIDS-associated PCP, corticosteroids (initially prednisone 40 mg twice daily, then tapered) should be added for patients with suspected PCP and with room air PaO₂ of 75 torr or less.⁵⁵³ TMP/SMX desensitization or atovaquone, dapsone, or pentamidine (aerosolized or IV) can be considered when PCP prophylaxis is required in patients who are

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TMP/SMX intolerant. For patients receiving dapsone, consider assessing G6PD levels.

Patients at the highest risk for CMV pneumonia include allogeneic HCT recipients in the post-engraftment setting (particularly if receiving IST for GVHD) and patients receiving treatment with alemtuzumab. Negative results from CMV surveillance testing (peripheral blood PCR) make CMV pneumonia very unlikely. CMV pneumonia is uncommon in non-transplanted patients receiving immunosuppressive chemotherapy for leukemia.⁵⁵⁴ Community respiratory viruses can cause severe pulmonary infection in neutropenic patients and in non-neutropenic patients with impaired cellular immunity. Noninfectious etiologies must also be considered, as previously stated. BAL is sensitive in diagnosing bacterial and viral pneumonia and PCP, and is often the initial invasive diagnostic procedure (see *Invasive Diagnostic Procedures for Pulmonary Infiltrates*).

Non-Invasive Diagnosis of Pneumonia

In patients with suspected pneumonia, routine sputum and blood cultures should be obtained, ideally before antibiotics are initiated or modified. Sputum cultures for *Legionella* species are sensitive if obtained before initiating antibiotics; however, specific culture conditions are required. Legionellosis can also be diagnosed based on urine antigen testing, which only detects *Legionella pneumophila* type I, the cause of most (but not all) cases of *Legionella* pneumonia.³⁵⁰ A nasopharyngeal wash is useful to diagnose community respiratory viral infections. The rapid test for influenza A and B may be performed using a throat or nasopharyngeal swab. Rapid antigen detection methods can provide a diagnosis within hours; however, if results are negative, a shell vial culture will take about 5 days.

Fungal pneumonia is suggested by the following: host factors predisposing the patient to invasive aspergillosis; appropriate symptoms or signs of infection; a compatible pulmonary lesion; and a positive serum galactomannan or beta-glucan assay. Host factors indicative of high risk for invasive aspergillosis include neutropenia for more than 10 days, receipt of an allogeneic HCT, prolonged use of high-dose systemic corticosteroids, or treatment with T-cell suppressants. The galactomannan assay is specific for invasive aspergillosis,^{510,555} whereas the beta-glucan assay detects aspergillosis and other invasive fungal infections (including invasive

candidiasis, *Pneumocystis jirovecii*, and fusariosis).⁵⁵⁶⁻⁵⁵⁸ Zygomycosis yields negative serum galactomannan and beta-glucan test results.

Antigen-based detection systems have advantages and limitations. A meta-analysis showed that the galactomannan assay had a sensitivity of 70% and specificity of 89% for proven invasive aspergillosis, though the accuracy of the test varied.⁵¹² The lack of consistent results likely relates to different cutoff values for a positive result, differences in patient populations, and possibly the use of mold-active prophylaxis. Several variables can affect the performance of the galactomannan assay,^{559,560} which may account for the different results. The sensitivity of the assay is significantly reduced by concomitant mold-active antifungal agents.^{511,561} False-positive results may be more common in children and allogeneic HCT recipients.⁵⁶² Historically, concomitant piperacillin/tazobactam has caused false-positive galactomannan results,^{563,564} however, current formulations available in the United States rarely cause false positives.⁵⁶⁵ False-positive beta-glucan results have also been reported in patients with surgical packing who are receiving immunoglobulin therapy and in patients receiving IV amoxicillin-clavulanate.^{566,567} Despite these limitations, a patient at high risk for invasive aspergillosis (eg, prolonged neutropenia or allogeneic HCT recipient) with clinical and radiologic findings (eg, a new pulmonary nodule ≥ 1 cm, infiltrate) compatible with invasive aspergillosis and with a positive serum galactomannan is likely to have invasive aspergillosis, and therefore a mold-active agent (voriconazole is preferred) should be added.

Additional assays can detect histoplasmosis, coccidioidomycosis, and *Pneumocystis jirovecii* as part of the noninvasive diagnosis of pneumonia. The assay for serum or urine Histoplasma antigen is a sensitive and specific test in patients with disseminated histoplasmosis (histoplasmosis is endemic to the Central United States). Coccidioidomycosis is endemic to the southwestern United States. Disseminated coccidioidomycosis can be diagnosed based on appropriate symptoms and signs of infection and on positive serum titers. As previously discussed, BAL is the diagnostic gold standard for PCP. In a small series, sputum induction with hypertonic saline was diagnostic of PCP in non-HIV-infected patients in about 60% of

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cases.⁵⁶⁸ A BAL should be performed if sputum induction is attempted, and the results are negative.

Invasive Diagnostic Procedures for Pulmonary Infiltrates

Invasive diagnostic procedures may be required in the following situations: 1) the clinical course does not suggest an acute bacterial process; 2) the infection has not responded to initial antibiotic therapy and/or; 3) noninvasive testing yields negative results. BAL has a high diagnostic yield in alveolar infiltrates, such as pneumonia caused by *Pneumocystis jirovecii*, *M tuberculosis*, and respiratory viruses. The sensitivity of BAL for focal lesions (such as nodules) is variable. In lesions greater than 2 cm, the sensitivity of BAL ranges from 50% to 80%; however, in smaller lesions, the diagnostic yield is usually about 15%.⁵⁶⁹ Quantitative cultures from either BAL or a protected brush catheter may increase the specificity in the diagnosis of bacterial pneumonia as distinguished from upper airway colonization in ventilated patients. It is recommended to use galactomannan and special stains or molecular techniques with BAL to aid in the identification of additional viral, protozoal, fungal, or bacterial pathogens, particularly if there is no response to the initial therapy or if diffuse infiltrates are present.

BAL cultures only detect about 50% of cases; therefore, it is relatively insensitive for diagnosing aspergillosis.⁵⁷⁰ Galactomannan detection in BAL fluid appears to be more sensitive than serum detection^{571,572} and can be used to support a diagnosis of probable aspergillosis.⁵⁷³ In patients with focal peripheral lesions, percutaneous biopsy may increase the diagnostic yield; however, in thrombocytopenic patients, the risk of bleeding may be unacceptably high. The microbiologic evaluation should take into account the clinical manifestations and nature of the immunosuppression. In highly immunocompromised patients (eg, those receiving chemotherapy for acute leukemia, HCT recipients), the following studies on BAL and lung biopsies should be considered: culture and stains for bacteria, fungi, *Legionella*, mycobacteria, *Nocardia*, HSV, CMV, community respiratory viruses (both rapid antigen and shell vial culture), and cytology or immunofluorescent studies for *Pneumocystis jirovecii*. In a patient with compatible host factors and radiologic findings, a positive galactomannan result from BAL is also indicative of probable invasive aspergillosis.⁵⁷³

For nondiagnostic BAL or percutaneous lung biopsy results, a thoracoscopic lung biopsy should be considered if an adequate platelet count is achievable. The thoracoscopic approach has less morbidity than an open lung biopsy and generally provides adequate tissue samples for the diagnosis of most infectious and noninfectious etiologies. This invasive procedure may identify the causative pathogen or the presence of a noninfectious etiology (eg, treatment-associated lung toxicity, hemorrhage, or bronchiolitis obliterans organizing pneumonia [BOOP]), which may allow for the elimination of potentially toxic or unnecessary antimicrobial therapies. Thoracoscopic and open lung biopsies sometimes do not provide a definitive diagnosis, either due to sampling error or nonspecific pathologic findings.

Skin and Soft Tissue Infections

When evaluating the potential for a skin/soft tissue infection, careful examination of all line sites and perineal areas is essential. Antimicrobial therapy should be tailored to the probable organism(s): staphylococci and streptococci for catheter-associated processes, and gram-negative and anaerobic organisms for perineal processes. Vancomycin may be considered for cellulitis, disseminated papules/lesions, and infections associated with VAD (see *Additions to Initial Empiric Regimen* in the algorithm and *Vascular Access Device Infections* in the discussion). Acyclovir, famciclovir, or valacyclovir should be considered for vesicular lesions after appropriate diagnostic tests (ie, scraping base of vesicle for HSV or VZV, direct fluorescent antibody tests, herpes virus culture) have been performed.

Skin lesions can be manifestations of systemic infection. Ecthyma gangrenosum is the most characteristic skin lesion associated with systemic *P aeruginosa* infection.⁵⁷⁴ Similar lesions can be caused by *S aureus*, enteric gram-negative bacilli infection, and filamentous fungi (including *Aspergillus*, Zygomycetes, and *Fusarium* species). A rapidly progressive deep soft tissue infection with gas formation suggests clostridial myonecrosis (or polymicrobial necrotizing fasciitis).⁵⁷⁵ Broad-spectrum antibiotics and surgical debridement may be lifesaving if initiated early. Hematogenously disseminated candidiasis with skin involvement

manifests as fever and erythematous cutaneous papules; blood cultures are expected to be positive for *Candida* species.

In the highly immunocompromised patient with cancer, the differential diagnosis of skin lesions is often broad and includes noninfectious etiologies such as drug reactions, Sweet's syndrome, erythema multiforme, leukemia cutis, and (in the case of allogeneic HCT recipients) GVHD. Biopsy of skin lesions for histology and culture is recommended. In allogeneic HCT recipients, the differential diagnosis of infectious etiologies is particularly broad, and cultures from skin biopsies for bacteria, fungi, viruses, and mycobacteria should be considered when infection is suspected.

Vascular Access Device Infections

VAD infections are common as a consequence of the ubiquity of VADs in patients undergoing intensive or cyclic chemotherapy. The risk of infection varies with the device used (long-term implanted catheters versus short-term central catheters), duration of placement, and extent of the patient's immunosuppression. Short-term central catheters coated with the antimicrobial agent chlorhexidine-silver sulfadiazine (CHSS) have been shown to significantly decrease the incidence of both catheter colonization and catheter-related bloodstream infections compared with standard (non-coated) catheters.^{576,577} However, this benefit with CHSS coating was not observed in the setting of patients with hematologic malignancies requiring longer use of central catheters (eg, duration of catheterization 20 days).⁵⁷⁸ In subsequent studies that evaluated the use of CHSS-coated short-term catheters compared with controls, CHSS-coated catheters significantly decreased the incidence of colonization but showed no difference in terms of incidence of catheter-related bloodstream infections.⁵⁷⁹⁻⁵⁸¹ The use of short-term catheters coated with minocycline and rifampin has been shown to significantly decrease the risks for catheter colonization and bloodstream infections compared with either controls or CHSS-coated catheters.^{582,583} However, conflicting results were reported by another study in which minocycline- and rifampin-coated catheters reduced the risk for coagulase-negative staphylococci colonization, but they increased the risk for colonization with *Candida* spp. Moreover, no significant difference was noted in the incidence of catheter-related bloodstream infections

compared with controls.⁵⁸⁴ Only limited data are available on the use of long-term catheters coated with minocycline and rifampin. In a prospective randomized double-blind study in patients with cancer requiring long-term catheterization (mean duration of catheterization, 63–66 days), a significant risk reduction in catheter-related bloodstream infections was observed with the coated catheter (1.6% vs. 8%; RR for uncoated vs. coated, 1.8; 95% CI, 1.4–2.3; $P = .003$).⁵⁸⁵ Published guidelines for the prevention of catheter-related infections (based on an interdisciplinary working group involving the IDSA and CDC) recommend the use of catheters impregnated with CHSS or minocycline/rifampin in patients requiring catheterization for greater than 5 days, if the rate of catheter-related bloodstream infections does not decrease despite implementation of comprehensive prevention measures at the local institution.⁵⁸⁶ A meta-analysis of prospective, randomized studies showed that use of a vancomycin lock solution in patients being treated with long-term central VADs reduced the risk of bloodstream infection.⁵⁸⁷ The panel does not currently endorse this practice due to concerns over the emergence of bacterial resistance if this approach were widely employed. The IDSA has published guidelines on the diagnosis and management of intravascular catheter-related infections.⁴¹⁸

VAD infections are categorized as entry or site inflammation versus tunnel infection, port pocket infection, or septic phlebitis (see *Initial Clinical Presentation* in the algorithm). The majority of these infections are caused by gram-positive pathogens, with coagulase-negative staphylococci recovered most frequently.⁴¹⁸ Accordingly, IV vancomycin is recommended for those infections that are serious and clinically obvious.

Most VAD exit-site infections can be treated effectively with appropriate antimicrobial therapy without the need for catheter removal. If clinical signs of catheter infection are present, a skin swab for culture from the exit site and blood cultures should be obtained. In a patient with neutropenic fever and clinical signs of a VAD-associated infection, an appropriate initial regimen would consist of an agent recommended for neutropenic fever and vancomycin (see *Initial Empiric Therapy for Fever and Neutropenia and Additions to Initial Empiric Regimen* in the algorithm). Linezolid is not advised as routine therapy for catheter-related infections nor is it FDA-approved for this indication.⁴⁴³ For a clinically apparent, serious, catheter-

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related infection (such as a tunnel or port pocket infection, or septic phlebitis), catheter removal should be performed immediately.

Determining the role of the catheter in bloodstream infections is frequently difficult if local catheter inflammation is not evident. A useful diagnostic tool for detecting VAD infections is the DTP. Early positivity of central venous blood cultures predicts catheter-related bacteremia and may be used to avoid unnecessary catheter removal in critically ill patients. It was shown that a DTP of 120 minutes or more (between centrally and peripherally drawn blood cultures) is highly sensitive and specific for diagnosing catheter-related bacteremia.^{443,588-592} However, these studies were only performed in patients with removable catheters, not implanted catheters (eg, Hickman or Mediport) that are frequently used in patients undergoing cancer treatment.

Most catheter-associated bloodstream infections respond to antimicrobial therapy alone without catheter removal, but immediate catheter removal is favored for patients with bloodstream infections caused by fungi (yeasts or molds) or nontuberculous mycobacteria (eg, *Mycobacterium chelonae*, *Mycobacterium abscessus*, *Mycobacterium fortuitum*).⁴¹⁸ Bloodstream infections caused by *Bacillus* organisms, *Candida*, *S aureus*, *Acinetobacter*, *C jeikeium*, *P aeruginosa*, *S maltophilia*, and VRE may be difficult to eradicate with antimicrobial therapy alone; therefore, catheter removal should be considered as part of initial therapy. In patients with mucositis, the bowel is likely to be the portal of entry for bloodstream infection by GI flora such as *Candida* spp. and enterococci. DTP may be useful to distinguish whether bloodstream infection by these organisms is catheter-related and to guide whether catheter removal should be performed. If not removed initially, catheter removal is advised for known or suspected VAD-associated bloodstream infections if the organism is recovered from blood obtained 48 hours after initiation of appropriate antibiotic therapy. In patients with VAD infection and clinical instability, removal of the infected catheter should be performed immediately.

The panel recognizes that certain conditions may preclude the ability to immediately replace IV catheters, such as limited options for IV access and thrombocytopenia refractory to platelet products. Administering antibiotics through each lumen of the involved catheter has been suggested to avoid

treatment failure caused by microbial sequestration. Some experts believe supplemental urokinase infusions can be helpful in patients with catheter-related infections.⁵⁹³ However, the panel believes data are insufficient to recommend either of these approaches.

Central Nervous System Infections

CNS infections in patients with cancer can be divided into surgical and nonsurgical complications. The IDSA has published guidelines on the management of bacterial meningitis.⁵⁹⁴ The most common organisms infecting intraventricular devices are coagulase-negative staphylococci, *S aureus*, and *Propionibacterium acnes*. Enterobacteriaceae and *P aeruginosa* account for only 10% of these infections. Coagulase-negative staphylococci and *Propionibacterium acnes* usually cause indolent late postoperative infections. Therapy with systemic antibiotics and removal of the entire device are the most effective approaches to eradicate infection. Use of parenteral and intraventricular instillation of antibiotics without removal of the device may not be effective, and recrudescence of infection is common. Antibiotic therapy should be tailored to the specific pathogen isolated from cerebrospinal fluid. In an acutely ill patient with suspected meningitis related to previous neurosurgery, empiric therapy can include parenteral vancomycin (which has activity against *Staphylococcus*, *Streptococcus*, and *Propionibacterium* species; dose 15 mg/kg every 8–12 hours to maintain a serum trough concentration of 15–20 mcg/mL) in combination with ceftazidime (2 g every 8 hours), cefepime (2 g every 8 hours), or meropenem (2 g every 8 hours) (which have activity against Enterobacteriaceae and *P aeruginosa*); these doses apply to adults with normal renal function.⁵⁹⁴ Ampicillin should be added to cover listeriosis; however, if meropenem is used, addition of ampicillin is unnecessary.

CNS infections unrelated to neurosurgery are relatively uncommon in patients with cancer. Initial evaluation generally involves a head CT scan to rule out intracranial bleeding and/or an MRI in addition to a lumbar puncture (assuming there are no contraindications). Cerebrospinal fluid studies should be tailored to specific host factors, epidemiologic exposures (eg, travel history), and clinical presentation. At a minimum, cell counts with differential, glucose and protein levels, Gram stain and bacterial culture, cryptococcal antigen, and fungal culture on cerebrospinal fluid should

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be obtained. Noninfectious causes of meningitis include nonsteroidal anti-inflammatory agents, TMP/SMX, carcinomatous meningitis, and serum sickness (eg, associated with anti-lymphocyte immunoglobulin preparations).

For suspected CNS infections, infectious disease and neurology consultation is strongly recommended, and empiric therapy should be initiated pending infectious disease consult. Empiric therapy for presumed meningitis should include an anti-pseudomonal beta-lactam agent that readily enters the CSF (eg, cefepime, ceftazidime, meropenem) plus vancomycin plus ampicillin (to cover listeriosis) (see *Additions to Initial Empiric Regimen* in the algorithm). If meropenem is used, addition of ampicillin is unnecessary because meropenem is active against *Listeria*. This regimen has activity against the common causes of bacterial meningitis, including penicillin-resistant pneumococci and listeriosis. In patients at risk for *P aeruginosa* meningitis (eg, neutropenia, neurosurgery within the past 2 months, allogeneic HCT, history of *P aeruginosa* infection), use of cefepime (2 g every 8 hours in adults with normal renal function) or meropenem (2 g every 8 hours in adults with normal renal function) instead of ceftriaxone in the initial empiric regimen is advised. The antibiotic regimen should be tailored based on culture results.

The use of dexamethasone as adjuvant therapy in the management of bacterial meningitis has been evaluated in a number of studies, although conflicting results have been reported. In an earlier systematic review of published data in patients with acute bacterial meningitis, adjuvant therapy with corticosteroids was associated with significantly lower risks for mortality (RR, 0.76; 95% CI, 0.59–0.98), severe hearing loss (RR, 0.36; 95% CI, 0.22–0.60), and long-term neurologic sequelae (RR, 0.66; 95% CI, 0.44–0.99).⁵⁹⁵ These outcomes mainly reflected the pediatric population, as only limited data were available for adults. In a prospective, randomized, double-blind study involving adult patients with acute bacterial meningitis (N = 301), adjuvant dexamethasone compared with placebo significantly reduced the risks for unfavorable outcomes (defined as a score of 1–4 on the Glasgow Outcome Scale) (RR, 0.59; 95% CI, 0.37–0.94; *P* = .03) and mortality (RR, 0.48; 95% CI, 0.24–0.98; *P* = .04); this benefit was observed in patients with pneumococcal meningitis.⁵⁹⁶ In a

more recent prospective, randomized, double-blinded study in adults and adolescents with suspected or confirmed bacterial meningitis (N = 435), adjuvant dexamethasone significantly reduced the risks for death at 1 month (RR, 0.43; 95% CI, 0.20–0.94) and death or disability at 6 months (RR, 0.56; 95% CI, 0.32–0.98) in patients with confirmed cases of bacterial meningitis, but not for those with suspected cases.⁵⁹⁷ Other prospective randomized studies in pediatric patients appear to conflict with the findings from the earlier systematic review. In these studies that evaluated the use of adjuvant dexamethasone, glycerol, or both, in children treated with ceftriaxone for bacterial meningitis, adjuvant dexamethasone alone was not associated with significant reductions in risks for death, deafness/hearing loss, or severe neurologic sequelae.^{598,599} Moreover, in a meta-analysis of 2029 patients, dexamethasone was not found to be associated with significant reductions in death or neurologic sequelae, although a statistically significant reduction in hearing loss was observed among surviving patients.⁶⁰⁰

The IDSA guidelines (2004) for the management of bacterial meningitis support the incorporation of adjuvant dexamethasone in pediatric patients with *H influenzae* type B meningitis and in adult patients with pneumococcal meningitis.⁵⁹⁴ In patients with suspected encephalitis (ie, fever, mental status changes, CSF pleocytosis), IV acyclovir (10 mg/kg every 8 hours in patients with normal renal function) should be considered as empiric therapy for HSV in addition to an appropriate antibacterial regimen.⁶⁰¹ An MRI and the following CSF studies should be performed: 1) cell count with differential; 2) glucose and protein levels; 3) Gram stain and culture for bacteria; 4) cryptococcal antigen and fungal culture; and 5) PCR for HSV. PCR for West Nile virus and other arboviruses should be considered in patients with exposure to endemic areas. Culture and PCR for tuberculosis should be considered in patients with known or suspected exposure to tuberculosis (eg, residence in an endemic area, shelter, or prison; previous positive PPD [purified protein derivative]). In patients with severe impairment of cellular immunity (eg, allogeneic HCT recipients, advanced AIDS), additional CSF studies should be considered (such as PCR for CMV, VZV, human herpesvirus-6 type B [HHV-6B], and toxoplasmosis). For cases of HHV-6B–associated encephalitis in severely immunocompromised patients, such as those who have received an

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allogeneic transplant, treatment is recommended; however, the optimal therapy is not known (with either foscarnet or ganciclovir).⁶⁰¹ Cytology to evaluate for CNS malignancy as a cause of meningitis or encephalitis should also be considered.

Brain abscesses usually manifest with headache, focal neurologic findings, or seizures. An MRI typically shows single or multiple lesions with edema and ring enhancement.⁶⁰² Bacterial abscesses in non-immunocompromised patients are typically caused by dental flora. In patients with prolonged neutropenia and in allogeneic HCT recipients, CNS aspergillosis must be considered. A chest CT showing a new nodule or infiltrate and a positive serum galactomannan result in this setting is highly suggestive of pulmonary aspergillosis with CNS dissemination. In patients with impaired cellular immunity, other causes of CNS abscesses include toxoplasmosis, nocardiosis, cryptococcosis, and mycobacterial infections. Noninfectious etiologies in patients with impaired cellular immunity include CNS malignancies (such as secondary lymphomas) and Epstein-Barr virus (EBV)-associated post-transplantation lymphoproliferative disorder (PTLD). Given the broad differential diagnosis of new CNS lesions in highly immunocompromised patients, a brain biopsy is strongly recommended (if feasible) with material submitted for histology and culture. Cultures and stains should include bacteria, fungi, mycobacteria, and *Nocardia* species.

In non-immunocompromised patients with a bacterial brain abscess, initial therapy with ceftriaxone (2 g every 12 hours in adults) plus metronidazole (7.5 mg/kg every 6 to 8 hours in adults with normal renal function) is advised.^{16,602,603} In patients with prolonged neutropenia without corticosteroids or lymphocyte-depleting agents, a reasonable initial regimen consists of combination cefepime, metronidazole, and voriconazole (IV 6 mg/kg every 12 hours for 2 doses followed by 4 mg/kg every 12 hours); however, IV voriconazole (but not the oral formulation) may worsen renal disease in patients with significant pre-existing renal impairment. Voriconazole (as well as itraconazole and posaconazole) has important drug-drug interactions with certain antiseizure agents (eg, phenytoin); therefore, the voriconazole package insert should be reviewed to guide dosing of these agents.¹⁶⁹ In allogeneic HCT recipients and other patients with severe T-cell impairment, addition of high-dose TMP/SMX

(trimethoprim component: 5 mg/kg every 8 hours) should be considered to cover toxoplasmosis and nocardiosis, pending a definitive diagnosis. An infectious disease consultation is advised in all cases of suspected or documented CNS infection.

Therapy for Invasive Fungal Infections

Invasive Candidiasis

Candida species are the fourth most common cause of nosocomial bloodstream infections in the United States.^{604,605} The crude mortality of candidemia ranges from 20% to 40%.^{605,606} This variable mortality rate reflects the presence of serious comorbidities (such as malignancy and neutropenia), patient population (adult versus pediatric), and illness requiring prolonged periods in the intensive care unit. *Candida albicans* is the most common *Candida* species isolated from the blood.⁶⁰⁵ The proportion of non-*albicans* *Candida* species varies among different centers, but accounts for approximately 50% of blood stream isolates.

A randomized study comparing IV fluconazole (400 mg daily) with amphotericin B as therapy for candidemia in non-neutropenic patients found both regimens equally effective, but fluconazole had less toxicity.⁶⁰⁷ In a subsequent study of non-neutropenic patients with candidemia, combination therapy with a higher dose of fluconazole (800 mg daily) and amphotericin B led to improved clearance of candidemia compared with fluconazole alone, but the combination regimen was associated with significantly more nephrotoxicity and with no survival benefit.⁵²⁶ Voriconazole was as equally effective as, but less nephrotoxic than a strategy of amphotericin B followed by fluconazole in non-neutropenic patients with invasive candidiasis.⁶⁰⁸ In trials of “invasive candidiasis,” most patients had candidemia, but those with deep organ involvement (eg, peritoneal, hepatic, or renal candidiasis) without positive blood cultures were also eligible for enrollment.

Four phase III randomized trials have been performed evaluating echinocandins as initial therapy for invasive candidiasis.^{189,609-611} When caspofungin was compared with conventional amphotericin B, there was a trend for a higher favorable response (defined as resolution of clinical symptoms and culture-confirmed eradication) rate in the caspofungin arm

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(73% vs. 62%) in the modified intent-to-treat analysis.⁶¹⁰ Among patients who met prespecified criteria for evaluation (those who met eligibility criteria and received at least 5 days of the study drug), caspofungin resulted in a significantly higher success rate compared with amphotericin B (81% vs. 65%; 95.6% CI, 1.1–29.7; $P = .03$). Caspofungin was less toxic than amphotericin B. Similarly, micafungin was shown to be as effective as L-AmB for invasive candidiasis, with fewer treatment-related adverse events (including those that led to treatment discontinuation).⁶⁰⁹ Anidulafungin was not inferior to fluconazole as therapy for invasive candidiasis and was possibly more efficacious.¹⁸⁹ At the end of IV therapy, successful outcomes (based on both clinical and microbiologic responses; primary endpoint) were achieved in a higher proportion of patients treated with anidulafungin compared with fluconazole (76% vs. 60%; 95% CI, 3.9–27.0; $P = .01$), though a center effect was observed in this study. Finally, caspofungin and micafungin were shown to be equally safe and efficacious as treatment for invasive candidiasis.⁶¹¹

The IDSA has published detailed updated guidelines for the management of candidiasis recommending fluconazole or an echinocandin as initial therapy for most non-neutropenic adult patients; an echinocandin is preferred in critically ill patients.⁶¹² Transition from an echinocandin to fluconazole is recommended for patients who have isolates that are likely to be susceptible to fluconazole (eg, *Candida albicans*), who are clinically stable, and who have not had recent azole exposure.⁶¹² Fluconazole-resistant *Candida* isolates are frequently cross-resistant to other azoles;⁶¹³ therefore, if candidemia occurs in a patient with recent azole exposure, a switch in class (eg, to an echinocandin) is recommended. *Candida krusei* is generally resistant to fluconazole. An echinocandin is the preferred therapy for *Candida glabrata* stains due to their variable sensitivity to azoles;⁶¹² however, transition to fluconazole or voriconazole can be considered if azole susceptibility is documented. *Candida auris* may be resistant to fluconazole or echinocandins. Echinocandins have reduced sensitivity to *Candida parapsilosis* compared to other candidal strains; fluconazole is recommended in this setting.⁶¹²

The IDSA recommends an echinocandin as initial therapy for candidemia in most neutropenic patients.⁶¹² The NCCN Guidelines Panel agrees

with this recommendation (category 1), but notes that because studies evaluating echinocandins have included very small numbers of neutropenic patients, the optimal therapy for invasive candidiasis in this population is not definitive. Given the availability of safer alternatives, the panel does not recommend amphotericin B products routinely for candidemia, although such agents may be considered in unusual or complicated cases, such as instances of meningitis and endocarditis.

Invasive Aspergillosis

Voriconazole has been evaluated as primary therapy for invasive aspergillosis. In an open-label, multicenter, randomized trial, voriconazole resulted in a significantly higher success rate (including complete and partial responses) compared with amphotericin B (53% vs. 32%; 95% CI, 10.4–32.9) and was associated with an improved survival rate at 12 weeks (71% vs. 58%; HR, 0.59; 95% CI, 0.40–0.88) in this patient population.⁶¹⁴ Success rates were similar for the 2 treatment arms in the subgroup of patients with neutropenia (51% with voriconazole vs. 32% with amphotericin B). In a retrospective analysis of 86 patients with CNS aspergillosis treated with voriconazole either as primary or subsequent-line therapy, 35% had a complete or partial response.⁶¹⁵ This success rate compares favorably to a previous series in which the frequency of successful responses to amphotericin B in CNS aspergillosis was almost nil.⁶¹⁶ Considerable inter-individual variability in voriconazole exposure can occur, and the utility of monitoring drug levels is controversial.^{617,618} Studies with a few patients have noted a relationship between low plasma voriconazole levels and treatment failure,¹⁵⁵ and between high voriconazole levels and toxicity.^{153,619} Voriconazole blood levels that are at least 1 to 2 mcg/mL are thought to be required for efficacy. One week after initiating treatment with voriconazole, it is recommended that trough levels by TDM be obtained to ensure adequate plasma concentration of the drug. Obtaining a serum voriconazole level should be considered in cases of breakthrough or refractory fungal disease or drug toxicity.

It is not clear what the optimal therapy is for breakthrough invasive aspergillosis in patients receiving mold-active prophylaxis. Breakthrough invasive aspergillosis in a patient receiving oral posaconazole prophylaxis may be caused by inadequate oral bioavailability due to mucositis or poor

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oral intake, or possibly resistance. Some experts would advise changing to a different class of antifungals (such as a lipid formulation of amphotericin B, with or without an echinocandin). Others would use IV voriconazole with or without an echinocandin.

Lipid formulations of amphotericin B have at least comparable efficacy and reduced renal toxicity compared to conventional amphotericin B deoxycholate. Some investigators have persuasively argued that lipid formulations should be considered suitable replacements for amphotericin B for primary therapy for many invasive fungal infections.⁴⁹⁹ ABCD was equally as effective as, but less nephrotoxic than amphotericin B as primary therapy for invasive aspergillosis.⁶²⁰ ABLC was shown to be as safe and efficacious as therapy for invasive aspergillosis based on an analysis of a registry database.⁶²¹

A randomized study compared L-AmB at either 3 or 10 mg/kg/d for 14 days, followed by 3 mg/kg/d as therapy for invasive mold infections.⁶²² Response rates (both complete and partial responses) after completion of treatment with the 3 mg/kg/d and 10 mg/kg/d dose groups were similar (50% vs. 46%); the 12-week survival rates were 72% and 59%, respectively (95% CI, -0.2–26%). The high-dose group was associated with significantly higher incidences of nephrotoxicity and hypokalemia, which suggested that the 3 mg/kg/d dosing was more optimal in this patient population.⁶²² Because 97% of enrolled patients had invasive aspergillosis, this study does not permit conclusions about optimal L-AmB dosing in patients with other mold infections (such as zygomycosis).

Echinocandins have not been evaluated as initial monotherapy for invasive aspergillosis in clinical trials. Caspofungin for treatment of refractory infections in patients with invasive aspergillosis led to a favorable response in 37 (45%) of 83 patients.¹⁸⁰ It might be possible to use combination antifungal therapy pairing an echinocandin with either an amphotericin B preparation or an azole with activity against *Aspergillus* species. The rationale is that echinocandins target a unique site (the beta-glucan constituent of the fungal cell wall), which is distinct from the polyenes and azoles that target the fungal cell membrane. The combination of an echinocandin with an azole or amphotericin B has shown neutral to synergistic activity in vitro. Enhanced efficacy of

combination regimens pairing an echinocandin with either an azole or an amphotericin B formulation was observed in some animal models of invasive aspergillosis⁶²³⁻⁶²⁶ but not in others.⁶²⁷⁻⁶²⁹ In two small retrospective series, the combination of caspofungin and L-AmB for infections refractory to first-line therapy led to a favorable outcome in approximately 40% to 60% of patients with invasive aspergillosis, although these series included cases of “possible” or “probable” aspergillosis.^{630,631} Marr et al reported a significant improvement in the 3-month survival rate with voriconazole plus caspofungin compared with voriconazole alone in a small retrospective analysis (N = 47) of invasive aspergillosis refractory to first-line therapy.⁶³² This database study, although encouraging, involved small numbers of patients and the 2 groups of patients evaluated were non-contemporaneous; therefore, other host and infection-related factors may have influenced the outcome. A noncomparative study of caspofungin combined with other mold-active drugs as subsequent-line therapy for invasive aspergillosis reported a success rate of 49% (25/51) at 12 weeks after initiation of combination therapy,⁶³³ which was similar to caspofungin monotherapy.¹⁸⁰ In an open-label study of invasive aspergillosis, micafungin combined with other antifungals led to a successful response in 29% (5/17) of patients treated as primary therapy and 35% (60/174) of patients with infection refractory to first-line therapy.⁶³⁴ These results did not appear favorable to response rates observed with micafungin alone (50% and 41% in primary and refractory treatment groups, respectively); however, the patient numbers in the micafungin monotherapy arms were too small to permit comparisons. In addition, the initial micafungin dose (75 mg/d) used in this study was low by current standards. More recently, data from a randomized, prospective clinical trial comparing voriconazole versus voriconazole plus anidulafungin as primary therapy for invasive aspergillosis evaluated response based on 6-week mortality (N = 454 patients with hematologic malignancies or HCT).⁶³⁵ The combination therapy had a trend towards reduced mortality compared to voriconazole alone (19.3% vs. 27.5%, respectively; 95% CI, -19.0–1.5; *P* = .087).⁶³⁵

Isavuconazonium sulfate was approved in March 2015 for the treatment of invasive aspergillosis and invasive mucormycosis.¹¹⁰ Unlike other azoles, isavuconazonium sulfate is dosed as a prodrug that is broken down to the active component, isavuconazole, upon infusion.⁶³⁶ A phase III, randomized

trial comparing isavuconazonium sulfate to voriconazole for the primary treatment of invasive aspergillosis and other filamentous fungi showed the non-inferiority of isavuconazonium sulfate compared with voriconazole (all-cause mortality of 19% vs. 20%; adjusted difference -1.0%; 95% CI, -7.8–5.7%).⁶³⁷ Treatment-emergent adverse events were similar between isavuconazonium sulfate and voriconazole (96% vs. 98%; $P = .122$) with GI disorders and infections or infestations as the most common (see *Toxicities and Drug-Drug Interactions of Azoles* for more information on safety). Isavuconazonium sulfate demonstrated a lower incidence of hepatobiliary disorders, eye disorders, and skin or subcutaneous tissue disorders. Drug-related adverse events were also lower for isavuconazonium sulfate compared to voriconazole (42% vs. 60%; $P < .001$). Based on these data, isavuconazonium sulfate can be considered for patients who have invasive, refractory infections or who have intolerance to amphotericin B formulations. A 2016 update to the IDSA Practice Guidelines lists isavuconazonium sulfate as an alternative therapy option for primary treatment of invasive aspergillosis.⁶³⁸

Posaconazole has shown activity as a second-line agent against a broad spectrum of invasive fungal infections.^{639,642} In an open-label study in patients with invasive aspergillosis refractory to or who had intolerance to standard antifungal therapy (N = 107), 42% had a complete or partial response with posaconazole.⁶⁴³ Posaconazole is approved in the European Union for the treatment of invasive aspergillosis and certain other invasive fungal infections refractory to standard antifungal agents. In the United States, posaconazole is approved by the FDA for prophylaxis of invasive *Aspergillus* and *Candida* infections, and for treatment of oropharyngeal candidiasis (including cases refractory to fluconazole or itraconazole), but is not indicated as primary or subsequent-line therapy for invasive fungal disease.¹²⁸

The NCCN Guidelines Panel recommends voriconazole monotherapy (category 1) as primary therapy for invasive aspergillosis (see *Antifungal Agents: Azoles* in the algorithm). Although combination antifungal therapy is used as treatment for invasive aspergillosis in some centers, the clinical evidence is inadequate to make conclusions about whether any

combination regimen is more effective than voriconazole alone, the current gold standard.

For patients receiving treatment with an echinocandin, the panel recommends TDM following initiation of treatment to ensure adequate plasma concentrations of the drug. Ongoing TDM is generally warranted.

Mucormycosis and Other Invasive Mold Infections

A higher frequency of mucormycosis (previously referred to as “zygomycosis”) has emerged at some institutions with the increased use of voriconazole.^{527,644,645} In a case-control study of invasive aspergillosis and mucormycosis in patients with acute leukemia and allogeneic HCT recipients, use of voriconazole and presence of fungal sinusitis each favored a diagnosis of mucormycosis.⁵²⁷ However, some transplant centers reported an increased frequency of mucormycosis that pre-dated the availability of voriconazole,^{646,647} a finding that likely reflects a greater proportion of patients with severe host defense impairment. Mucormycosis typically manifests as rhinocerebral or pulmonary disease. Histopathology showing broad aseptate or hyposeptate hyphae with 90-degree branching is suggestive of mucormycosis, although culture is required for confirmation.

To date, there have been no positive results from randomized studies for treatment of mucormycosis and other uncommon invasive mold infections. Therefore, recommendations for therapy are based on a limited number of patients from retrospective analyses, data registries, and open-label trials for refractory infections. Treatment of mucormycosis involves amphotericin B (a lipid formulation is advised over amphotericin B deoxycholate to reduce the chance of nephrotoxicity) plus early and aggressive surgical debridement, when feasible. A gap in knowledge exists regarding optimal dosing of amphotericin B lipid formulations for invasive non-*Aspergillus* mold infections; an initial dose of 5 mg/kg/d is commonly used. Isavuconazonium sulfate and posaconazole have shown promising results as therapy in mucormycosis refractory to or intolerant of amphotericin B formulations and may be considered for these patients.^{639,648,649} Data from an open-label, single-arm, case-control study showed that isavuconazonium sulfate had activity against rare fungi,

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including mucormycosis, compared to matched controls treated with amphotericin B-based treatment (crude all-cause mortality of 33% vs. 39%; 95% CIs, 14.6–57.0% and 22.9–57.9%, respectively).⁶⁴⁹ Ninety-five percent of patients treated with isavuconazonium sulfate had one or more adverse events during treatment, most commonly GI disorders (see *Toxicities and Drug-Drug Interactions of Azoles* for more information on safety).

While isavuconazonium sulfate is approved for the treatment of invasive mucormycosis, posaconazole has not been FDA approved for this indication. Isavuconazonium sulfate and posaconazole can also be considered as maintenance therapy for mucormycosis following control of infection with an amphotericin B formulation and/or surgical debridement.

Fusarium species⁶⁵⁰⁻⁶⁵² and *Scedosporium* species have emerged as important causes of invasive fungal infection-related mortality in leukemia and in allogeneic HCT recipients at some centers.^{647,653,654} The likelihood of infection by a *Fusarium* species is substantially increased by the presence of disseminated cutaneous lesions and isolation of a mold from blood culture.⁶⁵⁰ Therapy for invasive fusariosis generally involves voriconazole,⁶⁵⁵ posaconazole,⁶⁴² or a lipid formulation of amphotericin B.⁶⁵⁶ *Scedosporium* species are resistant to amphotericin B; therapy generally involves itraconazole, voriconazole, or posaconazole.^{657,658} An infectious disease consultation is advised in all cases of invasive mold infections, particularly for cases involving uncommon and resistant molds.

Early Diagnosis of Invasive Mold Infections

The frequency and diversity of invasive fungal pathogens have increased, and effectively treating these pathogens remains a major challenge. CT scanning of the chest may facilitate early detection of aspergillosis and other filamentous fungi.^{659,660} A CT scan may show peripheral or subpleural nodules that are not apparent on plain chest radiographs. The “halo sign” is a characteristic, but not pathognomonic, early chest CT feature of angioinvasive organisms.⁵⁵² The hazy alveolar infiltrates surrounding the central nodule or region of consolidation appear to correspond to regions of hemorrhage and are highly suggestive of invasive mold disease, aspergillosis being the most common. The panel recommends a chest CT scan in patients with 10 to 14 days of neutropenia and with persistent

or recurrent fever of unknown origin that is unresponsive to empiric antibacterial agents. A chest CT scan may be considered earlier in patients with multiple prior cycles of potentially cytotoxic chemotherapy and in patients receiving systemic corticosteroid therapy.

Studies differ regarding whether serum galactomannan is a useful surveillance tool in asymptomatic patients at high risk for mold infections and in patients with persistent neutropenic fever of unknown etiology. In one study, prospective serial monitoring of galactomannan antigenemia in allogeneic HCT recipients yielded positive and negative predictive values of 94.4% and 98.8%, respectively, and antigenemia preceded radiographic findings by more than 1 week in 80% of cases of invasive aspergillosis.⁶⁶¹ In another study, the sensitivity was only 64.5% in cases of definite invasive aspergillosis.⁵⁶² The PPV was poor when serum galactomannan was used as a surveillance tool in patients with persistent neutropenic fever (PPV = 7.1%) and in HCT (mostly autologous) recipients (PPV = 10%); the negative predictive value was 100% in both groups.⁵⁶²

Odabasi et al⁵⁵⁶ evaluated the beta-glucan assay as an early diagnostic marker for invasive fungal infections in patients with acute leukemia or MDS receiving antifungal prophylaxis.⁵⁵⁶ At least one serum sample was positive at a median of 10 days before the clinical diagnosis in all patients with a proven or probable invasive fungal infection, including candidiasis, fusariosis, trichosporonosis, and aspergillosis. The negative predictive value was 100%, and the specificity of the test was 90% for a single positive test result and at least 96% for 2 or more sequential positive results.⁵⁵⁶ The experience of the beta-glucan assay in HCT recipients is limited and requires additional study.

Although valuable as diagnostic adjuncts to support a diagnosis of probable invasive aspergillosis in patients with compatible host factors, clinical findings, and radiologic findings⁶⁶² (see *Initial Clinical Presentation for Lung Infiltrates: Evaluation* in the algorithm), the value of these laboratory markers as surveillance tools for invasive fungal infections is controversial. Use of surveillance markers as a trigger for additional diagnostic evaluation or to modify antifungal therapy is at an exploratory level,⁵¹³ and more research is required. Currently, the evidence is inadequate to



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recommend any of these methods as a surveillance tool in asymptomatic immunocompromised patients or in patients with neutropenic fever alone.

Summary

Substantial progress has been made in the prevention and treatment of infectious complications associated with neutropenia and IST in patients with cancer. Certain populations of patients are at increased risk for developing infectious complications during the course of their disease and cancer treatment. Infectious complications remain an important cause of morbidity and mortality in patients undergoing anti-tumor therapy. The extent of infectious risk is highly dependent on an individual patient's underlying malignancy, degree of neutropenia, past history of infections and exposure to pathogens, treatment with myelosuppressive regimens, and the overall status of immune function in the patient. It is therefore imperative that patients be evaluated individually for risk of infection in order to minimize the occurrence of infection-related complications.

Preventative measures for infection management in patients with cancer include routine surveillance to monitor for early laboratory indications of infection (especially in the context of viral reactivations) and the appropriate use of prophylaxis and/or preemptive therapy with antimicrobial agents in high-risk patient groups. It is important to note that upfront prophylaxis is not necessary in all patients with cancer; prophylactic measures should only be used in patients at high risk for specific pathogens during the high-risk period in order to avoid the emergence of resistant pathogens.

The development of antipseudomonal beta-lactam agents and the routine use of empiric antimicrobial therapy at the onset of neutropenic fever have contributed to reductions in mortality from bacterial infections. With more patients undergoing treatment with potent cytotoxic regimens (eg, in acute leukemia) and receiving allogeneic HCT, opportunistic viral and fungal infections have become important causes of mortality in these patients. In addition, the increasing prevalence of antibiotic-resistant pathogens is a challenge. Infection control should not only rely on anti-infective prophylaxis but should continue to incorporate standard infection control measures (eg, careful hand-washing by health care professionals). When selecting antimicrobial agents for prophylaxis and/or preemptive therapy,

consideration should be given to the local susceptibility and resistance patterns of pathogens.

In summary, prevention and treatment of infections in patients with cancer is a complex and continuously evolving field. However, these advances in treatment have only further emphasized the need for multidisciplinary care. The NCCN Guidelines for Prevention and Treatment of Cancer-Related Infections aim to provide an overview of the risk categorization and recommended strategies for prevention of infections in high-risk patient populations, and recommendations for empiric therapy, evaluation, follow-up, and monitoring in patients with signs and/or symptoms of infections. Individualized risk evaluation for infections, incorporation of preventative measures, and prompt identification and treatment of active infections are essential components of the overall spectrum of care in cancer management, and can contribute to optimizing treatment outcomes in patients with cancer.

References

- Hughes WT, Armstrong D, Bodey GP, et al. 2002 guidelines for the use of antimicrobial agents in neutropenic patients with cancer. *Clin Infect Dis* 2002;34:730-751. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11850858>.
- Pizzo PA. Management of fever in patients with cancer and treatment-induced neutropenia. *N Engl J Med* 1993;328:1323-1332. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8469254>.
- Rolston KV, Rubenstein EB, Freifeld A. Early empiric antibiotic therapy for febrile neutropenia patients at low risk. *Infect Dis Clin North Am* 1996;10:223-237. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8803619>.
- Talcott JA, Finberg R, Mayer RJ, Goldman L. The medical course of cancer patients with fever and neutropenia. Clinical identification of a low-risk subgroup at presentation. *Arch Intern Med* 1988;148:2561-2568. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/3196123>.
- Mihu CN, Schaub J, Kesh S, et al. Risk factors for late *Staphylococcus aureus* bacteremia after allogeneic hematopoietic stem cell transplantation: a single-institution, nested case-controlled study. *Biol Blood Marrow Transplant* 2008;14:1429-1433. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19041067>.
- Neofytos D, Horn D, Anaissie E, et al. Epidemiology and outcome of invasive fungal infection in adult hematopoietic stem cell transplant recipients: analysis of Multicenter Prospective Antifungal Therapy (PATH) Alliance registry. *Clin Infect Dis* 2009;48:265-273. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19115967>.
- Rizzo JD, Wingard JR, Tichelli A, et al. Recommended screening and preventive practices for long-term survivors after hematopoietic cell transplantation: joint recommendations of the European Group for Blood and Marrow Transplantation, the Center for International Blood and Marrow Transplant Research, and the American Society of Blood and Marrow Transplantation. *Biol Blood Marrow Transplant* 2006;12:138-151. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16443512>.
- Sullivan KM, Dykewicz CA, Longworth DL, et al. Preventing opportunistic infections after hematopoietic stem cell transplantation: the Centers for Disease Control and Prevention, Infectious Diseases Society of America, and American Society for Blood and Marrow Transplantation Practice Guidelines and beyond. *Hematology Am Soc Hematol Educ Program* 2001:392-421. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11722995>.
- U.S. National Library of Medicine-Key MEDLINE® Indicators. Available at: http://www.nlm.nih.gov/bsd/bsd_key.html. Accessed November 9, 2017.
- Griffiths H, Lea J, Bunch C, et al. Predictors of infection in chronic lymphocytic leukaemia (CLL). *Clin Exp Immunol* 1992;89:374-377. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1516254>.
- Savage DG, Lindenbaum J, Garrett TJ. Biphasic pattern of bacterial infection in multiple myeloma. *Ann Intern Med* 1982;96:47-50. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/6976144>.
- Molteni A, Nosari A, Montillo M, et al. Multiple lines of chemotherapy are the main risk factor for severe infections in patients with chronic lymphocytic leukemia with febrile episodes. *Haematologica* 2005;90:1145-1147. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16079122>.
- Perkins JG, Flynn JM, Howard RS, Byrd JC. Frequency and type of serious infections in fludarabine-refractory B-cell chronic lymphocytic leukemia and small lymphocytic lymphoma: implications for clinical trials in this patient population. *Cancer* 2002;94:2033-2039. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11932906>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

14. DiNubile MJ. Fever and neutropenia: still a challenge. *Contemp Intern Med* 1995;7:35-37. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10150331>.
15. Schimpff SC. Empiric antibiotic therapy for granulocytopenic cancer patients. *Am J Med* 1986;80:13-20. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/3521270>.
16. Freifeld AG, Bow EJ, Sepkowitz KA, et al. Clinical practice guideline for the use of antimicrobial agents in neutropenic patients with cancer: 2010 update by the infectious diseases society of america. *Clin Infect Dis* 2011;52:e56-93. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21258094>.
17. Rolston KV. The Infectious Diseases Society of America 2002 guidelines for the use of antimicrobial agents in patients with cancer and neutropenia: salient features and comments. *Clin Infect Dis* 2004;39 Suppl 1:S44-48. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15250020>.
18. Gerson SL, Talbot GH, Hurwitz S, et al. Prolonged granulocytopenia: the major risk factor for invasive pulmonary aspergillosis in patients with acute leukemia. *Ann Intern Med* 1984;100:345-351. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/6696356>.
19. Bodey GP, Buckley M, Sathe YS, Freireich EJ. Quantitative relationships between circulating leukocytes and infection in patients with acute leukemia. *Ann Intern Med* 1966;64:328-340. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/5216294>.
20. Bochud PY, Calandra T, Francioli P. Bacteremia due to viridans streptococci in neutropenic patients: a review. *Am J Med* 1994;97:256-264. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8092175>.
21. Engelhard D, Elishoov H, Or R, et al. Cytosine arabinoside as a major risk factor for *Streptococcus viridans* septicemia following bone marrow transplantation: a 5-year prospective study. *Bone Marrow Transplant* 1995;16:565-570. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8528173>.
22. Gonzalez-Barca E, Fernandez-Sevilla A, Carratala J, et al. Prospective study of 288 episodes of bacteremia in neutropenic cancer patients in a single institution. *Eur J Clin Microbiol Infect Dis* 1996;15:291-296. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8781879>.
23. Rossetti F, Cesaro S, Putti MC, Zanesco L. High-dose cytosine arabinoside and viridans streptococcus sepsis in children with leukemia. *Pediatr Hematol Oncol* 1995;12:387-392. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7577391>.
24. Chen YK, Hou HA, Chow JM, et al. The impact of oral herpes simplex virus infection and candidiasis on chemotherapy-induced oral mucositis among patients with hematological malignancies. *Eur J Clin Microbiol Infect Dis* 2011;30:753-759. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/21225303>.
25. Epstein JB, Hancock PJ, Nantel S. Oral candidiasis in hematopoietic cell transplantation patients: an outcome-based analysis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2003;96:154-163. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12931087>.
26. Kalhs P, Kier P, Lechner K. Functional asplenia after bone marrow transplantation. *Ann Intern Med* 1990;113:805-806. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2240887>.
27. Anaissie EJ, Kontoyiannis DP, O'Brien S, et al. Infections in patients with chronic lymphocytic leukemia treated with fludarabine. *Ann Intern Med* 1998;129:559-566. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9758577>.
28. Morrison VA, Rai KR, Peterson BL, et al. Impact of therapy With chlorambucil, fludarabine, or fludarabine plus chlorambucil on infections in patients with chronic lymphocytic leukemia: Intergroup Study Cancer and Leukemia Group B 9011. *J Clin Oncol* 2001;19:3611-3621. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11504743>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

29. Anaissie E, Kontoyiannis DP, Kantarjian H, et al. Listeriosis in patients with chronic lymphocytic leukemia who were treated with fludarabine and prednisone. *Ann Intern Med* 1992;117:466-469. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1354425>.
30. O'Brien S, Kantarjian H, Beran M, et al. Results of fludarabine and prednisone therapy in 264 patients with chronic lymphocytic leukemia with multivariate analysis-derived prognostic model for response to treatment. *Blood* 1993;82:1695-1700. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8400226>.
31. U. S. Food and Drug Administration. Prescribing information. Campath® (alemtuzumab) injection for intravenous use. 2014. Available at: https://www.accessdata.fda.gov/drugsatfda_docs/label/2014/103948s5150lbl.pdf. Accessed November 9, 2017.
32. Hillmen P, Skotnicki AB, Robak T, et al. Alemtuzumab compared with chlorambucil as first-line therapy for chronic lymphocytic leukemia. *J Clin Oncol* 2007;25:5616-5623. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17984186>.
33. Moreton P, Kennedy B, Lucas G, et al. Eradication of minimal residual disease in B-cell chronic lymphocytic leukemia after alemtuzumab therapy is associated with prolonged survival. *J Clin Oncol* 2005;23:2971-2979. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15738539>.
34. Stilgenbauer S, Zenz T, Winkler D, et al. Subcutaneous alemtuzumab in fludarabine-refractory chronic lymphocytic leukemia: clinical results and prognostic marker analyses from the CLL2H study of the German Chronic Lymphocytic Leukemia Study Group. *J Clin Oncol* 2009;27:3994-4001. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19597025>.
35. Keating MJ, Flinn I, Jain V, et al. Therapeutic role of alemtuzumab (Campath-1H) in patients who have failed fludarabine: results of a large international study. *Blood* 2002;99:3554-3561. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11986207>.
36. Thursky KA, Worth LJ, Seymour JF, et al. Spectrum of infection, risk and recommendations for prophylaxis and screening among patients with lymphoproliferative disorders treated with alemtuzumab*. *Br J Haematol* 2006;132:3-12. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16371014>.
37. Laurenti L, Piccioni P, Cattani P, et al. Cytomegalovirus reactivation during alemtuzumab therapy for chronic lymphocytic leukemia: incidence and treatment with oral ganciclovir. *Haematologica* 2004;89:1248-1252. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15477211>.
38. Nguyen DD, Cao TM, Dugan K, et al. Cytomegalovirus viremia during Campath-1H therapy for relapsed and refractory chronic lymphocytic leukemia and prolymphocytic leukemia. *Clin Lymphoma* 2002;3:105-110. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12435283>.
39. O'Brien S, Ravandi F, Riehl T, et al. Valganciclovir prevents cytomegalovirus reactivation in patients receiving alemtuzumab-based therapy. *Blood* 2008;111:1816-1819. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18039954>.
40. Sandherr M, Einsele H, Hebart H, et al. Antiviral prophylaxis in patients with haematological malignancies and solid tumours: Guidelines of the Infectious Diseases Working Party (AGIHO) of the German Society for Hematology and Oncology (DGHO). *Ann Oncol* 2006;17:1051-1059. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16410361>.
41. Oscier D, Fegan C, Hillmen P, et al. Guidelines on the diagnosis and management of chronic lymphocytic leukaemia. *Br J Haematol* 2004;125:294-317. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15086411>.
42. Hallek M, Cheson BD, Catovsky D, et al. Guidelines for the diagnosis and treatment of chronic lymphocytic leukemia: a report from the International Workshop on Chronic Lymphocytic Leukemia updating the National Cancer Institute-Working Group 1996 guidelines. *Blood* 2008;111:5446-5456. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18216293>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

43. U.S. Food and Drug Administration. FDA drug safety communication: Boxed warning and new recommendations to decrease risk of hepatitis B reactivation with the immune-suppressing and anti-cancer drugs Arzerra (ofatumumab) and Rituxan (rituximab). 2013. Available at: <http://www.fda.gov/Drugs/DrugSafety/ucm366406.htm>. Accessed November 9, 2017.

44. Genentech, Inc. Prescribing information. Rituxan® (rituximab) injection for intravenous use. 2016. Available at: https://www.gene.com/download/pdf/rituxan_prescribing.pdf. Accessed November 9, 2017.

45. Novartis Pharmaceuticals. Prescribing information. Arzerra® (ofatumumab) injection for intravenous infusion. 2016. Available at: <https://www.pharma.us.novartis.com/sites/www.pharma.us.novartis.com/files/arzerra.pdf>. Accessed November 9, 2017.

46. Dervite I, Hober D, Morel P. Acute hepatitis B in a patient with antibodies to hepatitis B surface antigen who was receiving rituximab. *N Engl J Med* 2001;344:68-69. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11187122>.

47. Kim EB, Kim DS, Park SJ, et al. Hepatitis B virus reactivation in a surface antigen-negative and antibody-positive patient after rituximab plus CHOP chemotherapy. *Cancer Res Treat* 2008;40:36-38. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19688064>.

48. Koo YX, Tay M, Teh YE, et al. Risk of hepatitis B virus (HBV) reactivation in hepatitis B surface antigen negative/hepatitis B core antibody positive patients receiving rituximab-containing combination chemotherapy without routine antiviral prophylaxis. *Ann Hematol* 2011;90:1219-1223. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/21520001>.

49. Matsue K, Kimura S, Takanashi Y, et al. Reactivation of hepatitis B virus after rituximab-containing treatment in patients with CD20-positive B-cell lymphoma. *Cancer* 2010;116:4769-4776. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20597091>.

50. Niitsu N, Hagiwara Y, Tanae K, et al. Prospective analysis of hepatitis B virus reactivation in patients with diffuse large B-cell lymphoma after rituximab combination chemotherapy. *J Clin Oncol* 2010;28:5097-5100. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20837949>.

51. Pei SN, Chen CH, Lee CM, et al. Reactivation of hepatitis B virus following rituximab-based regimens: a serious complication in both HBsAg-positive and HBsAg-negative patients. *Ann Hematol* 2010;89:255-262. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19697028>.

52. Carson KR, Evens AM, Richey EA, et al. Progressive multifocal leukoencephalopathy after rituximab therapy in HIV-negative patients: a report of 57 cases from the Research on Adverse Drug Events and Reports project. *Blood* 2009;113:4834-4840. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19264918>.

53. D'Souza A, Wilson J, Mukherjee S, Jaiyesimi I. Progressive multifocal leukoencephalopathy in chronic lymphocytic leukemia: a report of three cases and review of the literature. *Clin Lymphoma Myeloma Leuk* 2010;10:E1-9. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20223720>.

54. Hopfinger G, Plessl A, Grisold W, et al. Progressive multifocal leukoencephalopathy after rituximab in a patient with relapsed follicular lymphoma and low IgG levels and a low CD4+ lymphocyte count. *Leuk Lymphoma* 2008;49:2367-2369. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19052987>.

55. Paues J, Vrethem M. Fatal progressive multifocal leukoencephalopathy in a patient with non-Hodgkin lymphoma treated with rituximab. *J Clin Virol* 2010;48:291-293. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20558102>.

56. Reddy N, Abel TW, Jagasia M, et al. Progressive multifocal leukoencephalopathy in a patient with follicular lymphoma treated with multiple courses of rituximab. *Leuk Lymphoma* 2009;50:460-462. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19266387>.

NCCN Guidelines Version 1.2019
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57. Rey J, Belmecheri N, Bouayed N, et al. JC papovavirus leukoencephalopathy after first line treatment with CHOP and rituximab. *Haematologica* 2007;92:e101. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18024364>.
58. Tuccori M, Focosi D, Maggi F, et al. Progressive multifocal leukoencephalopathy: a report of three cases in HIV-negative patients with non-Hodgkin's lymphomas treated with rituximab. *Ann Hematol* 2010;89:519-522. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19727726>.
59. Yokoyama H, Watanabe T, Maruyama D, et al. Progressive multifocal leukoencephalopathy in a patient with B-cell lymphoma during rituximab-containing chemotherapy: case report and review of the literature. *Int J Hematol* 2008;88:443-447. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18855101>.
60. De Vos FY, Gijtenbeek JM, Bleeker-Rovers CP, van Herpen CM. *Pneumocystis jirovecii* pneumonia prophylaxis during temozolomide treatment for high-grade gliomas. *Crit Rev Oncol Hematol* 2013;85:373-382. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/22925496>.
61. Gilead Sciences, Inc. Prescribing Information. Zydelig® (idelalisib) tablets for oral use. 2016. Available at: http://www.gilead.com/~media/files/pdfs/medicines/oncology/zydelig/zydelig_pi.pdf?la=en. Accessed November 9, 2017.
62. Ahn IE, Jerussi T, Farooqui M, et al. Atypical *Pneumocystis jirovecii* pneumonia in previously untreated patients with CLL on single-agent ibrutinib. *Blood* 2016;128:1940-1943. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/27503501>.
63. Abkur TM, Saeed M, Ahmed SZ, et al. *Pneumocystis jirovecii* prophylaxis in patients undergoing Bendamustine treatment: the need for a standardized protocol. *Clin Case Rep* 2015;3:255-259. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/25914820>.
64. Crippa F, Holmberg L, Carter RA, et al. Infectious complications after autologous CD34-selected peripheral blood stem cell transplantation. *Biol Blood Marrow Transplant* 2002;8:281-289. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12064366>.
65. Rapoport AP, Miller Watelet LF, Linder T, et al. Analysis of factors that correlate with mucositis in recipients of autologous and allogeneic stem-cell transplants. *J Clin Oncol* 1999;17:2446-2453. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10561308>.
66. Ruescher TJ, Sodeifi A, Scrivani SJ, et al. The impact of mucositis on alpha-hemolytic streptococcal infection in patients undergoing autologous bone marrow transplantation for hematologic malignancies. *Cancer* 1998;82:2275-2281. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9610710>.
67. Sonis ST, Oster G, Fuchs H, et al. Oral mucositis and the clinical and economic outcomes of hematopoietic stem-cell transplantation. *J Clin Oncol* 2001;19:2201-2205. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11304772>.
68. Straka C, Sandherr M, Salwender H, et al. Testing G-CSF responsiveness predicts the individual susceptibility to infection and consecutive treatment in recipients of high-dose chemotherapy. *Blood* 2011;117:2121-2128. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21163927>.
69. Mackall C, Fry T, Gress R, et al. Background to hematopoietic cell transplantation, including post transplant immune recovery. *Bone Marrow Transplant* 2009;44:457-462. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19861978>.
70. Tomblyn M, Chiller T, Einsele H, et al. Guidelines for preventing infectious complications among hematopoietic cell transplantation recipients: a global perspective. *Biol Blood Marrow Transplant* 2009;15:1143-1238. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19747629>.



NCCN Guidelines Version 1.2019

Prevention and Treatment of Cancer-Related Infections

71. Meijer E, Dekker AW, Rozenberg-Arska M, et al. Influence of cytomegalovirus seropositivity on outcome after T cell-depleted bone marrow transplantation: contrasting results between recipients of grafts from related and unrelated donors. *Clin Infect Dis* 2002;35:703-712. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12203168>.

72. Marr KA, Carter RA, Boeckh M, et al. Invasive aspergillosis in allogeneic stem cell transplant recipients: changes in epidemiology and risk factors. *Blood* 2002;100:4358-4366. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12393425>.

73. Marr KA, Seidel K, White TC, Bowden RA. Candidemia in allogeneic blood and marrow transplant recipients: evolution of risk factors after the adoption of prophylactic fluconazole. *J Infect Dis* 2000;181:309-316. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10608780>.

74. Girmenia C, Barosi G, Piciocchi A, et al. Primary prophylaxis of invasive fungal diseases in allogeneic stem cell transplantation: revised recommendations from a consensus process by Gruppo Italiano Trapianto Midollo Osseo (GITMO). *Biol Blood Marrow Transplant* 2014;20:1080-1088. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/24582783>.

75. Winston DJ, Schiffman G, Wang DC, et al. Pneumococcal infections after human bone-marrow transplantation. *Ann Intern Med* 1979;91:835-841. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/42335>.

76. Kulkarni S, Powles R, Treleaven J, et al. Chronic graft versus host disease is associated with long-term risk for pneumococcal infections in recipients of bone marrow transplants. *Blood* 2000;95:3683-3686. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10845897>.

77. Bennett CL, Djulbegovic B, Norris LB, Armitage JO. Colony-stimulating factors for febrile neutropenia during cancer therapy. *N Engl J Med* 2013;368:1131-1139. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/23514290>.

78. Talcott JA, Siegel RD, Finberg R, Goldman L. Risk assessment in cancer patients with fever and neutropenia: a prospective, two-center validation of a prediction rule. *J Clin Oncol* 1992;10:316-322. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1732432>.

79. Engels EA, Lau J, Barza M. Efficacy of quinolone prophylaxis in neutropenic cancer patients: a meta-analysis. *J Clin Oncol* 1998;16:1179-1187. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9508206>.

80. Bow EJ, Rayner E, Louie TJ. Comparison of norfloxacin with cotrimoxazole for infection prophylaxis in acute leukemia. The trade-off for reduced gram-negative sepsis. *Am J Med* 1988;84:847-854. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/3284340>.

81. Elting LS, Bodey GP, Keefe BH. Septicemia and shock syndrome due to viridans streptococci: a case-control study of predisposing factors. *Clin Infect Dis* 1992;14:1201-1207. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1623076>.

82. Razonable RR, Litzow MR, Khaliq Y, et al. Bacteremia due to viridans group Streptococci with diminished susceptibility to Levofloxacin among neutropenic patients receiving levofloxacin prophylaxis. *Clin Infect Dis* 2002;34:1469-1474. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12015693>.

83. Eleutherakis-Papaiakovou E, Kostis E, Migkou M, et al. Prophylactic antibiotics for the prevention of neutropenic fever in patients undergoing autologous stem-cell transplantation: results of a single institution, randomized phase 2 trial. *Am J Hematol* 2010;85:863-867. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20882526>.

84. Gafter-Gvili A, Fraser A, Paul M, Leibovici L. Meta-analysis: antibiotic prophylaxis reduces mortality in neutropenic patients. *Ann Intern Med* 2005;142:979-995. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15968013>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

85. Gafter-Gvili A, Paul M, Fraser A, Leibovici L. Effect of quinolone prophylaxis in afebrile neutropenic patients on microbial resistance: systematic review and meta-analysis. *J Antimicrob Chemother* 2007;59:5-22. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17077101>.

86. Gafter-Gvili A, Fraser A, Paul M, et al. Antibiotic prophylaxis for bacterial infections in afebrile neutropenic patients following chemotherapy. *Cochrane Database Syst Rev* 2012;1:CD004386. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/22258955>.

87. Bucaneve G, Micozzi A, Menichetti F, et al. Levofloxacin to prevent bacterial infection in patients with cancer and neutropenia. *N Engl J Med* 2005;353:977-987. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16148283>.

88. Cullen M, Steven N, Billingham L, et al. Antibacterial prophylaxis after chemotherapy for solid tumors and lymphomas. *N Engl J Med* 2005;353:988-998. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16148284>.

89. Cullen MH, Billingham LJ, Gaunt CH, Steven NM. Rational selection of patients for antibacterial prophylaxis after chemotherapy. *J Clin Oncol* 2007;25:4821-4828. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17947731>.

90. Bartlett JG, Perl TM. The new *Clostridium difficile*--what does it mean? *N Engl J Med* 2005;353:2503-2505. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16322604>.

91. Cook PP, Catrou P, Gooch M, Holbert D. Effect of reduction in ciprofloxacin use on prevalence of meticillin-resistant *Staphylococcus aureus* rates within individual units of a tertiary care hospital. *J Hosp Infect* 2006;64:348-351. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17046104>.

92. Loo VG, Poirier L, Miller MA, et al. A predominantly clonal multi-institutional outbreak of *Clostridium difficile*-associated diarrhea with high morbidity and mortality. *N Engl J Med* 2005;353:2442-2449. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16322602>.

93. McDonald LC, Killgore GE, Thompson A, et al. An epidemic, toxin gene-variant strain of *Clostridium difficile*. *N Engl J Med* 2005;353:2433-2441. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16322603>.

94. Engelhard D, Cordonnier C, Shaw PJ, et al. Early and late invasive pneumococcal infection following stem cell transplantation: a European Bone Marrow Transplantation survey. *Br J Haematol* 2002;117:444-450. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11972532>.

95. Youssef S, Rodriguez G, Rolston KV, et al. Streptococcus pneumoniae infections in 47 hematopoietic stem cell transplantation recipients: clinical characteristics of infections and vaccine-breakthrough infections, 1989-2005. *Medicine (Baltimore)* 2007;86:69-77. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17435587>.

96. Engelhard D, Akova M, Boeckh MJ, et al. Bacterial infection prevention after hematopoietic cell transplantation. *Bone Marrow Transplant* 2009;44:467-470. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19861980>.

97. Brown SD, Rybak MJ. Antimicrobial susceptibility of Streptococcus pneumoniae, Streptococcus pyogenes and Haemophilus influenzae collected from patients across the USA, in 2001-2002, as part of the PROTEKT US study. *J Antimicrob Chemother* 2004;54 Suppl 1:i7-15. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/15265831>.

98. Kumashi P, Girgawy E, Tarrand JJ, et al. Streptococcus pneumoniae bacteremia in patients with cancer: disease characteristics and outcomes in the era of escalating drug resistance (1998-2002). *Medicine (Baltimore)* 2005;84:303-312. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16148730>.

99. Recommended adult immunization schedule: United States, 2012. *Ann Intern Med* 2012;156:211-217. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22298576>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

100. Rotstein C, Bow EJ, Laverdiere M, et al. Randomized placebo-controlled trial of fluconazole prophylaxis for neutropenic cancer patients: benefit based on purpose and intensity of cytotoxic therapy. The Canadian Fluconazole Prophylaxis Study Group. *Clin Infect Dis* 1999;28:331-340. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10064252>.

101. Goodman JL, Winston DJ, Greenfield RA, et al. A controlled trial of fluconazole to prevent fungal infections in patients undergoing bone marrow transplantation. *N Engl J Med* 1992;326:845-851. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1542320>.

102. Slavin MA, Osborne B, Adams R, et al. Efficacy and safety of fluconazole prophylaxis for fungal infections after marrow transplantation--a prospective, randomized, double-blind study. *J Infect Dis* 1995;171:1545-1552. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7769290>.

103. Marr KA, Seidel K, Slavin MA, et al. Prolonged fluconazole prophylaxis is associated with persistent protection against candidiasis-related death in allogeneic marrow transplant recipients: long-term follow-up of a randomized, placebo-controlled trial. *Blood* 2000;96:2055-2061. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10979947>.

104. Kern W, Behre G, Rudolf T, et al. Failure of fluconazole prophylaxis to reduce mortality or the requirement of systemic amphotericin B therapy during treatment for refractory acute myeloid leukemia: results of a prospective randomized phase III study. German AML Cooperative Group. *Cancer* 1998;83:291-301. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9669812>.

105. Winston DJ, Chandrasekar PH, Lazarus HM, et al. Fluconazole prophylaxis of fungal infections in patients with acute leukemia. Results of a randomized placebo-controlled, double-blind, multicenter trial. *Ann Intern Med* 1993;118:495-503. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8442620>.

106. Wingard JR, Carter SL, Walsh TJ, et al. Randomized, double-blind trial of fluconazole versus voriconazole for prevention of invasive fungal infection after allogeneic hematopoietic cell transplantation. *Blood* 2010;116:5111-5118. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20826719>.

107. Vazquez JA, Skiest DJ, Nieto L, et al. A multicenter randomized trial evaluating posaconazole versus fluconazole for the treatment of oropharyngeal candidiasis in subjects with HIV/AIDS. *Clin Infect Dis* 2006;42:1179-1186. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16575739>.

108. Cornely OA, Maertens J, Winston DJ, et al. Posaconazole vs. fluconazole or itraconazole prophylaxis in patients with neutropenia. *N Engl J Med* 2007;356:348-359. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17251531>.

109. Ullmann AJ, Lipton JH, Vesole DH, et al. Posaconazole or fluconazole for prophylaxis in severe graft-versus-host disease. *N Engl J Med* 2007;356:335-347. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17251530>.

110. Astellas Pharma. Prescribing information. Cresemba® (isavuconazonium sulfate) capsules and intravenous use. 2015. Available at: <https://www.astellas.us/docs/cresemba.pdf>. Accessed November 9, 2017.

111. Cowen EW, Nguyen JC, Miller DD, et al. Chronic phototoxicity and aggressive squamous cell carcinoma of the skin in children and adults during treatment with voriconazole. *J Am Acad Dermatol* 2010;62:31-37. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19896749>.

112. Gerber B, Guggenberger R, Fasler D, et al. Reversible skeletal disease and high fluoride serum levels in hematologic patients receiving voriconazole. *Blood* 2012;120:2390-2394. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22859610>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

113. Miller DD, Cowen EW, Nguyen JC, et al. Melanoma associated with long-term voriconazole therapy: a new manifestation of chronic photosensitivity. *Arch Dermatol* 2010;146:300-304. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20083676>.

114. Tarlock K, Johnson D, Cornell C, et al. Elevated fluoride levels and periostitis in pediatric hematopoietic stem cell transplant recipients receiving long-term voriconazole. *Pediatr Blood Cancer* 2015;62:918-920. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/25327935>.

115. Williams K, Mansh M, Chin-Hong P, et al. Voriconazole-associated cutaneous malignancy: a literature review on photocarcinogenesis in organ transplant recipients. *Clin Infect Dis* 2014;58:997-1002. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/24363331>.

116. Marr KA, Crippa F, Leisenring W, et al. Itraconazole versus fluconazole for prevention of fungal infections in patients receiving allogeneic stem cell transplants. *Blood* 2004;103:1527-1533. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14525770>.

117. Marr KA, Leisenring W, Crippa F, et al. Cyclophosphamide metabolism is affected by azole antifungals. *Blood* 2004;103:1557-1559. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14504090>.

118. US Food and Drug Administration. Isavuconazonium – invasive aspergillosis and invasive mucormycosis. Advisory Committee briefing document. 2015. Available at: <http://www.fda.gov/downloads/advisorycommittees/committeesmeetingmaterials/drugs/anti-infectivedrugsadvisorycommittee/ucm430748.pdf>. Accessed November 9, 2017.

119. Yap YG, Camm AJ. Drug induced QT prolongation and torsades de pointes. *Heart* 2003;89:1363-1372. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14594906>.

120. U.S. Food and Drug Administration. Prescribing information. Sporanox® (itraconazole) capsules. 2014. Available at: http://www.accessdata.fda.gov/drugsatfda_docs/label/2014/020083s053lbl.pdf. Accessed November 9, 2017.

121. Andes D, van Ogtrop M. Characterization and quantitation of the pharmacodynamics of fluconazole in a neutropenic murine disseminated candidiasis infection model. *Antimicrob Agents Chemother* 1999;43:2116-2120. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10471550>.

122. Brammer KW, Farrow PR, Faulkner JK. Pharmacokinetics and tissue penetration of fluconazole in humans. *Rev Infect Dis* 1990;12 Suppl 3:S318-326. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2184510>.

123. Clancy CJ, Yu VL, Morris AJ, et al. Fluconazole MIC and the fluconazole dose/MIC ratio correlate with therapeutic response among patients with candidemia. *Antimicrob Agents Chemother* 2005;49:3171-3177. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16048920>.

124. Csajka C, Decosterd LA, Buclin T, et al. Population pharmacokinetics of fluconazole given for secondary prevention of oropharyngeal candidiasis in HIV-positive patients. *Eur J Clin Pharmacol* 2001;57:723-727. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11829202>.

125. Rex JH, Pfaller MA, Galgiani JN, et al. Development of interpretive breakpoints for antifungal susceptibility testing: conceptual framework and analysis of in vitro-in vivo correlation data for fluconazole, itraconazole, and candida infections. Subcommittee on Antifungal Susceptibility Testing of the National Committee for Clinical Laboratory Standards. *Clin Infect Dis* 1997;24:235-247. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9114154>.

126. U.S. Food and Drug Administration. Prescribing information. Diflucan® (fluconazole) tablets, oral suspension, and intravenous use. 2014. Available at: http://www.accessdata.fda.gov/drugsatfda_docs/label/2014/019949s058,019950s062,020090s042lbl.pdf. Accessed November 9, 2017.

127. Krishna G, Moton A, Ma L, et al. Pharmacokinetics and absorption of posaconazole oral suspension under various gastric conditions in healthy volunteers. *Antimicrob Agents Chemother* 2009;53:958-966. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19075045>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

128. Merck. Prescribing information. Noxafil® (posaconazole) oral suspension, delayed-release tablet, intravenous use. 2017. Available at: http://www.merck.com/product/usa/pi_circulars/n/noxafil/noxafil_pi.pdf. Accessed November 9, 2017.

129. Gross BN, Ihorst G, Jung M, et al. Posaconazole therapeutic drug monitoring in the real-life setting: a single-center experience and review of the literature. *Pharmacotherapy* 2013;33:1117-1125. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23864486>.

130. Bryant AM, Slain D, Cumpston A, Craig M. A post-marketing evaluation of posaconazole plasma concentrations in neutropenic patients with haematological malignancy receiving posaconazole prophylaxis. *Int J Antimicrob Agents* 2011;37:266-269. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21236645>.

131. Bruggemann RJ, Touw DJ, Aarnoutse RE, et al. International interlaboratory proficiency testing program for measurement of azole antifungal plasma concentrations. *Antimicrob Agents Chemother* 2009;53:303-305. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19015363>.

132. Kraft WK, Chang PS, van Iersel ML, et al. Posaconazole tablet pharmacokinetics: lack of effect of concomitant medications altering gastric pH and gastric motility in healthy subjects. *Antimicrob Agents Chemother* 2014;58:4020-4025. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24798274>.

133. Heinz WJ, Egerer G, Lellek H, et al. Posaconazole after previous antifungal therapy with voriconazole for therapy of invasive aspergillus disease, a retrospective analysis. *Mycoses* 2013;56:304-310. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23170837>.

134. Maertens J, Cornely OA, Ullmann AJ, et al. Phase 1B study of the pharmacokinetics and safety of posaconazole intravenous solution in patients at risk for invasive fungal disease. *Antimicrob Agents Chemother* 2014;58:3610-3617. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24733463>.

135. Jang SH, Colangelo PM, Gobburu JV. Exposure-response of posaconazole used for prophylaxis against invasive fungal infections: evaluating the need to adjust doses based on drug concentrations in plasma. *Clin Pharmacol Ther* 2010;88:115-119. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20505665>.

136. Tonini J, Thiebaut A, Jourdil JF, et al. Therapeutic drug monitoring of posaconazole in allogeneic hematopoietic stem cell transplantation patients who develop gastrointestinal graft-versus-host disease. *Antimicrob Agents Chemother* 2012;56:5247-5252. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22850515>.

137. Shields RK, Clancy CJ, Vadnerkar A, et al. Posaconazole serum concentrations among cardiothoracic transplant recipients: factors impacting trough levels and correlation with clinical response to therapy. *Antimicrob Agents Chemother* 2011;55:1308-1311. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21189337>.

138. Eiden C, Meniane JC, Peyriere H, et al. Therapeutic drug monitoring of posaconazole in hematology adults under posaconazole prophylaxis: influence of food intake. *Eur J Clin Microbiol Infect Dis* 2012;31:161-167. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21611869>.

139. Hoenigl M, Raggam RB, Salzer HJ, et al. Posaconazole plasma concentrations and invasive mould infections in patients with haematological malignancies. *Int J Antimicrob Agents* 2012;39:510-513. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22481057>.

140. Lebeaux D, Lanternier F, Elie C, et al. Therapeutic drug monitoring of posaconazole: a monocentric study with 54 adults. *Antimicrob Agents Chemother* 2009;53:5224-5229. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19752284>.

141. Howard SJ, Cerar D, Anderson MJ, et al. Frequency and evolution of Azole resistance in *Aspergillus fumigatus* associated with treatment failure. *Emerg Infect Dis* 2009;15:1068-1076. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19624922>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

142. Mavridou E, Bruggemann RJ, Melchers WJ, et al. Efficacy of posaconazole against three clinical *Aspergillus fumigatus* isolates with mutations in the *cyp51A* gene. *Antimicrob Agents Chemother* 2010;54:860-865. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19917751>.

143. Boogaerts MA, Verhoef GE, Zachee P, et al. Antifungal prophylaxis with itraconazole in prolonged neutropenia: correlation with plasma levels. *Mycoses* 1989;32 Suppl 1:103-108. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2561181>.

144. Tricot G, Joosten E, Boogaerts MA, et al. Ketoconazole vs. itraconazole for antifungal prophylaxis in patients with severe granulocytopenia: preliminary results of two nonrandomized studies. *Rev Infect Dis* 1987;9 Suppl 1:S94-99. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/3027853>.

145. Glasmacher A, Hahn C, Leutner C, et al. Breakthrough invasive fungal infections in neutropenic patients after prophylaxis with itraconazole. *Mycoses* 1999;42:443-451. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10546485>.

146. Glasmacher A, Hahn C, Molitor E, et al. Itraconazole trough concentrations in antifungal prophylaxis with six different dosing regimens using hydroxypropyl-beta-cyclodextrin oral solution or coated-pellet capsules. *Mycoses* 1999;42:591-600. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10680434>.

147. Denning DW, Tucker RM, Hanson LH, et al. Itraconazole therapy for cryptococcal meningitis and cryptococcosis. *Arch Intern Med* 1989;149:2301-2308. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2552949>.

148. Denning DW, Tucker RM, Hanson LH, Stevens DA. Treatment of invasive aspergillosis with itraconazole. *Am J Med* 1989;86:791-800. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2543220>.

149. Sharkey PK, Rinaldi MG, Dunn JF, et al. High-dose itraconazole in the treatment of severe mycoses. *Antimicrob Agents Chemother* 1991;35:707-713. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1648887>.

150. Wheat J, Hafner R, Korzun AH, et al. Itraconazole treatment of disseminated histoplasmosis in patients with the acquired immunodeficiency syndrome. *AIDS Clinical Trial Group. Am J Med* 1995;98:336-342. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7709945>.

151. Lestner JM, Roberts SA, Moore CB, et al. Toxicodynamics of itraconazole: implications for therapeutic drug monitoring. *Clin Infect Dis* 2009;49:928-930. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19681707>.

152. Barone JA, Moskovitz BL, Guarnieri J, et al. Food interaction and steady-state pharmacokinetics of itraconazole oral solution in healthy volunteers. *Pharmacotherapy* 1998;18:295-301. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9545149>.

153. Pascual A, Calandra T, Bolay S, et al. Voriconazole therapeutic drug monitoring in patients with invasive mycoses improves efficacy and safety outcomes. *Clin Infect Dis* 2008;46:201-211. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18171251>.

154. Jeans AR, Howard SJ, Al-Nakeeb Z, et al. Combination of voriconazole and anidulafungin for treatment of triazole-resistant *aspergillus fumigatus* in an in vitro model of invasive pulmonary aspergillosis. *Antimicrob Agents Chemother* 2012;56:5180-5185. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22825124>.

155. Smith J, Safdar N, Knasinski V, et al. Voriconazole therapeutic drug monitoring. *Antimicrob Agents Chemother* 2006;50:1570-1572. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16569888>.

156. Troke PF, Hockey HP, Hope WW. Observational study of the clinical efficacy of voriconazole and its relationship to plasma concentrations in patients. *Antimicrob Agents Chemother* 2011;55:4782-4788. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21768513>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

157. Dolton MJ, Ray JE, Chen SC, et al. Multicenter study of voriconazole pharmacokinetics and therapeutic drug monitoring. *Antimicrob Agents Chemother* 2012;56:4793-4799. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22751544>.

158. Miyakis S, van Hal SJ, Ray J, Marriott D. Voriconazole concentrations and outcome of invasive fungal infections. *Clin Microbiol Infect* 2010;16:927-933. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19845698>.

159. Gomez-Lopez A, Cendejas-Bueno E, Cuesta I, et al. Voriconazole serum levels measured by high-performance liquid chromatography: a monocentric study in treated patients. *Med Mycol* 2012;50:439-445. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22070341>.

160. Ueda K, Nannya Y, Kumano K, et al. Monitoring trough concentration of voriconazole is important to ensure successful antifungal therapy and to avoid hepatic damage in patients with hematological disorders. *Int J Hematol* 2009;89:592-599. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19340528>.

161. Trifilio S, Singhal S, Williams S, et al. Breakthrough fungal infections after allogeneic hematopoietic stem cell transplantation in patients on prophylactic voriconazole. *Bone Marrow Transplant* 2007;40:451-456. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17589527>.

162. Mitsani D, Nguyen MH, Shields RK, et al. Prospective, observational study of voriconazole therapeutic drug monitoring among lung transplant recipients receiving prophylaxis: factors impacting levels of and associations between serum troughs, efficacy, and toxicity. *Antimicrob Agents Chemother* 2012;56:2371-2377. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22330924>.

163. Pascual A, Csajka C, Buclin T, et al. Challenging recommended oral and intravenous voriconazole doses for improved efficacy and safety: population pharmacokinetics-based analysis of adult patients with invasive fungal infections. *Clin Infect Dis* 2012;55:381-390. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22610925>.

164. Zonios DI, Gea-Banacloche J, Childs R, Bennett JE. Hallucinations during voriconazole therapy. *Clin Infect Dis* 2008;47:e7-e10. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18491963>.

165. Hamada Y, Seto Y, Yago K, Kuroyama M. Investigation and threshold of optimum blood concentration of voriconazole: a descriptive statistical meta-analysis. *J Infect Chemother* 2012;18:501-507. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22231601>.

166. Kim KH, Lee S, Lee S, et al. Voriconazole-associated severe hyponatremia. *Med Mycol* 2012;50:103-105. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21671829>.

167. Matsumoto K, Ikawa K, Abematsu K, et al. Correlation between voriconazole trough plasma concentration and hepatotoxicity in patients with different CYP2C19 genotypes. *Int J Antimicrob Agents* 2009;34:91-94. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19261446>.

168. Purkins L, Wood N, Kleinermans D, et al. Effect of food on the pharmacokinetics of multiple-dose oral voriconazole. *Br J Clin Pharmacol* 2003;56 Suppl 1:17-23. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14616409>.

169. Pfizer, Inc. Prescribing information. Vfend® (voriconazole) tablets, oral suspension, and intravenous use. 2017. Available at: <http://labeling.pfizer.com/ShowLabeling.aspx?id=618>. Accessed November 9, 2017.

170. Ashbee HR, Barnes RA, Johnson EM, et al. Therapeutic drug monitoring (TDM) of antifungal agents: guidelines from the British Society for Medical Mycology. *J Antimicrob Chemother* 2014;69:1162-1176. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24379304>.

171. Andes D, Pascual A, Marchetti O. Antifungal therapeutic drug monitoring: established and emerging indications. *Antimicrob Agents Chemother* 2009;53:24-34. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18955533>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

172. Koh LP, Kurup A, Goh YT, et al. Randomized trial of fluconazole versus low-dose amphotericin B in prophylaxis against fungal infections in patients undergoing hematopoietic stem cell transplantation. *Am J Hematol* 2002;71:260-267. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12447954>.

173. Winston DJ, Maziarz RT, Chandrasekar PH, et al. Intravenous and oral itraconazole versus intravenous and oral fluconazole for long-term antifungal prophylaxis in allogeneic hematopoietic stem-cell transplant recipients. A multicenter, randomized trial. *Ann Intern Med* 2003;138:705-713. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12729424>.

174. Bates DW, Su L, Yu DT, et al. Correlates of acute renal failure in patients receiving parenteral amphotericin B. *Kidney Int* 2001;60:1452-1459. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11576359>.

175. Wingard JR, Kubilis P, Lee L, et al. Clinical significance of nephrotoxicity in patients treated with amphotericin B for suspected or proven aspergillosis. *Clin Infect Dis* 1999;29:1402-1407. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10585786>.

176. Rijnders BJ, Cornelissen JJ, Slobbe L, et al. Aerosolized liposomal amphotericin B for the prevention of invasive pulmonary aspergillosis during prolonged neutropenia: a randomized, placebo-controlled trial. *Clin Infect Dis* 2008;46:1401-1408. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18419443>.

177. Perfect JR. Aerosolized antifungal prophylaxis: the winds of change? *Clin Infect Dis* 2008;46:1409-1411. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18419444>.

178. Espinel-Ingroff A. In vitro antifungal activities of anidulafungin and micafungin, licensed agents and the investigational triazole posaconazole as determined by NCCLS methods for 12,052 fungal isolates: review of the literature. *Rev Iberoam Micol* 2003;20:121-136. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15456349>.

179. Villanueva A, Arathoon EG, Gotuzzo E, et al. A randomized double-blind study of caspofungin versus amphotericin for the treatment of candidal esophagitis. *Clin Infect Dis* 2001;33:1529-1535. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11588698>.

180. Maertens J, Raad I, Petrikos G, et al. Efficacy and safety of caspofungin for treatment of invasive aspergillosis in patients refractory to or intolerant of conventional antifungal therapy. *Clin Infect Dis* 2004;39:1563-1571. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15578352>.

181. Kartsonis NA, Saah AJ, Joy Lipka C, et al. Salvage therapy with caspofungin for invasive aspergillosis: results from the caspofungin compassionate use study. *J Infect* 2005;50:196-205. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15780413>.

182. Astellas Pharma. Prescribing information. Mycamine (micafungin sodium) for injection; IV infusion only. 2016. Available at: <https://www.astellas.us/docs/mycamine.pdf>. Accessed November 9, 2017.

183. van Burik J-AH, Ratanatharathorn V, Stepan DE, et al. Micafungin versus fluconazole for prophylaxis against invasive fungal infections during neutropenia in patients undergoing hematopoietic stem cell transplantation. *Clin Infect Dis* 2004;39:1407-1416. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15546073>.

184. Yokote T, Akioka T, Oka S, et al. Successful treatment with micafungin of invasive pulmonary aspergillosis in acute myeloid leukemia, with renal failure due to amphotericin B therapy. *Ann Hematol* 2004;83:64-66. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14661114>.

185. Ota S, Tanaka J, Kahata K, et al. Successful micafungin (FK463) treatment of invasive pulmonary aspergillosis in a patient with acute lymphoblastic leukemia in a phase II study. *Int J Hematol* 2004;79:390-393. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15218972>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

186. Singer MS, Seibel NL, Vezina G, et al. Successful treatment of invasive aspergillosis in two patients with acute myelogenous leukemia. *J Pediatr Hematol Oncol* 2003;25:252-256. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12621247>.

187. Krause DS, Simjee AE, van Rensburg C, et al. A randomized, double-blind trial of anidulafungin versus fluconazole for the treatment of esophageal candidiasis. *Clin Infect Dis* 2004;39:770-775. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15472806>.

188. Vazquez JA, Schranz JA, Clark K, et al. A phase 2, open-label study of the safety and efficacy of intravenous anidulafungin as a treatment for azole-refractory mucosal candidiasis. *J Acquir Immune Defic Syndr* 2008;48:304-309. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18545153>.

189. Reboli AC, Rotstein C, Pappas PG, et al. Anidulafungin versus fluconazole for invasive candidiasis. *N Engl J Med* 2007;356:2472-2482. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17568028>.

190. Harnicar S, Adel N, Jurcic J. Modification of vincristine dosing during concomitant azole therapy in adult acute lymphoblastic leukemia patients. *J Oncol Pharm Pract* 2009;15:175-182. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/19282418>.

191. Bodey GP, Mardani M, Hanna HA, et al. The epidemiology of *Candida glabrata* and *Candida albicans* fungemia in immunocompromised patients with cancer. *Am J Med* 2002;112:380-385. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11904112>.

192. Weinberger M, Elattar I, Marshall D, et al. Patterns of infection in patients with aplastic anemia and the emergence of *Aspergillus* as a major cause of death. *Medicine (Baltimore)* 1992;71:24-43. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1549057>.

193. Walsh TJ, Whitcomb PO, Revankar SG, Pizzo PA. Successful treatment of hepatosplenic candidiasis through repeated cycles of chemotherapy and neutropenia. *Cancer* 1995;76:2357-2362. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8635043>.

194. Offner F, Cordonnier C, Ljungman P, et al. Impact of previous aspergillosis on the outcome of bone marrow transplantation. *Clin Infect Dis* 1998;26:1098-1103. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9597235>.

195. Fukuda T, Boeckh M, Guthrie KA, et al. Invasive aspergillosis before allogeneic hematopoietic stem cell transplantation: 10-year experience at a single transplant center. *Biol Blood Marrow Transplant* 2004;10:494-503. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15205670>.

196. Green H, Paul M, Vidal L, Leibovici L. Prophylaxis of *Pneumocystis pneumonia* in immunocompromised non-HIV-infected patients: systematic review and meta-analysis of randomized controlled trials. *Mayo Clin Proc* 2007;82:1052-1059. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17803871>.

197. Hughes WT, Kuhn S, Chaudhary S, et al. Successful chemoprophylaxis for *Pneumocystis carinii* pneumonitis. *N Engl J Med* 1977;297:1419-1426. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/412099>.

198. Hughes WT, Rivera GK, Schell MJ, et al. Successful intermittent chemoprophylaxis for *Pneumocystis carinii* pneumonitis. *N Engl J Med* 1987;316:1627-1632. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/3495732>.

199. Lindemulder S, Albano E. Successful intermittent prophylaxis with trimethoprim/sulfamethoxazole 2 days per week for *Pneumocystis carinii* (jiroveci) pneumonia in pediatric oncology patients. *Pediatrics* 2007;120:e47-51. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17606548>.

200. Marr KA, Bow E, Chiller T, et al. Fungal infection prevention after hematopoietic cell transplantation. *Bone Marrow Transplant* 2009;44:483-487. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19861982>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

201. Marras TK, Sanders K, Lipton JH, et al. Aerosolized pentamidine prophylaxis for *Pneumocystis carinii* pneumonia after allogeneic marrow transplantation. *Transpl Infect Dis* 2002;4:66-74. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12220242>.

202. Sangiolo D, Storer B, Nash R, et al. Toxicity and efficacy of daily dapsone as *Pneumocystis jirovecii* prophylaxis after hematopoietic stem cell transplantation: a case-control study. *Biol Blood Marrow Transplant* 2005;11:521-529. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15983552>.

203. Souza JP, Boeckh M, Gooley TA, et al. High rates of *Pneumocystis carinii* pneumonia in allogeneic blood and marrow transplant recipients receiving dapsone prophylaxis. *Clin Infect Dis* 1999;29:1467-1471. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10585797>.

204. Vasconcelles MJ, Bernardo MV, King C, et al. Aerosolized pentamidine as pneumocystis prophylaxis after bone marrow transplantation is inferior to other regimens and is associated with decreased survival and an increased risk of other infections. *Biol Blood Marrow Transplant* 2000;6:35-43. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10707997>.

205. DeMasi JM, Cox JA, Leonard D, et al. Intravenous pentamidine is safe and effective as primary pneumocystis pneumonia prophylaxis in children and adolescents undergoing hematopoietic stem cell transplantation. *Pediatr Infect Dis J* 2013;32:933-936. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23538522>.

206. Diri R, Anwer F, Yeager A, et al. Retrospective review of intravenous pentamidine for *Pneumocystis pneumonia* prophylaxis in allogeneic hematopoietic stem cell transplantation. *Transpl Infect Dis* 2016;18:63-69. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/26606757>.

207. Kim SY, Dabb AA, Glenn DJ, et al. Intravenous pentamidine is effective as second line *Pneumocystis pneumonia* prophylaxis in pediatric oncology patients. *Pediatr Blood Cancer* 2008;50:779-783. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17635000>.

208. National Institutes of Health. Prescribing information. Dapsone tablet. 2011. Available at: <https://dailymed.nlm.nih.gov/dailymed/drugInfo.cfm?setid=0792169d-c6f9-4af0-93ae-b75d710c47a9>. Accessed November 9, 2017.

209. El-Sadr WM, Murphy RL, Yurik TM, et al. Atovaquone compared with dapsone for the prevention of *Pneumocystis carinii* pneumonia in patients with HIV infection who cannot tolerate trimethoprim, sulfonamides, or both. Community Program for Clinical Research on AIDS and the AIDS Clinical Trials Group. *N Engl J Med* 1998;339:1889-1895. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9862944>.

210. Madden RM, Pui CH, Hughes WT, et al. Prophylaxis of *Pneumocystis carinii* pneumonia with atovaquone in children with leukemia. *Cancer* 2007;109:1654-1658. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17345613>.

211. Kritz A, Sepkowitz K, Weiss M, et al. *Pneumocystis carinii* pneumonia developing within one month of intensive chemotherapy for treatment of acute lymphoblastic leukemia. *N Engl J Med* 1991;325:661-662. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1861704>.

212. Sepkowitz KA. *Pneumocystis carinii* pneumonia in patients without AIDS. *Clin Infect Dis* 1993;17 Suppl 2:S416-422. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8274607>.

213. Sepkowitz KA. *Pneumocystis carinii* pneumonia among patients with neoplastic disease. *Semin Respir Infect* 1992;7:114-121. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1439321>.

214. Sepkowitz KA, Brown AE, Telzak EE, et al. *Pneumocystis carinii* pneumonia among patients without AIDS at a cancer hospital. *JAMA* 1992;267:832-837. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1732656>.

215. Merck & Co., Inc. Prescribing information. Temodar® (temozolomide) capsules, and injection (IV infusion). 2017. Available at: https://www.merck.com/product/usa/pi_circulars/t/temodar_capsules/temodar_pi.pdf. Accessed November 9, 2017.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

216. Meyers JD, Flournoy N, Thomas ED. Infection with herpes simplex virus and cell-mediated immunity after marrow transplant. *J Infect Dis* 1980;142:338-346. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/6255035>.

217. Saral R, Burns WH, Laskin OL, et al. Acyclovir prophylaxis of herpes-simplex-virus infections. *N Engl J Med* 1981;305:63-67. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/6264292>.

218. Saral R, Ambinder RF, Burns WH, et al. Acyclovir prophylaxis against herpes simplex virus infection in patients with leukemia. A randomized, double-blind, placebo-controlled study. *Ann Intern Med* 1983;99:773-776. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/6359995>.

219. Zaia J, Baden L, Boeckh MJ, et al. Viral disease prevention after hematopoietic cell transplantation. *Bone Marrow Transplant* 2009;44:471-482. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19861981>.

220. Keating M, Coutre S, Rai K, et al. Management guidelines for use of alemtuzumab in B-cell chronic lymphocytic leukemia. *Clin Lymphoma* 2004;4:220-227. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15072613>.

221. Boeckh M, Kim HW, Flowers MED, et al. Long-term acyclovir for prevention of varicella zoster virus disease after allogeneic hematopoietic cell transplantation--a randomized double-blind placebo-controlled study. *Blood* 2006;107:1800-1805. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16282339>.

222. Erard V, Guthrie KA, Varley C, et al. One-year acyclovir prophylaxis for preventing varicella-zoster virus disease after hematopoietic cell transplantation: no evidence of rebound varicella-zoster virus disease after drug discontinuation. *Blood* 2007;110:3071-3077. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17515400>.

223. Asano-Mori Y, Kanda Y, Oshima K, et al. Long-term ultra-low-dose acyclovir against varicella-zoster virus reactivation after allogeneic hematopoietic stem cell transplantation. *Am J Hematol* 2008;83:472-476. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18266207>.

224. Oshima K, Takahashi T, Mori T, et al. One-year low-dose valacyclovir as prophylaxis for varicella zoster virus disease after allogeneic hematopoietic stem cell transplantation. A prospective study of the Japan Hematology and Oncology Clinical Study Group. *Transpl Infect Dis* 2010;12:421-427. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20626711>.

225. Schuchter LM, Wingard JR, Piantadosi S, et al. Herpes zoster infection after autologous bone marrow transplantation. *Blood* 1989;74:1424-1427. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2548641>.

226. Chanan-Khan A, Sonneveld P, Schuster MW, et al. Analysis of herpes zoster events among bortezomib-treated patients in the phase III APEX study. *J Clin Oncol* 2008;26:4784-4790. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18711175>.

227. Reece DE, Rodriguez GP, Chen C, et al. Phase I-II trial of bortezomib plus oral cyclophosphamide and prednisone in relapsed and refractory multiple myeloma. *J Clin Oncol* 2008;26:4777-4783. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18645194>.

228. Tong Y, Qian J, Li Y, et al. The high incidence of varicella herpes zoster with the use of bortezomib in 10 patients. *Am J Hematol* 2007;82:403-404. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17133426>.

229. Varettoni M, Vassallo C, Borroni G, et al. Late onset of bortezomib-associated cutaneous reaction following herpes zoster. *Ann Hematol* 2007;86:301-302. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17131123>.

230. Amgen. Prescribing information. Kyprolis®(carfilzomib) for intravenous injection. 2017. Available at: http://pi.amgen.com/~media/amgen/repositorysites/pi-amgen-com/kyprolis/kyprolis_pi.ashx. Accessed November 9, 2017.

231. Pour L, Adam Z, Buresova L, et al. Varicella-zoster virus prophylaxis with low-dose acyclovir in patients with multiple myeloma treated with bortezomib. *Clin Lymphoma Myeloma* 2009;9:151-153. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19406726>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

232. Vickrey E, Allen S, Mehta J, Singhal S. Acyclovir to prevent reactivation of varicella zoster virus (herpes zoster) in multiple myeloma patients receiving bortezomib therapy. *Cancer* 2009;115:229-232. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19090004>.
233. George B, Pati N, Gilroy N, et al. Pre-transplant cytomegalovirus (CMV) serostatus remains the most important determinant of CMV reactivation after allogeneic hematopoietic stem cell transplantation in the era of surveillance and preemptive therapy. *Transpl Infect Dis* 2010;12:322-329. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20487414>.
234. Beck JC, Wagner JE, DeFor TE, et al. Impact of cytomegalovirus (CMV) reactivation after umbilical cord blood transplantation. *Biol Blood Marrow Transplant* 2010;16:215-222. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19786112>.
235. Milano F, Pergam SA, Xie H, et al. Intensive strategy to prevent CMV disease in seropositive umbilical cord blood transplant recipients. *Blood* 2011;118:5689-5696. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21937692>.
236. Montesinos P, Sanz J, Cantero S, et al. Incidence, risk factors, and outcome of cytomegalovirus infection and disease in patients receiving prophylaxis with oral valganciclovir or intravenous ganciclovir after umbilical cord blood transplantation. *Biol Blood Marrow Transplant* 2009;15:730-740. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19450758>.
237. Meyers JD, Reed EC, Shepp DH, et al. Acyclovir for prevention of cytomegalovirus infection and disease after allogeneic marrow transplantation. *N Engl J Med* 1988;318:70-75. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2827025>.
238. Prentice HG, Gluckman E, Powles RL, et al. Impact of long-term acyclovir on cytomegalovirus infection and survival after allogeneic bone marrow transplantation. European Acyclovir for CMV Prophylaxis Study Group. *Lancet* 1994;343:749-753. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7907729>.
239. Ljungman P, de La Camara R, Milpied N, et al. Randomized study of valacyclovir as prophylaxis against cytomegalovirus reactivation in recipients of allogeneic bone marrow transplants. *Blood* 2002;99:3050-3056. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11929799>.
240. Reusser P, Einsele H, Lee J, et al. Randomized multicenter trial of foscarnet versus ganciclovir for preemptive therapy of cytomegalovirus infection after allogeneic stem cell transplantation. *Blood* 2002;99:1159-1164. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11830461>.
241. Reusser P, Gambertoglio JG, Lilleby K, Meyers JD. Phase I-II trial of foscarnet for prevention of cytomegalovirus infection in autologous and allogeneic marrow transplant recipients. *J Infect Dis* 1992;166:473-479. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1323614>.
242. Bacigalupo A, Tedone E, Van Lint MT, et al. CMV prophylaxis with foscarnet in allogeneic bone marrow transplant recipients at high risk of developing CMV infections. *Bone Marrow Transplant* 1994;13:783-788. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7920315>.
243. Bregante S, Bertilson S, Tedone E, et al. Foscarnet prophylaxis of cytomegalovirus infections in patients undergoing allogeneic bone marrow transplantation (BMT): a dose-finding study. *Bone Marrow Transplant* 2000;26:23-29. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10918402>.
244. Einsele H, Reusser P, Bornhauser M, et al. Oral valganciclovir leads to higher exposure to ganciclovir than intravenous ganciclovir in patients following allogeneic stem cell transplantation. *Blood* 2006;107:3002-3008. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16352807>.
245. Winston DJ, Baden LR, Gabriel DA, et al. Pharmacokinetics of ganciclovir after oral valganciclovir versus intravenous ganciclovir in allogeneic stem cell transplant patients with graft-versus-host disease of the gastrointestinal tract. *Biol Blood Marrow Transplant* 2006;12:635-640. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16737936>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

246. Ayala E, Greene J, Sandin R, et al. Valganciclovir is safe and effective as pre-emptive therapy for CMV infection in allogeneic hematopoietic stem cell transplantation. *Bone Marrow Transplant* 2006;37:851-856. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16532016>.
247. Busca A, de Fabritiis P, Ghisetti V, et al. Oral valganciclovir as preemptive therapy for cytomegalovirus infection post allogeneic stem cell transplantation. *Transpl Infect Dis* 2007;9:102-107. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17461994>.
248. van der Heiden PLJ, Kalpoe JS, Barge RM, et al. Oral valganciclovir as pre-emptive therapy has similar efficacy on cytomegalovirus DNA load reduction as intravenous ganciclovir in allogeneic stem cell transplantation recipients. *Bone Marrow Transplant* 2006;37:693-698. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16501590>.
249. Kalil AC, Freifeld AG, Lyden ER, Stoner JA. Valganciclovir for cytomegalovirus prevention in solid organ transplant patients: an evidence-based reassessment of safety and efficacy. *PLoS One* 2009;4:e5512. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19436751>.
250. Kalil AC, Mindru C, Botha JF, et al. Risk of cytomegalovirus disease in high-risk liver transplant recipients on valganciclovir prophylaxis: a systematic review and meta-analysis. *Liver Transpl* 2012;18:1440-1447. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22887929>.
251. Genentech, Inc. Prescribing information. Valcyte (valganciclovir hydrochloride) tablets, oral solution. 2017. Available at: https://www.gene.com/download/pdf/valcyte_prescribing.pdf. Accessed November 9, 2017.
252. Bosi A, Bartolozzi B, Vannucchi AM, et al. Polymerase chain reaction-based “pre-emptive” therapy with cidofovir for cytomegalovirus reactivation in allogeneic hematopoietic stem cells transplantation recipients: a prospective study. *Haematologica* 2002;87:446-447. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11940492>.
253. Chakrabarti S, Collingham KE, Osman H, et al. Cidofovir as primary pre-emptive therapy for post-transplant cytomegalovirus infections. *Bone Marrow Transplant* 2001;28:879-881. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11781649>.
254. Ljungman P, Deliliers GL, Platzbecker U, et al. Cidofovir for cytomegalovirus infection and disease in allogeneic stem cell transplant recipients. The Infectious Diseases Working Party of the European Group for Blood and Marrow Transplantation. *Blood* 2001;97:388-392. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11154213>.
255. Platzbecker U, Bandt D, Thiede C, et al. Successful preemptive cidofovir treatment for CMV antigenemia after dose-reduced conditioning and allogeneic blood stem cell transplantation. *Transplantation* 2001;71:880-885. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11349720>.
256. Nguyen Q, Champlin R, Giral S, et al. Late cytomegalovirus pneumonia in adult allogeneic blood and marrow transplant recipients. *Clin Infect Dis* 1999;28:618-623. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10194088>.
257. Boeckh M, Leisenring W, Riddell SR, et al. Late cytomegalovirus disease and mortality in recipients of allogeneic hematopoietic stem cell transplants: importance of viral load and T-cell immunity. *Blood* 2003;101:407-414. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12393659>.
258. Hakki M, Riddell SR, Storek J, et al. Immune reconstitution to cytomegalovirus after allogeneic hematopoietic stem cell transplantation: impact of host factors, drug therapy, and subclinical reactivation. *Blood* 2003;102:3060-3067. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12843000>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

259. Montillo M, Schinkoethe T, Elter T. Eradication of minimal residual disease with alemtuzumab in B-cell chronic lymphocytic leukemia (B-CLL) patients: the need for a standard method of detection and the potential impact of bone marrow clearance on disease outcome. *Cancer Invest* 2005;23:488-496. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16203656>.

260. Moretti S, Zikos P, Van Lint MT, et al. Foscarnet vs ganciclovir for cytomegalovirus (CMV) antigenemia after allogeneic hemopoietic stem cell transplantation (HSCT): a randomised study. *Bone Marrow Transplant* 1998;22:175-180. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9707026>.

261. U.S. Food and Drug Administration. Prescribing information. Foscavir™ (foscarnet sodium) for injection. 2014. Available at: http://www.accessdata.fda.gov/drugsatfda_docs/label/2014/020068s020lbl.pdf. Accessed November 9, 2017.

262. Gilead Sciences, Inc. Prescribing information. Vistide® (cidofovir) injection. 2010. Available at: <http://www.gilead.com/~media/files/pdfs/medicines/other/vistide/vistide.pdf>. Accessed November 9, 2017.

263. O'Brien SM, Keating MJ, Mocarski ES. Updated guidelines on the management of cytomegalovirus reactivation in patients with chronic lymphocytic leukemia treated with alemtuzumab. *Clin Lymphoma Myeloma* 2006;7:125-130. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17026823>.

264. Liang R. How I treat and monitor viral hepatitis B infection in patients receiving intensive immunosuppressive therapies or undergoing hematopoietic stem cell transplantation. *Blood* 2009;113:3147-3153. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19144986>.

265. Brechot C, Degos F, Lugassy C, et al. Hepatitis B virus DNA in patients with chronic liver disease and negative tests for hepatitis B surface antigen. *N Engl J Med* 1985;312:270-276. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2981408>.

266. Dhedin N, Douvin C, Kuentz M, et al. Reverse seroconversion of hepatitis B after allogeneic bone marrow transplantation: a retrospective study of 37 patients with pretransplant anti-HBs and anti-HBc. *Transplantation* 1998;66:616-619. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9753342>.

267. Borentain P, Colson P, Coso D, et al. Clinical and virological factors associated with hepatitis B virus reactivation in HBsAg-negative and anti-HBc antibodies-positive patients undergoing chemotherapy and/or autologous stem cell transplantation for cancer. *J Viral Hepat* 2010;17:807-815. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20002298>.

268. Evens AM, Jovanovic BD, Su YC, et al. Rituximab-associated hepatitis B virus (HBV) reactivation in lymphoproliferative diseases: meta-analysis and examination of FDA safety reports. *Ann Oncol* 2011;22:1170-1180. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21115603>.

269. Fukushima N, Mizuta T, Tanaka M, et al. Retrospective and prospective studies of hepatitis B virus reactivation in malignant lymphoma with occult HBV carrier. *Ann Oncol* 2009;20:2013-2017. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19561036>.

270. Ji D, Cao J, Hong X, et al. Low incidence of hepatitis B virus reactivation during chemotherapy among diffuse large B-cell lymphoma patients who are HBsAg-negative/ HBcAb-positive: a multicenter retrospective study. *Eur J Haematol* 2010;85:243-250. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20491883>.

271. Koo YX, Tan DS, Tan IB, et al. Hepatitis B virus reactivation and role of antiviral prophylaxis in lymphoma patients with past hepatitis B virus infection who are receiving chemoimmunotherapy. *Cancer* 2010;116:115-121. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19899164>.

272. Lalazar G, Rund D, Shouval D. Screening, prevention and treatment of viral hepatitis B reactivation in patients with haematological malignancies. *Br J Haematol* 2007;136:699-712. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17338776>.

273. Lau GKK, He M-L, Fong DYT, et al. Preemptive use of lamivudine reduces hepatitis B exacerbation after allogeneic hematopoietic cell transplantation. *Hepatology* 2002;36:702-709. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12198664>.
274. Yeo W, Chan PK, Zhong S, et al. Frequency of hepatitis B virus reactivation in cancer patients undergoing cytotoxic chemotherapy: a prospective study of 626 patients with identification of risk factors. *J Med Virol* 2000;62:299-307. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11055239>.
275. Yeo W, Chan TC, Leung NW, et al. Hepatitis B virus reactivation in lymphoma patients with prior resolved hepatitis B undergoing anticancer therapy with or without rituximab. *J Clin Oncol* 2009;27:605-611. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19075267>.
276. European Association For The Study Of The L. EASL 2017 Clinical Practice Guidelines on the management of hepatitis B virus infection. *J Hepatol* 2017;67:370-398. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/28427875>.
277. Liang RH, Lok AS, Lai CL, et al. Hepatitis B infection in patients with lymphomas. *Hematol Oncol* 1990;8:261-270. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1701155>.
278. Dai MS, Lu JJ, Chen YC, et al. Reactivation of precore mutant hepatitis B virus in chemotherapy-treated patients. *Cancer* 2001;92:2927-2932. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11753968>.
279. Steinberg JL, Yeo W, Zhong S, et al. Hepatitis B virus reactivation in patients undergoing cytotoxic chemotherapy for solid tumours: precore/core mutations may play an important role. *J Med Virol* 2000;60:249-255. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10630955>.
280. Galbraith RM, Eddleston AL, Williams R, Zuckerman AJ. Fulminant hepatic failure in leukaemia and choriocarcinoma related to withdrawal of cytotoxic drug therapy. *Lancet* 1975;2:528-530. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/51345>.
281. Pinto PC, Hu E, Bernstein-Singer M, et al. Acute hepatic injury after the withdrawal of immunosuppressive chemotherapy in patients with hepatitis B. *Cancer* 1990;65:878-884. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2297658>.
282. Yeo W, Chan PK, Hui P, et al. Hepatitis B virus reactivation in breast cancer patients receiving cytotoxic chemotherapy: a prospective study. *J Med Virol* 2003;70:553-561. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12794717>.
283. Yeo W, Hui EP, Chan AT, et al. Prevention of hepatitis B virus reactivation in patients with nasopharyngeal carcinoma with lamivudine. *Am J Clin Oncol* 2005;28:379-384. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16062080>.
284. Vignano M, Vener C, Lampertico P, et al. Risk of hepatitis B surface antigen seroreversion after allogeneic hematopoietic SCT. *Bone Marrow Transplant* 2011;46:125-131. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20383209>.
285. Hammond SP, Borchelt AM, Ukomadu C, et al. Hepatitis B virus reactivation following allogeneic hematopoietic stem cell transplantation. *Biol Blood Marrow Transplant* 2009;15:1049-1059. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19660717>.
286. Rossi G, Pelizzari A, Motta M, Puoti M. Primary prophylaxis with lamivudine of hepatitis B virus reactivation in chronic HbsAg carriers with lymphoid malignancies treated with chemotherapy. *Br J Haematol* 2001;115:58-62. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11722410>.
287. Yeo W, Chan PKS, Ho WM, et al. Lamivudine for the prevention of hepatitis B virus reactivation in hepatitis B s-antigen seropositive cancer patients undergoing cytotoxic chemotherapy. *J Clin Oncol* 2004;22:927-934. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14990649>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

288. Ziakas PD, Karsaliakos P, Mylonakis E. Effect of prophylactic lamivudine for chemotherapy-associated hepatitis B reactivation in lymphoma: a meta-analysis of published clinical trials and a decision tree addressing prolonged prophylaxis and maintenance. *Haematologica* 2009;94:998-1005. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19454492>.

289. Giaccone L, Festuccia M, Marengo A, et al. Hepatitis B virus reactivation and efficacy of prophylaxis with lamivudine in patients undergoing allogeneic stem cell transplantation. *Biol Blood Marrow Transplant* 2010;16:809-817. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20060484>.

290. Gish RG. Hepatitis B treatment: Current best practices, avoiding resistance. *Cleve Clin J Med* 2009;76 Suppl 3:S14-19. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19465704>.

291. Cortelezzi A, Vigano M, Zilioli VR, et al. Adefovir added to lamivudine for hepatitis B recurrent infection in refractory B-cell chronic lymphocytic leukemia on prolonged therapy with Campath-1H. *J Clin Virol* 2006;35:467-469. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16316778>.

292. Peters MG, Hann Hw H, Martin P, et al. Adefovir dipivoxil alone or in combination with lamivudine in patients with lamivudine-resistant chronic hepatitis B. *Gastroenterology* 2004;126:91-101. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14699491>.

293. Yu S, Luo H, Pan M, et al. Comparison of entecavir and lamivudine in preventing HBV reactivation in lymphoma patients undergoing chemotherapy: a meta-analysis. *Int J Clin Pharm* 2016;38:1035-1043. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/27450506>.

294. Agarwal K, Fung SK, Nguyen TT, et al. Twenty-eight day safety, antiviral activity, and pharmacokinetics of tenofovir alafenamide for treatment of chronic hepatitis B infection. *J Hepatol* 2015;62:533-540. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/25450717>.

295. Marcellin P, Heathcote EJ, Buti M, et al. Tenofovir disoproxil fumarate versus adefovir dipivoxil for chronic hepatitis B. *N Engl J Med* 2008;359:2442-2455. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19052126>.

296. Buti M, Gane E, Seto WK, et al. Tenofovir alafenamide versus tenofovir disoproxil fumarate for the treatment of patients with HBeAg-negative chronic hepatitis B virus infection: a randomised, double-blind, phase 3, non-inferiority trial. *Lancet Gastroenterol Hepatol* 2016;1:196-206. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/28404092>.

297. Chan HL, Fung S, Seto WK, et al. Tenofovir alafenamide versus tenofovir disoproxil fumarate for the treatment of HBeAg-positive chronic hepatitis B virus infection: a randomised, double-blind, phase 3, non-inferiority trial. *Lancet Gastroenterol Hepatol* 2016;1:185-195. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/28404091>.

298. Kitrinou KM, Corsa A, Liu Y, et al. No detectable resistance to tenofovir disoproxil fumarate after 6 years of therapy in patients with chronic hepatitis B. *Hepatology* 2014;59:434-442. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23939953>.

299. Marcellin P, Gane E, Buti M, et al. Regression of cirrhosis during treatment with tenofovir disoproxil fumarate for chronic hepatitis B: a 5-year open-label follow-up study. *Lancet* 2013;381:468-475. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23234725>.

300. Leung N, Peng C-Y, Hann H-W, et al. Early hepatitis B virus DNA reduction in hepatitis B e antigen-positive patients with chronic hepatitis B: A randomized international study of entecavir versus adefovir. *Hepatology* 2009;49:72-79. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19065670>.

301. Chan HL, Heathcote EJ, Marcellin P, et al. Treatment of hepatitis B e antigen positive chronic hepatitis with telbivudine or adefovir: a randomized trial. *Ann Intern Med* 2007;147:745-754. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17909201>.



302. Watanabe M, Shibuya A, Takada J, et al. Entecavir is an optional agent to prevent hepatitis B virus (HBV) reactivation: a review of 16 patients. *Eur J Intern Med* 2010;21:333-337. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20603047>.

303. Liu WP, Zheng W, Song YQ, et al. Hepatitis B surface antigen seroconversion after HBV reactivation in non-Hodgkin's lymphoma. *World J Gastroenterol* 2014;20:5165-5170. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24803836>.

304. Tenney DJ, Rose RE, Baldick CJ, et al. Long-term monitoring shows hepatitis B virus resistance to entecavir in nucleoside-naïve patients is rare through 5 years of therapy. *Hepatology* 2009;49:1503-1514. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19280622>.

305. Hadziyannis SJ, Tassopoulos NC, Heathcote EJ, et al. Long-term therapy with adefovir dipivoxil for HBeAg-negative chronic hepatitis B for up to 5 years. *Gastroenterology* 2006;131:1743-1751. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17087951>.

306. Heathcote EJ, Marcellin P, Buti M, et al. Three-year efficacy and safety of tenofovir disoproxil fumarate treatment for chronic hepatitis B. *Gastroenterology* 2011;140:132-143. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20955704>.

307. Wang Y, Thongsawat S, Gane EJ, et al. Efficacy and safety of continuous 4-year telbivudine treatment in patients with chronic hepatitis B. *J Viral Hepat* 2013;20:e37-46. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23490388>.

308. Ha NB, Ha NB, Garcia RT, et al. Renal dysfunction in chronic hepatitis B patients treated with adefovir dipivoxil. *Hepatology* 2009;50:727-734. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19517525>.

309. Izzedine H, Hulot JS, Launay-Vacher V, et al. Renal safety of adefovir dipivoxil in patients with chronic hepatitis B: two double-blind, randomized, placebo-controlled studies. *Kidney Int* 2004;66:1153-1158. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15327411>.

310. Nelson MR, Katlama C, Montaner JS, et al. The safety of tenofovir disoproxil fumarate for the treatment of HIV infection in adults: the first 4 years. *AIDS* 2007;21:1273-1281. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17545703>.

311. Marcellin P, Wursthorn K, Wedemeyer H, et al. Telbivudine plus pegylated interferon alfa-2a in a randomized study in chronic hepatitis B is associated with an unexpected high rate of peripheral neuropathy. *J Hepatol* 2015;62:41-47. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/25152207>.

312. Liaw YF, Gane E, Leung N, et al. 2-Year GLOBE trial results: telbivudine is superior to lamivudine in patients with chronic hepatitis B. *Gastroenterology* 2009;136:486-495. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19027013>.

313. Artz AS, Somerfield MR, Feld JJ, et al. American Society of Clinical Oncology provisional clinical opinion: chronic hepatitis B virus infection screening in patients receiving cytotoxic chemotherapy for treatment of malignant diseases. *J Clin Oncol* 2010;28:3199-3202. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20516452>.

314. Lok AS, McMahon BJ. Chronic hepatitis B: update 2009. *Hepatology* 2009;50:661-662. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19714720>.

315. McQuillan GM, Townsend TR, Johannes CB, et al. Prevention of perinatal transmission of hepatitis B virus: the sensitivity, specificity, and predictive value of the recommended screening questions to detect high-risk women in an obstetric population. *Am J Epidemiol* 1987;126:484-491. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/3618580>.

316. IOM. Hepatitis and liver cancer: A national strategy for prevention and control of hepatitis B and C: National Academies Press; 2010. Available at: <http://www.cdc.gov/hepatitis/pdfs/iom-hepatitisandlivercancerreport.pdf>. Accessed November 9, 2017.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

317. Hatzakis A, Wait S, Bruix J, et al. The state of hepatitis B and C in Europe: report from the hepatitis B and C summit conference*. J Viral Hepat 2011;18 Suppl 1:1-16. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/21824223>.

318. Weinbaum CM, Williams I, Mast EE, et al. Recommendations for identification and public health management of persons with chronic hepatitis B virus infection. MMWR Recomm Rep 2008;57:1-20. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18802412>.

319. Ghany MG, Strader DB, Thomas DL, Seeff LB. Diagnosis, management, and treatment of hepatitis C: an update. Hepatology 2009;49:1335-1374. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19330875>.

320. Lok AS, McMahon BJ. Chronic hepatitis B. Hepatology 2007;45:507-539. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17256718>.

321. Zelenetz AD, Wierda WG, Abramson JS, et al. Non-Hodgkin's Lymphomas, Version 1.2013. J Natl Compr Canc Netw 2013;11:257-273. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23486452>.

322. National Comprehensive Cancer Network. NCCN Clinical Practice Guidelines in Oncology (NCCN Guidelines®) for B-cell Lymphomas v5.2017. 2017. Available at: www.nccn.org. Accessed November 9, 2017.

323. Lee MH, Yang HI, Lu SN, et al. Chronic hepatitis C virus infection increases mortality from hepatic and extrahepatic diseases: a community-based long-term prospective study. J Infect Dis 2012;206:469-477. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22811301>.

324. Yazici O, Sendur MA, Aksoy S. Hepatitis C virus reactivation in cancer patients in the era of targeted therapies. World J Gastroenterol 2014;20:6716-6724. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24944464>.

325. Borchardt RA, Torres HA. Challenges in managing hepatitis C virus infection in cancer patients. World J Gastroenterol 2014;20:2771-2776. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24659870>.

326. AASLD/IDSA: recommendations for testing, managing, and treating hepatitis C. Available at: www.hcvguidelines.org. Accessed November 9, 2017.

327. HIV Surveillance Report. Vol. 27; 2015. Available at: <http://www.cdc.gov/hiv/library/reports/surveillance/>.

328. Chiao EY, Dezube BJ, Krown SE, et al. Time for oncologists to opt in for routine opt-out HIV testing? JAMA 2010;304:334-339. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20639567>.

329. Silverberg MJ, Chao C, Leyden WA, et al. HIV infection, immunodeficiency, viral replication, and the risk of cancer. Cancer Epidemiol Biomarkers Prev 2011;20:2551-2559. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22109347>.

330. Shiels MS, Pfeiffer RM, Gail MH, et al. Cancer burden in the HIV-infected population in the United States. J Natl Cancer Inst 2011;103:753-762. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21483021>.

331. Biggar RJ, Engels EA, Ly S, et al. Survival after cancer diagnosis in persons with AIDS. J Acquir Immune Defic Syndr 2005;39:293-299. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15980688>.

332. Yarchoan R, Tosato G, Little RF. Therapy insight: AIDS-related malignancies--the influence of antiviral therapy on pathogenesis and management. Nat Clin Pract Oncol 2005;2:406-415; quiz 423. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/16130937>.

333. Rudek MA, Flexner C, Ambinder RF. Use of antineoplastic agents in patients with cancer who have HIV/AIDS. Lancet Oncol 2011;12:905-912. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21570912>.

334. Hwang JP, Granwehr BP, Torres HA, et al. HIV testing in patients with cancer at the initiation of therapy at a large US comprehensive cancer center. J Oncol Pract 2015;11:384-390. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/26243649>.

335. Branson BM, Handsfield HH, Lampe MA, et al. Revised recommendations for HIV testing of adults, adolescents, and pregnant women in health-care settings. *MMWR Recomm Rep* 2006;55:1-17; quiz CE11-14. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16988643>.

336. Gross AE, Bryson ML. Oral ribavirin for the treatment of noninfluenza respiratory viral infections: a systematic review. *Ann Pharmacother* 2015;49:1125-1135. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/26228937>.

337. Beard OE, Freifeld A, Ison MG, et al. Current practices for treatment of respiratory syncytial virus and other non-influenza respiratory viruses in high-risk patient populations: a survey of institutions in the Midwestern Respiratory Virus Collaborative. *Transpl Infect Dis* 2016;18:210-215. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/26923867>.

338. Hoellein A, Hecker J, Hoffmann D, et al. Serious outbreak of human metapneumovirus in patients with hematologic malignancies. *Leuk Lymphoma* 2016;57:623-627. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/26122193>.

339. Godet C, Le Goff J, Beby-Defaux A, et al. Human metapneumovirus pneumonia in patients with hematological malignancies. *J Clin Virol* 2014;61:593-596. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/25440914>.

340. Shah DP, Shah PK, Azzi JM, Chemaly RF. Parainfluenza virus infections in hematopoietic cell transplant recipients and hematologic malignancy patients: A systematic review. *Cancer Lett* 2016;370:358-364. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/26582658>.

341. Anak S, Atay D, Unuvar A, et al. Respiratory syncytial virus infection outbreak among pediatric patients with oncologic diseases and/or BMT. *Pediatr Pulmonol* 2010;45:307-311. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20146398>.

342. Choi JH, Choi EH, Kang HJ, et al. Respiratory viral infections after hematopoietic stem cell transplantation in children. *J Korean Med Sci* 2013;28:36-41. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23341709>.

343. Khanna N, Widmer AF, Decker M, et al. Respiratory syncytial virus infection in patients with hematological diseases: single-center study and review of the literature. *Clin Infect Dis* 2008;46:402-412. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18181739>.

344. Asner S, Stephens D, Pedulla P, et al. Risk factors and outcomes for respiratory syncytial virus-related infections in immunocompromised children. *Pediatr Infect Dis J* 2013;32:1073-1076. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23732222>.

345. Lo MS, Lee GM, Gunawardane N, et al. The impact of RSV, adenovirus, influenza, and parainfluenza infection in pediatric patients receiving stem cell transplant, solid organ transplant, or cancer chemotherapy. *Pediatr Transplant* 2013;17:133-143. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23228170>.

346. Whimbey E, Champlin RE, Englund JA, et al. Combination therapy with aerosolized ribavirin and intravenous immunoglobulin for respiratory syncytial virus disease in adult bone marrow transplant recipients. *Bone Marrow Transplant* 1995;16:393-399. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8535312>.

347. Marcelin JR, Wilson JW, Razonable RR, et al. Oral ribavirin therapy for respiratory syncytial virus infections in moderately to severely immunocompromised patients. *Transpl Infect Dis* 2014;16:242-250. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24621016>.

348. Centers for Disease Control and Prevention. Antiviral agents for the treatment and chemoprophylaxis of influenza. *Morbidity and Mortality Weekly Report* 2011;60:1-26. Available at: <http://www.cdc.gov/mmwr/pdf/rr/rr6001.pdf>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

349. Fiore AE, Fry A, Shay D, et al. Antiviral agents for the treatment and chemoprophylaxis of influenza --- recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Recomm Rep* 2011;60:1-24. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/21248682>.
350. Mandell LA, Wunderink RG, Anzueto A, et al. Infectious Diseases Society of America/American Thoracic Society consensus guidelines on the management of community-acquired pneumonia in adults. *Clin Infect Dis* 2007;44 Suppl 2:27-72. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17278083>.
351. Genentech. Prescribing information. Tamiflu® (oseltamivir phosphate) capsules, oral suspension. 2016. Available at: https://www.gene.com/download/pdf/tamiflu_prescribing.pdf. Accessed November 9, 2017.
352. GlaxoSmithKline. Prescribing information. Relenza (zanamivir) inhalation powder for oral inhalation. 2016. Available at: https://www.gsksource.com/pharma/content/dam/GlaxoSmithKline/US/en/Prescribing_Information/Relenza/pdf/RELENZA-PI.PDF. Accessed November 9, 2017.
353. U.S. Food and Drug Administration. Influenza (flu) antiviral drugs and related information. Rockville, MD: 2016. Available at: <http://www.fda.gov/Drugs/DrugSafety/InformationbyDrugClass/ucm100228.htm>. Accessed November 9, 2017.
354. Ison MG, Hui DS, Clezy K, et al. A clinical trial of intravenous peramivir compared with oral oseltamivir for the treatment of seasonal influenza in hospitalized adults. *Antivir Ther* 2013;18:651-661. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23111657>.
355. BioCryst Pharmaceuticals, Inc. Prescribing information. Rapivab® (peramivir) for intravenous injection. 2017. Available at: <http://labeling.cslbehrling.com/PI/US/Rapivab/EN/Rapivab-Prescribing-Information.pdf>. Accessed November 9, 2017.
356. Raval M, Gulbis A, Bollard C, et al. Evaluation and management of BK virus-associated nephropathy following allogeneic hematopoietic cell transplantation. *Biol Blood Marrow Transplant* 2011;17:1589-1593. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21767514>.
357. Gilis L, Morisset S, Billaud G, et al. High burden of BK virus-associated hemorrhagic cystitis in patients undergoing allogeneic hematopoietic stem cell transplantation. *Bone Marrow Transplant* 2014;49:664-670. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24488049>.
358. Philippe M, Ranchon F, Gilis L, et al. Cidofovir in the treatment of BK virus-associated hemorrhagic cystitis after allogeneic hematopoietic stem cell transplantation. *Biol Blood Marrow Transplant* 2016;22:723-730. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/26718666>.
359. Bowden RA. Respiratory virus infections after marrow transplant: the Fred Hutchinson Cancer Research Center experience. *Am J Med* 1997;102:27-30. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10868139>.
360. Ljungman P. Respiratory virus infections in stem cell transplant patients: the European experience. *Biol Blood Marrow Transplant* 2001;7 Suppl:5S-7S. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11777102>.
361. Whimbey E, Champlin RE, Couch RB, et al. Community respiratory virus infections among hospitalized adult bone marrow transplant recipients. *Clin Infect Dis* 1996;22:778-782. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8722930>.
362. Feldman S, Webster RG, Sugg M. Influenza in children and young adults with cancer: 20 cases. *Cancer* 1977;39:350-353. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/576210>.
363. Kempe A, Hall CB, MacDonald NE, et al. Influenza in children with cancer. *J Pediatr* 1989;115:33-39. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2738793>.



364. Elting LS, Whimbey E, Lo W, et al. Epidemiology of influenza A virus infection in patients with acute or chronic leukemia. *Support Care Cancer* 1995;3:198-202. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7655781>.

365. Fiore AE, Uyeki TM, Broder K, et al. Prevention and control of influenza with vaccines: recommendations of the Advisory Committee on Immunization Practices (ACIP), 2010. *MMWR Recomm Rep* 2010;59:1-62. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20689501>.

366. Keam B, Kim MK, Choi Y, et al. Optimal timing of influenza vaccination during 3-week cytotoxic chemotherapy cycles. *Cancer* 2017;123:841-848. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/27997703>.

367. Harper SA, Fukuda K, Cox NJ, Bridges CB. Using live, attenuated influenza vaccine for prevention and control of influenza: supplemental recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Recomm Rep* 2003;52:1-8. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14557799>.

368. Hakim H, Allison KJ, Van de Velde LA, et al. Immunogenicity and safety of high-dose trivalent inactivated influenza vaccine compared to standard-dose vaccine in children and young adults with cancer or HIV infection. *Vaccine* 2016;34:3141-3148. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/27129426>.

369. Jamshed S, Walsh EE, Dimitroff LJ, et al. Improved immunogenicity of high-dose influenza vaccine compared to standard-dose influenza vaccine in adult oncology patients younger than 65 years receiving chemotherapy: A pilot randomized clinical trial. *Vaccine* 2016;34:630-635. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/26721330>.

370. Hamborsky J, Kroger A, Wolfe S, eds. *Epidemiology and prevention of vaccine-preventable diseases* (ed 13th). Washington D.C.: Centers for Disease Control and Prevention, Public Health Foundation; 2015.

371. Kroger AT, Atkinson WL, Marcuse EK, Pickering LK. General recommendations on immunization: recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Recomm Rep* 2006;55:1-48. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17136024>.

372. Davies JM, Lewis MP, Wimperis J, et al. Review of guidelines for the prevention and treatment of infection in patients with an absent or dysfunctional spleen: prepared on behalf of the British Committee for Standards in Haematology by a working party of the Haemato-Oncology task force. *Br J Haematol* 2011;155:308-317. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21988145>.

373. Rubin LG, Schaffner W. Clinical practice. Care of the asplenic patient. *N Engl J Med* 2014;371:349-356. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/25054718>.

374. Recommended adult immunization schedule --- United States, 2010. Advisory Committee on Immunization Practices and the Centers for Disease Control and Prevention; 2010. Available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5901a5.htm>. Accessed November 9, 2017.

375. Zugmaier G, Topp MS, Alekar S, et al. Long-term follow-up of serum immunoglobulin levels in blinatumomab-treated patients with minimal residual disease-positive B-precursor acute lymphoblastic leukemia. *Blood Cancer J* 2014;4:244. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/25192414>.

376. Bluml S, McKeever K, Ettinger R, et al. B-cell targeted therapeutics in clinical development. *Arthritis Res Ther* 2013;15 Suppl 1:S4. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23566679>.

377. Diwakar L, Gorrie S, Richter A, et al. Does rituximab aggravate pre-existing hypogammaglobulinaemia? *J Clin Pathol* 2010;63:275-277. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20203231>.



378. Casulo C, Maragulia J, Zelenetz AD. Incidence of hypogammaglobulinemia in patients receiving rituximab and the use of intravenous immunoglobulin for recurrent infections. *Clin Lymphoma Myeloma Leuk* 2013;13:106-111. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23276889>.

379. Walker AR, Kleiner A, Rich L, et al. Profound hypogammaglobulinemia 7 years after treatment for indolent lymphoma. *Cancer Invest* 2008;26:431-433. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18443965>.

380. Irie E, Shirota Y, Suzuki C, et al. Severe hypogammaglobulinemia persisting for 6 years after treatment with rituximab combined chemotherapy due to arrest of B lymphocyte differentiation together with alteration of T lymphocyte homeostasis. *Int J Hematol* 2010;91:501-508. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20217285>.

381. Kasamon YL, Jones RJ, Brodsky RA, et al. Immunologic recovery following autologous stem-cell transplantation with pre- and posttransplantation rituximab for low-grade or mantle cell lymphoma. *Ann Oncol* 2010;21:1203-1210. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19880437>.

382. Nishio M, Fujimoto K, Yamamoto S, et al. Delayed redistribution of CD27, CD40 and CD80 positive B cells and the impaired in vitro immunoglobulin production in patients with non-Hodgkin lymphoma after rituximab treatment as an adjuvant to autologous stem cell transplantation. *Br J Haematol* 2007;137:349-354. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17456057>.

383. Ortbals DW, Liebhaber H, Presant CA, et al. Influenza immunization of adult patients with malignant diseases. *Ann Intern Med* 1977;87:552-557. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/921082>.

384. Sommer AL, Wachel BK, Smith JA. Evaluation of vaccine dosing in patients with solid tumors receiving myelosuppressive chemotherapy. *J Oncol Pharm Pract* 2006;12:143-154. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17022869>.

385. Hahn T, Cummings KM, Michalek AM, et al. Efficacy of high-efficiency particulate air filtration in preventing aspergillosis in immunocompromised patients with hematologic malignancies. *Infect Control Hosp Epidemiol* 2002;23:525-531. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12269451>.

386. Donowitz GR, Harman C, Pope T, Stewart FM. The role of the chest roentgenogram in febrile neutropenic patients. *Arch Intern Med* 1991;151:701-704. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2012451>.

387. Gaur AH, Flynn PM, Giannini MA, et al. Difference in time to detection: a simple method to differentiate catheter-related from non-catheter-related bloodstream infection in immunocompromised pediatric patients. *Clin Infect Dis* 2003;37:469-475. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12905129>.

388. Siegman-Igra Y, Anglim AM, Shapiro DE, et al. Diagnosis of vascular catheter-related bloodstream infection: a meta-analysis. *J Clin Microbiol* 1997;35:928-936. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9157155>.

389. Guerrant RL, Van Gilder T, Steiner TS, et al. Practice guidelines for the management of infectious diarrhea. *Clin Infect Dis* 2001;32:331-351. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11170940>.

390. Englund JA, Sullivan CJ, Jordan MC, et al. Respiratory syncytial virus infection in immunocompromised adults. *Ann Intern Med* 1988;109:203-208. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/3389604>.

391. Harrington RD, Hooton TM, Hackman RC, et al. An outbreak of respiratory syncytial virus in a bone marrow transplant center. *J Infect Dis* 1992;165:987-993. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1583345>.

392. Wade JC. Management of infection in patients with acute leukemia. *Hematol Oncol Clin North Am* 1993;7:293-315. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8449863>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

393. Bow EJ, Rotstein C, Noskin GA, et al. A randomized, open-label, multicenter comparative study of the efficacy and safety of piperacillin-tazobactam and cefepime for the empirical treatment of febrile neutropenic episodes in patients with hematologic malignancies. *Clin Infect Dis* 2006;43:447-459. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16838234>.

394. Cometta A, Calandra T, Gaya H, et al. Monotherapy with meropenem versus combination therapy with ceftazidime plus amikacin as empiric therapy for fever in granulocytopenic patients with cancer. The International Antimicrobial Therapy Cooperative Group of the European Organization for Research and Treatment of Cancer and the Gruppo Italiano Malattie Ematologiche Maligne dell'Adulto Infection Program. *Antimicrob Agents Chemother* 1996;40:1108-1115. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8723449>.

395. De Pauw BE, Deresinski SC, Feld R, et al. Ceftazidime compared with piperacillin and tobramycin for the empiric treatment of fever in neutropenic patients with cancer. A multicenter randomized trial. The Intercontinental Antimicrobial Study Group. *Ann Intern Med* 1994;120:834-844. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8154643>.

396. Freifeld AG, Walsh T, Marshall D, et al. Monotherapy for fever and neutropenia in cancer patients: a randomized comparison of ceftazidime versus imipenem. *J Clin Oncol* 1995;13:165-176. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7799016>.

397. Ramphal R, Gucaip R, Rotstein C, et al. Clinical experience with single agent and combination regimens in the management of infection in the febrile neutropenic patient. *Am J Med* 1996;100:83S-89S. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8678102>.

398. Paul M, Yahav D, Fraser A, Leibovici L. Empirical antibiotic monotherapy for febrile neutropenia: systematic review and meta-analysis of randomized controlled trials. *J Antimicrob Chemother* 2006;57:176-189. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16344285>.

399. Yahav D, Paul M, Fraser A, et al. Efficacy and safety of cefepime: a systematic review and meta-analysis. *Lancet Infect Dis* 2007;7:338-348. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17448937>.

400. Horita N, Shibata Y, Watanabe H, et al. Comparison of antipseudomonal beta-lactams for febrile neutropenia empiric therapy: systematic review and network meta-analysis. *Clin Microbiol Infect* 2017;23:723-729. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/28377312>.

401. Information for healthcare professionals: Cefepime (marketed as maxipime). Rockville, MD: U.S. Food and Drug Administration; 2009. Available at: <http://www.fda.gov/Drugs/DrugSafety/PostmarketDrugSafetyInformationforPatientsandProviders/DrugSafetyInformationforHealthcareProfessionals/ucm167254.htm>. Accessed November 9, 2017.

402. Jing Y, Li J, Yuan L, et al. Piperacillin-tazobactam vs. imipenem-cilastatin as empirical therapy in hematopoietic stem cell transplantation recipients with febrile neutropenia. *Clin Transplant* 2016;30:263-269. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/26701371>.

403. US Food and Drug Administration. FDA updates warnings for fluoroquinolone antibiotics. 2016. Available at: <http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm513183.htm>. Accessed November 9, 2017.

404. Cometta A, Zinner S, de Bock R, et al. Piperacillin-tazobactam plus amikacin versus ceftazidime plus amikacin as empiric therapy for fever in granulocytopenic patients with cancer. The International Antimicrobial Therapy Cooperative Group of the European Organization for Research and Treatment of Cancer. *Antimicrob Agents Chemother* 1995;39:445-452. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7726513>.

405. Cordonnier C, Herbrecht R, Pico JL, et al. Cefepime/amikacin versus ceftazidime/amikacin as empirical therapy for febrile episodes in neutropenic patients: a comparative study. The French Cefepime Study Group. *Clin Infect Dis* 1997;24:41-51. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8994754>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

406. Flaherty JP, Waitley D, Edlin B, et al. Multicenter, randomized trial of ciprofloxacin plus azlocillin versus ceftazidime plus amikacin for empiric treatment of febrile neutropenic patients. *Am J Med* 1989;87:278S-282S. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2686429>.

407. Rybak MJ, Abate BJ, Kang SL, et al. Prospective evaluation of the effect of an aminoglycoside dosing regimen on rates of observed nephrotoxicity and ototoxicity. *Antimicrob Agents Chemother* 1999;43:1549-1555. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10390201>.

408. Edmond MB, Ober JF, Weinbaum DL, et al. Vancomycin-resistant *Enterococcus faecium* bacteremia: risk factors for infection. *Clin Infect Dis* 1995;20:1126-1133. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7619987>.

409. Montecalvo MA, Shay DK, Patel P, et al. Bloodstream infections with vancomycin-resistant enterococci. *Arch Intern Med* 1996;156:1458-1462. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8678715>.

410. Vancomycin added to empirical combination antibiotic therapy for fever in granulocytopenic cancer patients. European Organization for Research and Treatment of Cancer (EORTC) International Antimicrobial Therapy Cooperative Group and the National Cancer Institute of Canada-Clinical Trials Group. *J Infect Dis* 1991;163:951-958. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2019772>.

411. Shenep JL, Hughes WT, Roberson PK, et al. Vancomycin, ticarcillin, and amikacin compared with ticarcillin-clavulanate and amikacin in the empirical treatment of febrile, neutropenic children with cancer. *N Engl J Med* 1988;319:1053-1058. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/3050517>.

412. Granowetter L, Wells H, Lange BJ. Ceftazidime with or without vancomycin vs. cephalothin, carbenicillin and gentamicin as the initial therapy of the febrile neutropenic pediatric cancer patient. *Pediatr Infect Dis J* 1988;7:165-170. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/3282214>.

413. Finks J, Wells E, Dyke TL, et al. Vancomycin-resistant *Staphylococcus aureus*, Michigan, USA, 2007. *Emerg Infect Dis* 2009;15:943-945. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19523298>.

414. Sievert DM, Rudrik JT, Patel JB, et al. Vancomycin-resistant *Staphylococcus aureus* in the United States, 2002-2006. *Clin Infect Dis* 2008;46:668-674. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18257700>.

415. Management of multidrug-resistant organisms in healthcare settings, 2006. Department of Health and Human Services USA, Centers for Disease Control; 2006. Available at: <http://www.cdc.gov/hicpac/pdf/MDRO/MDROGuideline2006.pdf>. Accessed November 9, 2017.

416. Guideline for isolation precautions: preventing transmission of infectious agents in healthcare settings. Department of Health and Human Services USA, Centers for Disease Control; 2007. Available at: <http://www.cdc.gov/hicpac/pdf/isolation/isolation2007.pdf>. Accessed November 9, 2017.

417. Lin MY, Hayden MK. Methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant enterococcus: recognition and prevention in intensive care units. *Crit Care Med* 2010;38:S335-344. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20647791>.

418. Mermel LA, Allon M, Bouza E, et al. Clinical practice guidelines for the diagnosis and management of intravascular catheter-related infection: 2009 Update by the Infectious Diseases Society of America. *Clin Infect Dis* 2009;49:1-45. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19489710>.

419. Dellinger RP, Levy MM, Carlet JM, et al. Surviving Sepsis Campaign: international guidelines for management of severe sepsis and septic shock: 2008. *Intensive Care Med* 2008;34:17-60. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18058085>.

420. Kaul DR, Collins CD, Hyzy RC. New developments in antimicrobial use in sepsis. *Curr Pharm Des* 2008;14:1912-1920. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18691102>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

421. Daum RS. Clinical practice. Skin and soft-tissue infections caused by methicillin-resistant *Staphylococcus aureus*. *N Engl J Med* 2007;357:380-390. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17652653>.

422. Martin JH, Norris R, Barras M, et al. Therapeutic monitoring of vancomycin in adult patients: a consensus review of the American Society of Health-System Pharmacists, the Infectious Diseases Society of America, and the Society Of Infectious Diseases Pharmacists. *Clin Biochem Rev* 2010;31:21-24. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20179794>.

423. Reduction of fever and streptococcal bacteremia in granulocytopenic patients with cancer. A trial of oral penicillin V or placebo combined with pefloxacin. International Antimicrobial Therapy Cooperative Group of the European Organization for Research and Treatment of Cancer. *JAMA* 1994;272:1183-1189. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7933348>.

424. Arning M, Wolf HH, Aul C, et al. Infection prophylaxis in neutropenic patients with acute leukaemia--a randomized, comparative study with ofloxacin, ciprofloxacin and co-trimoxazole/colistin. *J Antimicrob Chemother* 1990;26 Suppl D:137-142. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2286588>.

425. Kerr KG, Armitage HT, McWhinney PH. Activity of quinolones against viridans group streptococci isolated from blood cultures of patients with haematological malignancy. *Support Care Cancer* 1999;7:28-30. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9926971>.

426. McWhinney PH, Patel S, Whiley RA, et al. Activities of potential therapeutic and prophylactic antibiotics against blood culture isolates of viridans group streptococci from neutropenic patients receiving ciprofloxacin. *Antimicrob Agents Chemother* 1993;37:2493-2495. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8285642>.

427. Kimura M, Araoka H, Yoshida A, et al. Breakthrough viridans streptococcal bacteremia in allogeneic hematopoietic stem cell transplant recipients receiving levofloxacin prophylaxis in a Japanese hospital. *BMC Infect Dis* 2016;16:372. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/27495798>.

428. Tunkel AR, Sepkowitz KA. Infections caused by viridans streptococci in patients with neutropenia. *Clin Infect Dis* 2002;34:1524-1529. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12015700>.

429. Cometta A, Kern WV, De Bock R, et al. Vancomycin versus placebo for treating persistent fever in patients with neutropenic cancer receiving piperacillin-tazobactam monotherapy. *Clin Infect Dis* 2003;37:382-389. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12884163>.

430. Viscoli C, Cometta A, Kern WV, et al. Piperacillin-tazobactam monotherapy in high-risk febrile and neutropenic cancer patients. *Clin Microbiol Infect* 2006;12:212-216. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16451406>.

431. Linden PK, Moellering RC, Wood CA, et al. Treatment of vancomycin-resistant *Enterococcus faecium* infections with quinupristin/dalfopristin. *Clin Infect Dis* 2001;33:1816-1823. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11668430>.

432. Mave V, Garcia-Diaz J, Islam T, Hasbun R. Vancomycin-resistant enterococcal bacteraemia: is daptomycin as effective as linezolid? *J Antimicrob Chemother* 2009;64:175-180. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19423543>.

433. Moellering RC. Linezolid: the first oxazolidinone antimicrobial. *Ann Intern Med* 2003;138:135-142. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12529096>.

434. Moise PA, Forrest A, Birmingham MC, Schentag JJ. The efficacy and safety of linezolid as treatment for *Staphylococcus aureus* infections in compassionate use patients who are intolerant of, or who have failed to respond to, vancomycin. *J Antimicrob Chemother* 2002;50:1017-1026. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12461026>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

435. Shorr AF, Kunkel MJ, Kollef M. Linezolid versus vancomycin for Staphylococcus aureus bacteraemia: pooled analysis of randomized studies. *J Antimicrob Chemother* 2005;56:923-929. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16195255>.

436. Suleyman G, Mahan M, Zervos MJ. Comparison of Daptomycin and Linezolid in the Treatment of Vancomycin-Resistant Enterococcus faecium in the Absence of Endocarditis. *Infectious Diseases in Clinical Practice* 2017;25:151-154. Available at: http://journals.lww.com/infectdis/Abstract/2017/05000/Comparison_of_Daptomycin_and_Linezolid_in_the.8.aspx.

437. Jaksic B, Martinelli G, Perez-Oteyza J, et al. Efficacy and safety of linezolid compared with vancomycin in a randomized, double-blind study of febrile neutropenic patients with cancer. *Clin Infect Dis* 2006;42:597-607. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16447103>.

438. Smith PF, Birmingham MC, Noskin GA, et al. Safety, efficacy and pharmacokinetics of linezolid for treatment of resistant Gram-positive infections in cancer patients with neutropenia. *Ann Oncol* 2003;14:795-801. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12702536>.

439. Liu C, Bayer A, Cosgrove SE, et al. Clinical practice guidelines by the infectious diseases society of america for the treatment of methicillin-resistant Staphylococcus aureus infections in adults and children: executive summary. *Clin Infect Dis* 2011;52:285-292. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21217178>.

440. Powers JH, Ross DB, Lin D, Soreth J. Linezolid and vancomycin for methicillin-resistant Staphylococcus aureus nosocomial pneumonia: the subtleties of subgroup analyses. *Chest* 2004;126:314-315. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15249482>.

441. Wunderink RG, Mendelson MH, Somero MS, et al. Early microbiological response to linezolid vs vancomycin in ventilator-associated pneumonia due to methicillin-resistant Staphylococcus aureus. *Chest* 2008;134:1200-1207. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18719064>.

442. Wunderink RG, Rello J, Cammarata SK, et al. Linezolid vs vancomycin: analysis of two double-blind studies of patients with methicillin-resistant Staphylococcus aureus nosocomial pneumonia. *Chest* 2003;124:1789-1797. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14605050>.

443. U.S. Food and Drug Administration. Information for healthcare professionals: Linezolid (marketed as zyvox). Rockville, MD: 2007. Available at: <http://www.fda.gov/Drugs/DrugSafety/PostmarketDrugSafetyInformationforPatientsandProviders/DrugSafetyInformationforHealthcareProfessionals/ucm085249.htm>. Accessed November 9, 2017.

444. Jones T, Yeaman MR, Sakoulas G, et al. Failures in clinical treatment of Staphylococcus aureus Infection with daptomycin are associated with alterations in surface charge, membrane phospholipid asymmetry, and drug binding. *Antimicrob Agents Chemother* 2008;52:269-278. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17954690>.

445. Silverman JA, Mortin LI, Vanpraagh ADG, et al. Inhibition of daptomycin by pulmonary surfactant: in vitro modeling and clinical impact. *J Infect Dis* 2005;191:2149-2152. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15898002>.

446. Merck & Co. Prescribing information. Cubicin® (daptomycin) for intravenous injection. 2017. Available at: http://www.merck.com/product/usa/pi_circulars/c/cubicin/cubicin_pi.pdf. Accessed November 9, 2017.

447. Abbanat D, Macielag M, Bush K. Novel antibacterial agents for the treatment of serious Gram-positive infections. *Expert Opin Investig Drugs* 2003;12:379-399. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12605562>.

448. Bozdogan B, Esel D, Whitener C, et al. Antibacterial susceptibility of a vancomycin-resistant Staphylococcus aureus strain isolated at the Hershey Medical Center. *J Antimicrob Chemother* 2003;52:864-868. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14563898>.



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Prevention and Treatment of Cancer-Related Infections

449. Bubalo JS, Munar MY, Cherala G, et al. Daptomycin pharmacokinetics in adult oncology patients with neutropenic fever. *Antimicrob Agents Chemother* 2009;53:428-434. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19015332>.
450. Fowler VG, Boucher HW, Corey GR, et al. Daptomycin versus standard therapy for bacteremia and endocarditis caused by *Staphylococcus aureus*. *N Engl J Med* 2006;355:653-665. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16914701>.
451. Chaftari AM, Hachem R, Mulanovich V, et al. Efficacy and safety of daptomycin in the treatment of Gram-positive catheter-related bloodstream infections in cancer patients. *Int J Antimicrob Agents* 2010;36:182-186. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20452752>.
452. Raad I, Hachem R, Hanna H, et al. Prospective, randomized study comparing quinupristin-dalfopristin with linezolid in the treatment of vancomycin-resistant *Enterococcus faecium* infections. *J Antimicrob Chemother* 2004;53:646-649. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14998986>.
453. Theravance Biopharma US, Inc. Prescribing Information. Vibativ® (telavancin) for intravenous injection. 2016. Available at: <https://www.vibativ.com/pdf/PrescribingInformation.pdf>. Accessed November 9, 2017.
454. Forest Laboratories, LLC. Prescribing information. Teflaro™ (ceftaroline fosamil) for intravenous injection. 2016. Available at: http://www.allergan.com/assets/pdf/teflaro_pi. Accessed November 9, 2017.
455. Corey GR, Jiang H, Moeck G. Dalbavancin or oritavancin for skin infections. *N Engl J Med* 2014;371:1162-1163. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/25243251>.
456. Corey GR, Kabler H, Mehra P, et al. Single-dose oritavancin in the treatment of acute bacterial skin infections. *N Engl J Med* 2014;370:2180-2190. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24897083>.
457. Annane D, Sebille V, Charpentier C, et al. Effect of treatment with low doses of hydrocortisone and fludrocortisone on mortality in patients with septic shock. *JAMA* 2002;288:862-871. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12186604>.
458. Bauer W, Ball J, Grounds M. Unanswered questions from Corticus and pragmatic suggestions. *Crit Care* 2008;12:426-426. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18768090>.
459. Finfer S. Corticosteroids in septic shock. *N Engl J Med* 2008;358:188-190. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18184965>.
460. Groeneveld ABJ, Molenaar N, Beishuizen B. Should we abandon corticosteroids during septic shock? No. *Curr Opin Crit Care* 2008;14:384-389. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18614900>.
461. Sprung CL, Annane D, Keh D, et al. Hydrocortisone therapy for patients with septic shock. *N Engl J Med* 2008;358:111-124. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18184957>.
462. Bollaert PE, Charpentier C, Levy B, et al. Reversal of late septic shock with supraphysiologic doses of hydrocortisone. *Crit Care Med* 1998;26:645-650. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9559600>.
463. Briegel J, Forst H, Haller M, et al. Stress doses of hydrocortisone reverse hyperdynamic septic shock: a prospective, randomized, double-blind, single-center study. *Crit Care Med* 1999;27:723-732. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10321661>.
464. Effect of high-dose glucocorticoid therapy on mortality in patients with clinical signs of systemic sepsis. The Veterans Administration Systemic Sepsis Cooperative Study Group. *N Engl J Med* 1987;317:659-665. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2888017>.
465. Bone RC, Fisher CJ, Jr., Clemmer TP, et al. A controlled clinical trial of high-dose methylprednisolone in the treatment of severe sepsis and septic shock. *N Engl J Med* 1987;317:653-658. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/3306374>.



NCCN Guidelines Version 1.2019

Prevention and Treatment of Cancer-Related Infections

466. Cronin L, Cook DJ, Carlet J, et al. Corticosteroid treatment for sepsis: a critical appraisal and meta-analysis of the literature. *Crit Care Med* 1995;23:1430-1439. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7634816>.
467. Slotman GJ, Fisher CJ, Bone RC, et al. Detrimental effects of high-dose methylprednisolone sodium succinate on serum concentrations of hepatic and renal function indicators in severe sepsis and septic shock. The Methylprednisolone Severe Sepsis Study Group. *Crit Care Med* 1993;21:191-195. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8428468>.
468. Freifeld A, Marchigiani D, Walsh T, et al. A double-blind comparison of empirical oral and intravenous antibiotic therapy for low-risk febrile patients with neutropenia during cancer chemotherapy. *N Engl J Med* 1999;341:305-311. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10423464>.
469. Rolston K, Rubenstein EB, eds. Textbook of febrile neutropenia. London: Informa Healthcare; 2001.
470. Rubenstein EB, Rolston K, Benjamin RS, et al. Outpatient treatment of febrile episodes in low-risk neutropenic patients with cancer. *Cancer* 1993;71:3640-3646. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8490912>.
471. Talcott JA, Whalen A, Clark J, et al. Home antibiotic therapy for low-risk cancer patients with fever and neutropenia: a pilot study of 30 patients based on a validated prediction rule. *J Clin Oncol* 1994;12:107-114. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8270967>.
472. Malik IA, Khan WA, Karim M, et al. Feasibility of outpatient management of fever in cancer patients with low-risk neutropenia: results of a prospective randomized trial. *Am J Med* 1995;98:224-231. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7872337>.
473. Mullen CA, Petropoulos D, Roberts WM, et al. Outpatient treatment of fever and neutropenia for low risk pediatric cancer patients. *Cancer* 1999;86:126-134. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10391572>.
474. Innes H, Lim SL, Hall A, et al. Management of febrile neutropenia in solid tumours and lymphomas using the Multinational Association for Supportive Care in Cancer (MASCC) risk index: feasibility and safety in routine clinical practice. *Support Care Cancer* 2008;16:485-491. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17899215>.
475. Klastersky J, Paesmans M, Georgala A, et al. Outpatient oral antibiotics for febrile neutropenic cancer patients using a score predictive for complications. *J Clin Oncol* 2006;24:4129-4134. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16943529>.
476. Klastersky J, Paesmans M, Rubenstein EB, et al. The Multinational Association for Supportive Care in Cancer risk index: A multinational scoring system for identifying low-risk febrile neutropenic cancer patients. *J Clin Oncol* 2000;18:3038-3051. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10944139>.
477. Uys A, Rapoport BL, Anderson R. Febrile neutropenia: a prospective study to validate the Multinational Association of Supportive Care of Cancer (MASCC) risk-index score. *Support Care Cancer* 2004;12:555-560. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15197637>.
478. Rubin M, Hathorn JW, Pizzo PA. Controversies in the management of febrile neutropenic cancer patients. *Cancer Invest* 1988;6:167-184. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/3132310>.
479. Hidalgo M, Hornedo J, Lumbreras C, et al. Outpatient therapy with oral ofloxacin for patients with low risk neutropenia and fever: a prospective, randomized clinical trial. *Cancer* 1999;85:213-219. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9921995>.
480. Fernandez HM, Callahan KE, Likourezos A, Leipzig RM. House staff member awareness of older inpatients' risks for hazards of hospitalization. *Arch Intern Med* 2008;168:390-396. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18299494>.
481. Schimmel EM. The hazards of hospitalization. 1964. *Qual Saf Health Care* 2003;12:58-63; discussion 63-54. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12571347>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

482. Carstensen M, Sorensen JB. Outpatient management of febrile neutropenia: time to revise the present treatment strategy. *J Support Oncol* 2008;6:199-208. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18551855>.

483. Kern WV, Cometta A, De Bock R, et al. Oral versus intravenous empirical antimicrobial therapy for fever in patients with granulocytopenia who are receiving cancer chemotherapy. International Antimicrobial Therapy Cooperative Group of the European Organization for Research and Treatment of Cancer. *N Engl J Med* 1999;341:312-318. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10423465>.

484. Niho S, Ohe Y, Goto K, et al. Randomized trial of oral versus intravenous antibiotics in low-risk febrile neutropenic patients with lung cancer. *Jpn J Clin Oncol* 2004;34:69-73. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15067098>.

485. Aquino VM, Herrera L, Sandler ES, Buchanan GR. Feasibility of oral ciprofloxacin for the outpatient management of febrile neutropenia in selected children with cancer. *Cancer* 2000;88:1710-1714. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10738231>.

486. Giamarellou H, Bassaris HP, Petrikos G, et al. Monotherapy with intravenous followed by oral high-dose ciprofloxacin versus combination therapy with ceftazidime plus amikacin as initial empiric therapy for granulocytopenic patients with fever. *Antimicrob Agents Chemother* 2000;44:3264-3271. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11083625>.

487. Paganini H, Rodriguez-Briehcke T, Zubizarreta P, et al. Oral ciprofloxacin in the management of children with cancer with lower risk febrile neutropenia. *Cancer* 2001;91:1563-1567. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11301406>.

488. Rolston KV, Frisbee-Hume SE, Patel S, et al. Oral moxifloxacin for outpatient treatment of low-risk, febrile neutropenic patients. *Support Care Cancer* 2010;18:89-94. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/19387695>.

489. Kern WV, Marchetti O, Drgona L, et al. Oral antibiotics for fever in low-risk neutropenic patients with cancer: a double-blind, randomized, multicenter trial comparing single daily moxifloxacin with twice daily ciprofloxacin plus amoxicillin/clavulanic acid combination therapy--EORTC infectious diseases group trial XV. *J Clin Oncol* 2013;31:1149-1156. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23358983>.

490. Freifeld A, Sankaranarayanan J, Ullrich F, Sun J. Clinical practice patterns of managing low-risk adult febrile neutropenia during cancer chemotherapy in the USA. *Support Care Cancer* 2008;16:181-191. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17943327>.

491. Rolston KV, Berkey P, Bodey GP, et al. A comparison of imipenem to ceftazidime with or without amikacin as empiric therapy in febrile neutropenic patients. *Arch Intern Med* 1992;152:283-291. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1739355>.

492. Karthaus M, Wolf HH, Kampfe D, et al. Ceftriaxone monotherapy in the treatment of low-risk febrile neutropenia. *Chemotherapy* 1998;44:343-354. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9732151>.

493. Bhatti Z, Shaukat A, Almyroudis NG, Segal BH. Review of epidemiology, diagnosis, and treatment of invasive mould infections in allogeneic hematopoietic stem cell transplant recipients. *Mycopathologia* 2006;162:1-15. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16830186>.

494. Michallet M, Ito JI. Approaches to the management of invasive fungal infections in hematologic malignancy and hematopoietic cell transplantation. *J Clin Oncol* 2009;27:3398-3409. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19487382>.

495. Pizzo PA, Robichaud KJ, Gill FA, Witebsky FG. Empiric antibiotic and antifungal therapy for cancer patients with prolonged fever and granulocytopenia. *Am J Med* 1982;72:101-111. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7058815>.



NCCN Guidelines Version 1.2019

Prevention and Treatment of Cancer-Related Infections

496. Staber P, Langner S, Dornbusch HJ, Neumeister P. Antifungal management in cancer patients. *Wien Med Wochenschr* 2007;157:503-510. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18030555>.

497. Wingard JR. Empirical antifungal therapy in treating febrile neutropenic patients. *Clin Infect Dis* 2004;39 Suppl 1:S38-43. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15250019>.

498. Walsh TJ, Finberg RW, Arndt C, et al. Liposomal amphotericin B for empirical therapy in patients with persistent fever and neutropenia. National Institute of Allergy and Infectious Diseases Mycoses Study Group. *N Engl J Med* 1999;340:764-771. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10072411>.

499. Ostrosky-Zeichner L, Marr KA, Rex JH, Cohen SH. Amphotericin B: time for a new “gold standard”. *Clin Infect Dis* 2003;37:415-425. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12884167>.

500. Bates DW, Su L, Yu DT, et al. Mortality and costs of acute renal failure associated with amphotericin B therapy. *Clin Infect Dis* 2001;32:686-693. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11229835>.

501. Viscoli C, Castagnola E, Van Lint MT, et al. Fluconazole versus amphotericin B as empirical antifungal therapy of unexplained fever in granulocytopenic cancer patients: a pragmatic, multicentre, prospective and randomised clinical trial. *Eur J Cancer* 1996;32A:814-820. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9081359>.

502. Winston DJ, Hathorn JW, Schuster MG, et al. A multicenter, randomized trial of fluconazole versus amphotericin B for empiric antifungal therapy of febrile neutropenic patients with cancer. *Am J Med* 2000;108:282-289. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11014720>.

503. Boogaerts M, Winston DJ, Bow EJ, et al. Intravenous and oral itraconazole versus intravenous amphotericin B deoxycholate as empirical antifungal therapy for persistent fever in neutropenic patients with cancer who are receiving broad-spectrum antibacterial therapy. A randomized, controlled trial. *Ann Intern Med* 2001;135:412-422. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11560454>.

504. Walsh TJ, Pappas P, Winston DJ, et al. Voriconazole compared with liposomal amphotericin B for empirical antifungal therapy in patients with neutropenia and persistent fever. *N Engl J Med* 2002;346:225-234. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11807146>.

505. Powers JH, Dixon CA, Goldberger MJ. Voriconazole versus liposomal amphotericin B in patients with neutropenia and persistent fever. *N Engl J Med* 2002;346:289-290. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11807157>.

506. Walsh TJ, Teppler H, Donowitz GR, et al. Caspofungin versus liposomal amphotericin B for empirical antifungal therapy in patients with persistent fever and neutropenia. *N Engl J Med* 2004;351:1391-1402. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15459300>.

507. Merck & Co. Prescribing information. Cancidas® (caspofungin acetate) for intravenous injection. 2017. Available at: https://www.merck.com/product/usa/pi_circulars/c/cancidas/cancidas_pi.pdf. Accessed November 9, 2017.

508. Oyake T, Kowata S, Murai K, et al. Comparison of micafungin and voriconazole as empirical antifungal therapies in febrile neutropenic patients with hematological disorders: a randomized controlled trial. *Eur J Haematol* 2016;96:602-609. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/26216048>.

509. Segal BH, Almyroudis NG, Battiwalla M, et al. Prevention and early treatment of invasive fungal infection in patients with cancer and neutropenia and in stem cell transplant recipients in the era of newer broad-spectrum antifungal agents and diagnostic adjuncts. *Clin Infect Dis* 2007;44:402-409. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17205448>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

510. Foy PC, van Burik J-AH, Weisdorf DJ. Galactomannan antigen enzyme-linked immunosorbent assay for diagnosis of invasive aspergillosis after hematopoietic stem cell transplantation. *Biol Blood Marrow Transplant* 2007;13:440-443. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17287156>.

511. Marr KA, Laverdiere M, Gugel A, Leisenring W. Antifungal therapy decreases sensitivity of the Aspergillus galactomannan enzyme immunoassay. *Clin Infect Dis* 2005;40:1762-1769. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15909264>.

512. Pfeiffer CD, Fine JP, Safdar N. Diagnosis of invasive aspergillosis using a galactomannan assay: a meta-analysis. *Clin Infect Dis* 2006;42:1417-1427. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16619154>.

513. Maertens J, Theunissen K, Verhoef G, et al. Galactomannan and computed tomography-based preemptive antifungal therapy in neutropenic patients at high risk for invasive fungal infection: a prospective feasibility study. *Clin Infect Dis* 2005;41:1242-1250. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16206097>.

514. Cordonnier C, Pautas C, Maury S, et al. Empirical versus preemptive antifungal therapy for high-risk, febrile, neutropenic patients: a randomized, controlled trial. *Clin Infect Dis* 2009;48:1042-1051. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19281327>.

515. Elting LS, Rubenstein EB, Rolston K, et al. Time to clinical response: an outcome of antibiotic therapy of febrile neutropenia with implications for quality and cost of care. *J Clin Oncol* 2000;18:3699-3706. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11054443>.

516. Serody JS, Berrey MM, Albritton K, et al. Utility of obtaining blood cultures in febrile neutropenic patients undergoing bone marrow transplantation. *Bone Marrow Transplant* 2000;26:533-538. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11019843>.

517. Averbuch D, Orasch C, Cordonnier C, et al. European guidelines for empirical antibacterial therapy for febrile neutropenic patients in the era of growing resistance: summary of the 2011 4th European Conference on Infections in Leukemia. *Haematologica* 2013;98:1826-1835. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/24323983>.

518. Smith TJ, Khatcheressian J, Lyman GH, et al. 2006 update of recommendations for the use of white blood cell growth factors: an evidence-based clinical practice guideline. *J Clin Oncol* 2006;24:3187-3205. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16682719>.

519. Mokart D, Slehofer G, Lambert J, et al. De-escalation of antimicrobial treatment in neutropenic patients with severe sepsis: results from an observational study. *Intensive Care Med* 2014;40:41-49. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/24231857>.

520. Elting LS, Rubenstein EB, Rolston KV, Bodey GP. Outcomes of bacteremia in patients with cancer and neutropenia: observations from two decades of epidemiological and clinical trials. *Clin Infect Dis* 1997;25:247-259. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9332520>.

521. U.S. Food and Drug Administration. Prescribing information. Zovirax® (acyclovir) 2004. Available at: http://www.accessdata.fda.gov/drugsatfda_docs/label/2004/18603slr027_zovirax_ibl.pdf. Accessed November 9, 2017.

522. GlaxoSmithKline. Prescribing information. Valtrex (valacyclovir hydrochloride) caplets. 2013. Available at: https://www.gsksource.com/pharma/content/dam/GlaxoSmithKline/US/en/Prescribing_Information/Valtrex/pdf/VALTREX-PI-PIL.PDF. Accessed November 9, 2017.

523. Novartis Pharmaceuticals. Prescribing information. Famvir® (famciclovir) tablets. 2016. Available at: <https://www.pharma.us.novartis.com/sites/www.pharma.us.novartis.com/files/Famvir.pdf>. Accessed November 9, 2017.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

524. Wade JC, Newton B, McLaren C, et al. Intravenous acyclovir to treat mucocutaneous herpes simplex virus infection after marrow transplantation: a double-blind trial. *Ann Intern Med* 1982;96:265-269. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7036816>.
525. Baglin TP, Gray JJ, Marcus RE, Wreghitt TG. Antibiotic resistant fever associated with herpes simplex virus infection in neutropenic patients with haematological malignancy. *J Clin Pathol* 1989;42:1255-1258. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2613919>.
526. Rex JH, Pappas PG, Karchmer AW, et al. A randomized and blinded multicenter trial of high-dose fluconazole plus placebo versus fluconazole plus amphotericin B as therapy for candidemia and its consequences in nonneutropenic subjects. *Clin Infect Dis* 2003;36:1221-1228. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12746765>.
527. Kontoyiannis DP, Lionakis MS, Lewis RE, et al. Zygomycosis in a tertiary-care cancer center in the era of Aspergillus-active antifungal therapy: a case-control observational study of 27 recent cases. *J Infect Dis* 2005;191:1350-1360. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15776383>.
528. Walsh TJ, Anaissie EJ, Denning DW, et al. Treatment of aspergillosis: clinical practice guidelines of the Infectious Diseases Society of America. *Clin Infect Dis* 2008;46:327-360. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18177225>.
529. Eggimann P, Francioli P, Bille J, et al. Fluconazole prophylaxis prevents intra-abdominal candidiasis in high-risk surgical patients. *Crit Care Med* 1999;27:1066-1072. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10397206>.
530. Gorschluter M, Glasmacher A, Hahn C, et al. Clostridium difficile infection in patients with neutropenia. *Clin Infect Dis* 2001;33:786-791. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11512083>.
531. Teasley DG, Gerding DN, Olson MM, et al. Prospective randomised trial of metronidazole versus vancomycin for Clostridium-difficile-associated diarrhoea and colitis. *Lancet* 1983;2:1043-1046. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/6138597>.
532. Wenisch C, Parschalk B, Hasenhundl M, et al. Comparison of vancomycin, teicoplanin, metronidazole, and fusidic acid for the treatment of Clostridium difficile-associated diarrhea. *Clin Infect Dis* 1996;22:813-818. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8722937>.
533. Musher DM, Aslam S, Logan N, et al. Relatively poor outcome after treatment of Clostridium difficile colitis with metronidazole. *Clin Infect Dis* 2005;40:1586-1590. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15889354>.
534. Louie TJ, Miller MA, Mullane KM, et al. Fidaxomicin versus vancomycin for Clostridium difficile infection. *N Engl J Med* 2011;364:422-431. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21288078>.
535. Cornely OA, Crook DW, Esposito R, et al. Fidaxomicin versus vancomycin for infection with Clostridium difficile in Europe, Canada, and the USA: a double-blind, non-inferiority, randomised controlled trial. *Lancet Infect Dis* 2012;12:281-289. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22321770>.
536. Cornely OA, Miller MA, Fantin B, et al. Resolution of Clostridium difficile-associated diarrhea in patients with cancer treated with fidaxomicin or vancomycin. *J Clin Oncol* 2013;31:2493-2499. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/23715579>.
537. Blossom DB, McDonald LC. The challenges posed by reemerging Clostridium difficile infection. *Clin Infect Dis* 2007;45:222-227. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17578783>.
538. van Nood E, Vrieze A, Nieuwdorp M, et al. Duodenal infusion of donor feces for recurrent Clostridium difficile. *N Engl J Med* 2013;368:407-415. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23323867>.



539. Cammarota G, Masucci L, Ianiro G, et al. Randomised clinical trial: faecal microbiota transplantation by colonoscopy vs. vancomycin for the treatment of recurrent *Clostridium difficile* infection. *Aliment Pharmacol Ther* 2015;41:835-843. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/25728808>.

540. U.S. Food and Drug Administration. Prescribing Information. Zinplava™ (bezlotoxumab) injection, for intravenous use. 2016. Available at: https://www.accessdata.fda.gov/drugsatfda_docs/label/2016/761046s000lbl.pdf. Accessed October 23, 2017.

541. Wilcox MH, Gerding DN, Poxton IR, et al. Bezlotoxumab for Prevention of Recurrent *Clostridium difficile* Infection. *N Engl J Med* 2017;376:305-317. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/28121498>.

542. Gerding DN, Johnson S, Peterson LR, et al. *Clostridium difficile*-associated diarrhea and colitis. *Infect Control Hosp Epidemiol* 1995;16:459-477. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7594392>.

543. Olson MM, Shanholtzer CJ, Lee JT, Gerding DN. Ten years of prospective *Clostridium difficile*-associated disease surveillance and treatment at the Minneapolis VA Medical Center, 1982-1991. *Infect Control Hosp Epidemiol* 1994;15:371-381. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7632199>.

544. Aslam S, Hamill RJ, Musher DM. Treatment of *Clostridium difficile*-associated disease: old therapies and new strategies. *Lancet Infect Dis* 2005;5:549-557. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16122678>.

545. Bartlett JG. Narrative review: the new epidemic of *Clostridium difficile*-associated enteric disease. *Ann Intern Med* 2006;145:758-764. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17116920>.

546. Cloutier RL. Neutropenic enterocolitis. *Hematol Oncol Clin North Am* 2010;24:577-584. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20488355>.

547. Ullery BW, Pieracci FM, Rodney JR, Barie PS. Neutropenic enterocolitis. *Surg Infect (Larchmt)* 2009;10:307-314. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19566419>.

548. Song HK, Kreisel D, Canter R, et al. Changing presentation and management of neutropenic enterocolitis. *Arch Surg* 1998;133:979-982. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9749851>.

549. Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. *Am J Respir Crit Care Med* 2005;171:388-416. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15699079>.

550. Nordmann P, Cuzon G, Naas T. The real threat of *Klebsiella pneumoniae* carbapenemase-producing bacteria. *Lancet Infect Dis* 2009;9:228-236. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19324295>.

551. Mulinde J, Joshi M. The diagnostic and therapeutic approach to lower respiratory tract infections in the neutropenic patient. *J Antimicrob Chemother* 1998;41 Suppl D:51-55. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9688451>.

552. Greene RE, Schlamm HT, Oestmann J-W, et al. Imaging findings in acute invasive pulmonary aspergillosis: clinical significance of the halo sign. *Clin Infect Dis* 2007;44:373-379. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17205443>.

553. Bozzette SA, Sattler FR, Chiu J, et al. A controlled trial of early adjunctive treatment with corticosteroids for *Pneumocystis carinii* pneumonia in the acquired immunodeficiency syndrome. California Collaborative Treatment Group. *N Engl J Med* 1990;323:1451-1457. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2233917>.

554. Nguyen Q, Estey E, Raad I, et al. Cytomegalovirus pneumonia in adults with leukemia: an emerging problem. *Clin Infect Dis* 2001;32:539-545. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11181115>.



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Prevention and Treatment of Cancer-Related Infections

555. Rovira M, Jimenez M, De La Bellacasa JP, et al. Detection of Aspergillus galactomannan by enzyme immunoabsorbent assay in recipients of allogeneic hematopoietic stem cell transplantation: a prospective study. *Transplantation* 2004;77:1260-1264. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15114095>.

556. Odabasi Z, Mattiuzzi G, Estey E, et al. Beta-D-glucan as a diagnostic adjunct for invasive fungal infections: validation, cutoff development, and performance in patients with acute myelogenous leukemia and myelodysplastic syndrome. *Clin Infect Dis* 2004;39:199-205. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15307029>.

557. Ostrosky-Zeichner L, Alexander BD, Kett DH, et al. Multicenter clinical evaluation of the (1-->3) beta-D-glucan assay as an aid to diagnosis of fungal infections in humans. *Clin Infect Dis* 2005;41:654-659. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16080087>.

558. Tasaka S, Hasegawa N, Kobayashi S, et al. Serum indicators for the diagnosis of pneumocystis pneumonia. *Chest* 2007;131:1173-1180. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17426225>.

559. Mennink-Kersten MASH, Donnelly JP, Verweij PE. Detection of circulating galactomannan for the diagnosis and management of invasive aspergillosis. *Lancet Infect Dis* 2004;4:349-357. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15172343>.

560. Wheat LJ. Rapid diagnosis of invasive aspergillosis by antigen detection. *Transpl Infect Dis* 2003;5:158-166. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14987199>.

561. Marr KA, Balajee SA, McLaughlin L, et al. Detection of galactomannan antigenemia by enzyme immunoassay for the diagnosis of invasive aspergillosis: variables that affect performance. *J Infect Dis* 2004;190:641-649. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15243943>.

562. Herbrecht R, Letscher-Bru V, Oprea C, et al. Aspergillus galactomannan detection in the diagnosis of invasive aspergillosis in cancer patients. *J Clin Oncol* 2002;20:1898-1906. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11919250>.

563. Sulahian A, Touratier S, Ribaud P. False positive test for aspergillus antigenemia related to concomitant administration of piperacillin and tazobactam. *N Engl J Med* 2003;349:2366-2367. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14668472>.

564. Walsh TJ, Shoham S, Petraitiene R, et al. Detection of galactomannan antigenemia in patients receiving piperacillin-tazobactam and correlations between in vitro, in vivo, and clinical properties of the drug-antigen interaction. *J Clin Microbiol* 2004;42:4744-4748. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15472335>.

565. Vergidis P, Razonable RR, Wheat LJ, et al. Reduction in false-positive Aspergillus serum galactomannan enzyme immunoassay results associated with use of piperacillin-tazobactam in the United States. *J Clin Microbiol* 2014;52:2199-2201. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/24719434>.

566. Mennink-Kersten MASH, Warris A, Verweij PE. 1,3-beta-D-glucan in patients receiving intravenous amoxicillin-clavulanic acid. *N Engl J Med* 2006;354:2834-2835. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16807428>.

567. Ogawa M, Hori H, Niiguchi S, et al. False-positive plasma (1-->3)-beta-D-glucan test following immunoglobulin product replacement in an adult bone marrow recipient. *Int J Hematol* 2004;80:97-98. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15293578>.

568. Masur H, Gill VJ, Ognibene FP, et al. Diagnosis of Pneumocystis pneumonia by induced sputum technique in patients without the acquired immunodeficiency syndrome. *Ann Intern Med* 1988;109:755-756. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/2461132>.

569. Shelhamer JH, Toews GB, Masur H, et al. NIH conference. Respiratory disease in the immunosuppressed patient. *Ann Intern Med* 1992;117:415-431. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1503334>.

570. Levine SJ. An approach to the diagnosis of pulmonary infections in immunosuppressed patients. *Semin Respir Infect* 1992;7:81-95. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/1439323>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

571. Meersseman W, Lagrou K, Maertens J, et al. Galactomannan in bronchoalveolar lavage fluid: a tool for diagnosing aspergillosis in intensive care unit patients. *Am J Respir Crit Care Med* 2008;177:27-34. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17885264>.
572. Wheat LJ, Walsh TJ. Diagnosis of invasive aspergillosis by galactomannan antigenemia detection using an enzyme immunoassay. *Eur J Clin Microbiol Infect Dis* 2008;27:245-251. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18193305>.
573. De Pauw B, Walsh TJ, Donnelly JP, et al. Revised definitions of invasive fungal disease from the European Organization for Research and Treatment of Cancer/Invasive Fungal Infections Cooperative Group and the National Institute of Allergy and Infectious Diseases Mycoses Study Group (EORTC/MSG) Consensus Group. *Clin Infect Dis* 2008;46:1813-1821. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18462102>.
574. Sevinsky LD, Viece C, Ballesteros DO, Stengel F. Ecthyma gangrenosum: a cutaneous manifestation of *Pseudomonas aeruginosa* sepsis. *J Am Acad Dermatol* 1993;29:104-106. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8315066>.
575. Brook I. Microbiology and management of soft tissue and muscle infections. *Int J Surg* 2008;6:328-338. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17720643>.
576. Maki DG, Stolz SM, Wheeler S, Mermel LA. Prevention of central venous catheter-related bloodstream infection by use of an antiseptic-impregnated catheter. A randomized, controlled trial. *Ann Intern Med* 1997;127:257-266. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9265424>.
577. Veenstra DL, Saint S, Saha S, et al. Efficacy of antiseptic-impregnated central venous catheters in preventing catheter-related bloodstream infection: a meta-analysis. *JAMA* 1999;281:261-267. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9918482>.
578. Logghe C, Van Ossel C, D'Hoore W, et al. Evaluation of chlorhexidine and silver-sulfadiazine impregnated central venous catheters for the prevention of bloodstream infection in leukaemic patients: a randomized controlled trial. *J Hosp Infect* 1997;37:145-156. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9364263>.
579. Brun-Buisson C, Doyon F, Sollet JP, et al. Prevention of intravascular catheter-related infection with newer chlorhexidine-silver sulfadiazine-coated catheters: a randomized controlled trial. *Intensive Care Med* 2004;30:837-843. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15060765>.
580. Ostendorf T, Meinhold A, Harter C, et al. Chlorhexidine and silver-sulfadiazine coated central venous catheters in haematological patients--a double-blind, randomised, prospective, controlled trial. *Support Care Cancer* 2005;13:993-1000. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15834740>.
581. Rupp ME, Lisco SJ, Lipsett PA, et al. Effect of a second-generation venous catheter impregnated with chlorhexidine and silver sulfadiazine on central catheter-related infections: a randomized, controlled trial. *Ann Intern Med* 2005;143:570-580. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16230723>.
582. Darouiche RO, Raad II, Heard SO, et al. A comparison of two antimicrobial-impregnated central venous catheters. Catheter Study Group. *N Engl J Med* 1999;340:1-8. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9878638>.
583. Raad I, Darouiche R, Dupuis J, et al. Central venous catheters coated with minocycline and rifampin for the prevention of catheter-related colonization and bloodstream infections. A randomized, double-blind trial. The Texas Medical Center Catheter Study Group. *Ann Intern Med* 1997;127:267-274. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9265425>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

584. Leon C, Ruiz-Santana S, Rello J, et al. Benefits of minocycline and rifampin-impregnated central venous catheters. A prospective, randomized, double-blind, controlled, multicenter trial. *Intensive Care Med* 2004;30:1891-1899. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15278273>.

585. Hanna H, Benjamin R, Chatzinikolaou I, et al. Long-term silicone central venous catheters impregnated with minocycline and rifampin decrease rates of catheter-related bloodstream infection in cancer patients: a prospective randomized clinical trial. *J Clin Oncol* 2004;22:3163-3171. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15284269>.

586. O'Grady NP, Alexander M, Burns LA, et al. Guidelines for the prevention of intravascular catheter-related infections. *Clin Infect Dis* 2011;52:e162-e193. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21460264>.

587. Safdar N, Maki DG. Use of vancomycin-containing lock or flush solutions for prevention of bloodstream infection associated with central venous access devices: a meta-analysis of prospective, randomized trials. *Clin Infect Dis* 2006;43:474-484. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16838237>.

588. Abdelkefi A, Achour W, Ben Othman T, et al. Difference in time to positivity is useful for the diagnosis of catheter-related bloodstream infection in hematopoietic stem cell transplant recipients. *Bone Marrow Transplant* 2005;35:397-401. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15640824>.

589. Blot F, Nitenberg G, Chachaty E, et al. Diagnosis of catheter-related bacteraemia: a prospective comparison of the time to positivity of hub-blood versus peripheral-blood cultures. *Lancet* 1999;354:1071-1077. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10509498>.

590. Blot F, Schmidt E, Nitenberg G, et al. Earlier positivity of central-venous- versus peripheral-blood cultures is highly predictive of catheter-related sepsis. *J Clin Microbiol* 1998;36:105-109. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9431930>.

591. Krause R, Auner HW, Gorkiewicz G, et al. Detection of catheter-related bloodstream infections by the differential-time-to-positivity method and gram stain-acridine orange leukocyte cytospin test in neutropenic patients after hematopoietic stem cell transplantation. *J Clin Microbiol* 2004;42:4835-4837. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15472355>.

592. Raad I, Hanna HA, Alakech B, et al. Differential time to positivity: a useful method for diagnosing catheter-related bloodstream infections. *Ann Intern Med* 2004;140:18-25. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14706968>.

593. La Quaglia MP, Caldwell C, Lucas A, et al. A prospective randomized double-blind trial of bolus urokinase in the treatment of established Hickman catheter sepsis in children. *J Pediatr Surg* 1994;29:742-745. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8078010>.

594. Tunkel AR, Hartman BJ, Kaplan SL, et al. Practice guidelines for the management of bacterial meningitis. *Clin Infect Dis* 2004;39:1267-1284. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15494903>.

595. van de Beek D, de Gans J, McIntyre P, Prasad K. Corticosteroids in acute bacterial meningitis. *Cochrane Database Syst Rev* 2003:CD004405. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12918010>.

596. de Gans J, van de Beek D. Dexamethasone in adults with bacterial meningitis. *N Engl J Med* 2002;347:1549-1556. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12432041>.

597. Nguyen TH, Tran TH, Thwaites G, et al. Dexamethasone in Vietnamese adolescents and adults with bacterial meningitis. *N Engl J Med* 2007;357:2431-2440. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18077808>.

598. Peltola H, Roine I, Fernandez J, et al. Hearing impairment in childhood bacterial meningitis is little relieved by dexamethasone or glycerol. *Pediatrics* 2010;125:e1-8. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20008417>.



NCCN Guidelines Version 1.2019

Prevention and Treatment of Cancer-Related Infections

599. Peltola H, Roine I, Fernandez J, et al. Adjuvant glycerol and/or dexamethasone to improve the outcomes of childhood bacterial meningitis: a prospective, randomized, double-blind, placebo-controlled trial. *Clin Infect Dis* 2007;45:1277-1286. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17968821>.

600. van de Beek D, Farrar JJ, de Gans J, et al. Adjunctive dexamethasone in bacterial meningitis: a meta-analysis of individual patient data. *Lancet Neurol* 2010;9:254-263. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20138011>.

601. Tunkel AR, Glaser CA, Bloch KC, et al. The management of encephalitis: clinical practice guidelines by the Infectious Diseases Society of America. *Clin Infect Dis* 2008;47:303-327. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18582201>.

602. Bernardini GL. Diagnosis and management of brain abscess and subdural empyema. *Curr Neurol Neurosci Rep* 2004;4:448-456. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15509445>.

603. Jansson AK, Enblad P, Sjolín J. Efficacy and safety of cefotaxime in combination with metronidazole for empirical treatment of brain abscess in clinical practice: a retrospective study of 66 consecutive cases. *Eur J Clin Microbiol Infect Dis* 2004;23:7-14. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14669073>.

604. Edmond MB, Wallace SE, McClish DK, et al. Nosocomial bloodstream infections in United States hospitals: a three-year analysis. *Clin Infect Dis* 1999;29:239-244. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10476719>.

605. Wisplinghoff H, Bischoff T, Tallent SM, et al. Nosocomial bloodstream infections in US hospitals: analysis of 24,179 cases from a prospective nationwide surveillance study. *Clin Infect Dis* 2004;39:309-317. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15306996>.

606. Wisplinghoff H, Seifert H, Tallent SM, et al. Nosocomial bloodstream infections in pediatric patients in United States hospitals: epidemiology, clinical features and susceptibilities. *Pediatr Infect Dis J* 2003;22:686-691. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12913767>.

607. Rex JH, Bennett JE, Sugar AM, et al. A randomized trial comparing fluconazole with amphotericin B for the treatment of candidemia in patients without neutropenia. Candidemia Study Group and the National Institute. *N Engl J Med* 1994;331:1325-1330. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7935701>.

608. Kullberg BJ, Sobel JD, Ruhnke M, et al. Voriconazole versus a regimen of amphotericin B followed by fluconazole for candidaemia in non-neutropenic patients: a randomised non-inferiority trial. *Lancet* 2005;366:1435-1442. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16243088>.

609. Kuse E-R, Chetchotisakd P, da Cunha CA, et al. Micafungin versus liposomal amphotericin B for candidaemia and invasive candidosis: a phase III randomised double-blind trial. *Lancet* 2007;369:1519-1527. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17482982>.

610. Mora-Duarte J, Betts R, Rotstein C, et al. Comparison of caspofungin and amphotericin B for invasive candidiasis. *N Engl J Med* 2002;347:2020-2029. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12490683>.

611. Pappas PG, Rotstein CMF, Betts RF, et al. Micafungin versus caspofungin for treatment of candidemia and other forms of invasive candidiasis. *Clin Infect Dis* 2007;45:883-893. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17806055>.

612. Pappas PG, Kauffman CA, Andes D, et al. Clinical practice guidelines for the management of candidiasis: 2009 update by the Infectious Diseases Society of America. *Clin Infect Dis* 2009;48:503-535. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19191635>.



613. Pfaller MA, Messer SA, Boyken L, et al. Selection of a surrogate agent (fluconazole or voriconazole) for initial susceptibility testing of posaconazole against *Candida* spp.: results from a global antifungal surveillance program. *J Clin Microbiol* 2008;46:551-559. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18094129>.

614. Herbrecht R, Denning DW, Patterson TF, et al. Voriconazole versus amphotericin B for primary therapy of invasive aspergillosis. *N Engl J Med* 2002;347:408-415. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12167683>.

615. Schwartz S, Ruhnke M, Ribaud P, et al. Improved outcome in central nervous system aspergillosis, using voriconazole treatment. *Blood* 2005;106:2641-2645. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15998833>.

616. Denning DW. Therapeutic outcome in invasive aspergillosis. *Clin Infect Dis* 1996;23:608-615. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8879787>.

617. Pascual A, Nieth V, Calandra T, et al. Variability of voriconazole plasma levels measured by new high-performance liquid chromatography and bioassay methods. *Antimicrob Agents Chemother* 2007;51:137-143. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17088483>.

618. Trifilio S, Pennick G, Pi J, et al. Monitoring plasma voriconazole levels may be necessary to avoid subtherapeutic levels in hematopoietic stem cell transplant recipients. *Cancer* 2007;109:1532-1535. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17351937>.

619. Tan K, Brayshaw N, Tomaszewski K, et al. Investigation of the potential relationships between plasma voriconazole concentrations and visual adverse events or liver function test abnormalities. *J Clin Pharmacol* 2006;46:235-243. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16432276>.

620. Bowden R, Chandrasekar P, White MH, et al. A double-blind, randomized, controlled trial of amphotericin B colloidal dispersion versus amphotericin B for treatment of invasive aspergillosis in immunocompromised patients. *Clin Infect Dis* 2002;35:359-366. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12145716>.

621. Chandrasekar PH, Ito JI. Amphotericin B lipid complex in the management of invasive aspergillosis in immunocompromised patients. *Clin Infect Dis* 2005;40 Suppl 6:392-400. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15809925>.

622. Cornely OA, Maertens J, Bresnik M, et al. Liposomal amphotericin B as initial therapy for invasive mold infection: a randomized trial comparing a high-loading dose regimen with standard dosing (AmBiLoad trial). *Clin Infect Dis* 2007;44:1289-1297. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17443465>.

623. Dennis CG, Greco WR, Brun Y, et al. Effect of amphotericin B and micafungin combination on survival, histopathology, and fungal burden in experimental aspergillosis in the p47phox^{-/-} mouse model of chronic granulomatous disease. *Antimicrob Agents Chemother* 2006;50:422-427. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16436692>.

624. Kirkpatrick WR, Perea S, Coco BJ, Patterson TF. Efficacy of caspofungin alone and in combination with voriconazole in a Guinea pig model of invasive aspergillosis. *Antimicrob Agents Chemother* 2002;46:2564-2568. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12121933>.

625. Luque JC, Clemons KV, Stevens DA. Efficacy of micafungin alone or in combination against systemic murine aspergillosis. *Antimicrob Agents Chemother* 2003;47:1452-1455. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12654692>.

626. Petraitis V, Petraitiene R, Sarafandi AA, et al. Combination therapy in treatment of experimental pulmonary aspergillosis: synergistic interaction between an antifungal triazole and an echinocandin. *J Infect Dis* 2003;187:1834-1843. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12792859>.

NCCN Guidelines Version 1.2019
Prevention and Treatment of Cancer-Related Infections

627. Chandrasekar PH, Cutright JL, Manavathu EK. Efficacy of voriconazole plus amphotericin B or micafungin in a guinea-pig model of invasive pulmonary aspergillosis. *Clin Microbiol Infect* 2004;10:925-928. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15373889>.

628. Graybill JR, Bocanegra R, Gonzalez GM, Najvar LK. Combination antifungal therapy of murine aspergillosis: liposomal amphotericin B and micafungin. *J Antimicrob Chemother* 2003;52:656-662. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12972452>.

629. Sivak O, Bartlett K, Risovic V, et al. Assessing the antifungal activity and toxicity profile of amphotericin B lipid complex (ABLC; Abelcet) in combination with caspofungin in experimental systemic aspergillosis. *J Pharm Sci* 2004;93:1382-1389. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15124198>.

630. Aliff TB, Maslak PG, Jurcic JG, et al. Refractory Aspergillus pneumonia in patients with acute leukemia: successful therapy with combination caspofungin and liposomal amphotericin. *Cancer* 2003;97:1025-1032. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12569602>.

631. Kontoyiannis DP, Hachem R, Lewis RE, et al. Efficacy and toxicity of caspofungin in combination with liposomal amphotericin B as primary or salvage treatment of invasive aspergillosis in patients with hematologic malignancies. *Cancer* 2003;98:292-299. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12872348>.

632. Marr KA, Boeckh M, Carter RA, et al. Combination antifungal therapy for invasive aspergillosis. *Clin Infect Dis* 2004;39:797-802. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15472810>.

633. Maertens J, Glasmacher A, Herbrecht R, et al. Multicenter, noncomparative study of caspofungin in combination with other antifungals as salvage therapy in adults with invasive aspergillosis. *Cancer* 2006;107:2888-2897. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17103444>.

634. Denning DW, Marr KA, Lau WM, et al. Micafungin (FK463), alone or in combination with other systemic antifungal agents, for the treatment of acute invasive aspergillosis. *J Infect* 2006;53:337-349. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16678903>.

635. Marr KA, Schlamm HT, Herbrecht R, et al. Combination antifungal therapy for invasive aspergillosis: a randomized trial. *Ann Intern Med* 2015;162:81-89. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/25599346>.

636. Miceli MH, Kauffman CA. Isavuconazole: A New Broad-Spectrum Triazole Antifungal Agent. *Clin Infect Dis* 2015;61:1558-1565. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/26179012>.

637. Maertens JA, Raad, II, Marr KA, et al. Isavuconazole versus voriconazole for primary treatment of invasive mould disease caused by Aspergillus and other filamentous fungi (SECURE): a phase 3, randomised-controlled, non-inferiority trial. *Lancet* 2016;387:760-769. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/26684607>.

638. Patterson TF, Thompson GR, 3rd, Denning DW, et al. Practice Guidelines for the Diagnosis and Management of Aspergillosis: 2016 Update by the Infectious Diseases Society of America. *Clin Infect Dis* 2016;63:e1-e60. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/27365388>.

639. Greenberg RN, Mullane K, van Burik JAH, et al. Posaconazole as salvage therapy for zygomycosis. *Antimicrob Agents Chemother* 2006;50:126-133. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16377677>.

640. Pitisuttithum P, Negroni R, Graybill JR, et al. Activity of posaconazole in the treatment of central nervous system fungal infections. *J Antimicrob Chemother* 2005;56:745-755. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16135526>.

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641. Raad II, Graybill JR, Bustamante AB, et al. Safety of long-term oral posaconazole use in the treatment of refractory invasive fungal infections. *Clin Infect Dis* 2006;42:1726-1734. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16705579>.

642. Raad II, Hachem RY, Herbrecht R, et al. Posaconazole as salvage treatment for invasive fusariosis in patients with underlying hematologic malignancy and other conditions. *Clin Infect Dis* 2006;42:1398-1403. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16619151>.

643. Walsh TJ, Raad I, Patterson TF, et al. Treatment of invasive aspergillosis with posaconazole in patients who are refractory to or intolerant of conventional therapy: an externally controlled trial. *Clin Infect Dis* 2007;44:2-12. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17143808>.

644. Imhof A, Balajee SA, Fredricks DN, et al. Breakthrough fungal infections in stem cell transplant recipients receiving voriconazole. *Clin Infect Dis* 2004;39:743-746. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15356792>.

645. Marty FM, Cosimi LA, Baden LR. Breakthrough zygomycosis after voriconazole treatment in recipients of hematopoietic stem-cell transplants. *N Engl J Med* 2004;350:950-952. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14985500>.

646. Kontoyiannis DP, Wessel VC, Bodey GP, Rolston KV. Zygomycosis in the 1990s in a tertiary-care cancer center. *Clin Infect Dis* 2000;30:851-856. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10852735>.

647. Marr KA, Carter RA, Crippa F, et al. Epidemiology and outcome of mould infections in hematopoietic stem cell transplant recipients. *Clin Infect Dis* 2002;34:909-917. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11880955>.

648. van Burik J-AH, Hare RS, Solomon HF, et al. Posaconazole is effective as salvage therapy in zygomycosis: a retrospective summary of 91 cases. *Clin Infect Dis* 2006;42:61-65. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16511748>.

649. Marty FM, Ostrosky-Zeichner L, Cornely OA, et al. Isavuconazole treatment for mucormycosis: a single-arm open-label trial and case-control analysis. *Lancet Infect Dis* 2016;16:828-837. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/26969258>.

650. Boutati EI, Anaissie EJ. Fusarium, a significant emerging pathogen in patients with hematologic malignancy: ten years' experience at a cancer center and implications for management. *Blood* 1997;90:999-1008. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/9242529>.

651. Kontoyiannis DP, Bodey GP, Hanna H, et al. Outcome determinants of fusariosis in a tertiary care cancer center: the impact of neutrophil recovery. *Leuk Lymphoma* 2004;45:139-141. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15061210>.

652. Nucci M, Marr KA, Queiroz-Telles F, et al. Fusarium infection in hematopoietic stem cell transplant recipients. *Clin Infect Dis* 2004;38:1237-1242. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15127334>.

653. Jahagirdar BN, Morrison VA. Emerging fungal pathogens in patients with hematologic malignancies and marrow/stem-cell transplant recipients. *Semin Respir Infect* 2002;17:113-120. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12070830>.

654. Walsh TJ, Groll A, Hiemenz J, et al. Infections due to emerging and uncommon medically important fungal pathogens. *Clin Microbiol Infect* 2004;10 Suppl 1:48-66. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14748802>.

655. Perfect JR, Marr KA, Walsh TJ, et al. Voriconazole treatment for less-common, emerging, or refractory fungal infections. *Clin Infect Dis* 2003;36:1122-1131. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12715306>.

656. Perfect JR. Treatment of non-Aspergillus moulds in immunocompromised patients, with amphotericin B lipid complex. *Clin Infect Dis* 2005;40 Suppl 6:S401-408. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15809926>.



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657. Cuenca-Estrella M, Gomez-Lopez A, Mellado E, et al. Head-to-head comparison of the activities of currently available antifungal agents against 3,378 Spanish clinical isolates of yeasts and filamentous fungi. *Antimicrob Agents Chemother* 2006;50:917-921. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16495251>.

658. Espinel-Ingroff A, Johnson E, Hockey H, Troke P. Activities of voriconazole, itraconazole and amphotericin B in vitro against 590 moulds from 323 patients in the voriconazole Phase III clinical studies. *J Antimicrob Chemother* 2008;61:616-620. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18222957>.

659. Caillot D, Casasnovas O, Bernard A, et al. Improved management of invasive pulmonary aspergillosis in neutropenic patients using early thoracic computed tomographic scan and surgery. *J Clin Oncol* 1997;15:139-147. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8996135>.

660. Kuhlman JE, Fishman EK, Burch PA, et al. Invasive pulmonary aspergillosis in acute leukemia. The contribution of CT to early diagnosis and aggressive management. *Chest* 1987;92:95-99. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/3595255>.

661. Maertens J, Van Eldere J, Verhaegen J, et al. Use of circulating galactomannan screening for early diagnosis of invasive aspergillosis in allogeneic stem cell transplant recipients. *J Infect Dis* 2002;186:1297-1306. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12402199>.

662. Ascoglu S, Rex JH, de Pauw B, et al. Defining opportunistic invasive fungal infections in immunocompromised patients with cancer and hematopoietic stem cell transplants: an international consensus. *Clin Infect Dis* 2002;34:7-14. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11731939>.