Antimicrobial Prophylaxis in Adults

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On completion of this article, readers should be able to: (1) identify common surgical and nonsurgical indications for the use of antimicrobial prophylaxis in adults, (2) formulate selected surgical and nonsurgical antimicrobial prophylaxis regimens for adults, and (3) summarize the arguments for and against the use of antimicrobial prophylaxis in adults.

Antimicrobial prophylaxis is commonly used by clinicians for the prevention of numerous infectious diseases, including herpes simplex infection, rheumatic fever, recurrent cellulitis, meningococcal disease, recurrent uncomplicated urinary tract infections in women, spontaneous bacterial peritonitis in patients with cirrhosis, influenza, infective endocarditis, pertussis, and acute necrotizing pancreatitis, as well as infections associated with open fractures, recent prosthetic joint placement, and bite wounds. Perioperative antimicrobial prophylaxis is recommended for various surgical procedures to prevent surgical site infections. Optimal antimicrobial agents for prophylaxis should be bactericidal, nontoxic, inexpensive, and active against the typical pathogens that can cause surgical site infection postoperatively. To maximize its effectiveness, intravenous perioperative prophylaxis should be administered within 30 to 60 minutes before the surgical incision. Antimicrobial prophylaxis should be of short duration to decrease toxicity and antimicrobial resistance and to reduce cost.

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AAOS = American Association of Orthopedic Surgeons; ADA = American Dental Association; ANP = acute necrotizing pancreatitis; AP = antimicrobial prophylaxis; AUA = American Urological Association; CP = chemoprophylaxis; FDA = US Food and Drug Administration; HIV = human immunodeficiency virus; IDSA = Infectious Diseases Society of America; IE = infective endocarditis; IS = Information Statement; MRSA = methicillin-resistant *Staphylococcus aureus*; PJI = prosthetic joint infection; PJR = prosthetic joint replacement; RF = rheumatic fever; SBP = spontaneous bacterial peritonitis; SCIP = Surgical Care Improvement Project; Tdap = tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis vaccine, adsorbed; UGI = upper gastrointestinal; UTI = urinary tract infection

Antimicrobial prophylaxis (AP) can be used effectively to prevent infection, but its use should be limited to specific, well-accepted indications to avoid excess cost, toxicity, and antimicrobial resistance. Antimicrobial prophylaxis may be considered primary (prevention of an initial infection) or secondary (prevention of the recurrence or reactivation of an infection), or it may also be administered to prevent infection by eliminating a colonizing organism. This article reviews widely accepted indications for AP in nonsurgical and surgical patients and is an update of a previously published review of this topic.[1] In selected situations, vaccination may be recommended as part of a prophylaxis regimen. This article is meant to be a point-of-care overview topic for the busy clinician. Many of these recommendations are based on expert opinion rather than on prospective clinical trials. Most of the recommended antimicrobial agents are not approved by the US Food and Drug Administration (FDA) for prophylaxis. Current full prescribing information available in the package insert of each drug should be consulted before prescribing any product. Detailed information on individual topics can be found in the cited references.

The potential risks and benefits of AP should be discussed in detail with the patient. Potential risks include allergic reactions that may be severe or life-threatening as well as *Clostridium difficile* colitis with the use of antibacterial agents.[2] Patients taking fluoroquinolones should be warned of the risk of developing tendinitis, including Achilles tendon rupture.[3] For all antibiotic dosing recommended in this article, normal hepatic and renal function are assumed.

NONSURGICAL AP

Rheumatic Fever

Rheumatic fever (RF), which is associated with tonsillopharyngitis caused by the group A β-hemolytic streptococci, may result in carditis with or without valvulopathy. Primary prevention of RF involves prompt and appropriate antibiotic treatment of group A β-hemolytic streptococcal pharyngitis with a penicillin (drug of choice) or alternative antibiotic.[4] Continuous secondary AP prevents recurrent episodes of RF, which could otherwise lead to worsening of the severity of rheumatic heart disease that developed after the initial attack or the development of rheumatic carditis in those who did not develop carditis with the initial RF episode. Guidelines for secondary AP of RF have recently been updated (recommendations for AP regimens are summarized in Table 1).[4] Penicillins are the antibiotics of choice for secondary prophylaxis for RF, and intramus-

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cular penicillin is superior to oral penicillins.[25] Macrolides (eg, erythromycin, clarithromycin, azithromycin) should be reserved for patients who are allergic to both penicillin and sulfa antibiotics. The duration of secondary prophylaxis for RF is reviewed in detail elsewhere and is summarized in Table 2.[4] Physicians should tailor the duration of secondary prophylaxis to the individual patient, taking into account the patient's risk factors for RF recurrence, such as exposure to young children and the presence of carditis with or without underlying valvular disease. Antimicrobial prophylaxis should be considered for at least 10 years or until age 40 years (whichever is longer) for patients with carditis with persistent valvular disease. Prophylaxis should be continued in patients even after prosthetic valve replacement surgery. Antibiotic suppression for the prevention of RF is not adequate for infective endocarditis (IE) prophylaxis before dental procedures.

Recurrent Cellulitis

Patients with lymphedema or severe venous insufficiency of their extremities are at increased risk of recurring β-streptococcal cellulitis. Common scenarios for recurrent cellulitis of the lower extremity include patients with venous insufficiency after saphenous vein graft harvesting or pelvic lymphadenectomy. Recurrent cellulitis has been observed in the upper extremity after lymphadenectomy performed at the time of mastectomy for breast cancer. Antimicrobial prophylaxis may be a useful addition to the control of lymphedema with local measures and treatment of concurrent tinea pedis in the prevention of recurrent cellulitis. However, this recommendation is based on small, uncontrolled studies.[26-28] Typically, more than 2 or 3 episodes per year should occur before AP is initiated. Recommended prophylactic antibiotics for recurrent cellulitis are summarized in Table 1. Oral penicillin V (phenoxymethylpenicillin) is a reasonable first choice, but optimal dosing of this agent is not well established.[5-7] Although monthly administration of 1.2 MU of intramuscular benzathine penicillin is recommended as an alternative to oral penicillin V, this dosing regimen was shown to be effective only in those patients not at risk of cellulitis recurrence.[28] Some experts recommend intramuscular administration of benzathine penicillin every 2 to 3 weeks for individuals who break through once-monthly intramuscular benzathine penicillin regimens.[5]

Recurrent pyogenic skin infections caused by *Staphylococcus aureus*, including methicillin-resistant *S aureus* (MRSA), may be managed by encouraging good personal hygiene, the avoidance of shared personal items, and the diligent cleaning of high-touch environmental surfaces. If a patient is found to be colonized by *S aureus* , nasal decolonization with mupirocin for 5 to 10 days with or without a topical body decolonization with a skin antiseptic solution such as 4% chlorhexidine for 5 to 14 days may be reasonable in an attempt to decolonize the patient.[8] Antimicrobial prophylaxis options are listed in Table 1 for recurrent methicillin-susceptible *S aureus* skin infections.[9,29] Long-term oral AP of recurrent MRSA skin infections is not well studied, and formal recommendations for this situation were not included in recently published MRSA treatment guidelines.[8]

Meningococcal Disease

Antimicrobial prophylaxis for meningococcal diseases should be offered to close contacts of sporadic cases of *Neisseria meningitidis* infection (Table 1). Close contacts include household members, day care center staff, and any person directly exposed to an infected person's oral secretions (for example, through kissing, mouth-to-mouth resuscitation, endotracheal intubation, or endotracheal tube management).[11] Public health authorities may recommend population-based prophylaxis in the event of an outbreak. Prophylaxis should be offered as soon as possible. Close contacts should be offered meningococcal vaccination if the outbreak strain is one that is contained in the currently available meningococcal tetravalent conjugate vaccine.[30]

Asplenic Patients

Penicillin prophylaxis is recommended in children during the first few years after splenectomy to prevent overwhelming *Streptococcus pneumoniae* sepsis.[31] French and American authorities have advocated this form of prophylaxis (eg, 250 mg of oral penicillin V or amoxicillin twice daily) in adults for 1 to 2 years after splenectomy, although data showing the efficacy of this approach are lacking.[31-33] *Haemophilus influenzae* type B, meningococcal, and pneumococcal vaccinations should be current in asplenic adults.

Urinary Tract Infection

Several prophylactic antibiotic options are available to nonpregnant women with recurrent (≥3 per year), uncomplicated urinary tract infections (UTIs)[13] (Table 1). Continuous low-dose AP and patient-initiated treatment after onset of symptoms are both effective.[13,14] During AP, monthly urine cultures should be performed to monitor for bacteriuria and the development of antibiotic resistance.[34] Structural abnormality of the urinary tract, renal involvement with infection, or chronic prostatitis (in men) should be considered in the setting of recurrent UTIs. Methenamine hippurate (dosage, 1 g twice daily) has been approved by the FDA for UTI prophylaxis. A recent Cochrane review concluded that methenamine hippurate may be effective for short-term prophylaxis (≤1 week) in patients without known renal tract abnormalities.[35] The typical duration of an initial trial of continuous AP is 6 months. Patients with prolonged exposure to nitrofurantoin should be counseled

TABLE 1. **Selected Nonsurgical Antimicrobial Prophylaxis Regimens for Adults**[a,b]

Condition	Antimicrobial agent	Dose
Rheumatic fever[4]	Primary prophylaxis	
	Appropriate treatment of group A streptococcal pharyngitis	
	Secondary prophylaxis[c]	
	Preferred	
	Penicillin G benzathine	1.2 million U IM every 4 wk (every 3 wk for patients at high risk[d])
	Preferred oral agents	
	Penicillin V (preferred)	250 mg orally twice daily
	or Sulfadiazine	1 g orally daily
	or Sulfasoxazole	1 g orally daily
	Alternative oral agents	
	Erythromycin	250 mg orally twice daily
	or Clarithromycin[e]	
	or Azithromycin[e]	
Recurrent cellulitis in conjunction with upper or lower extremity lymphedema or erysipelas[5-7]	Penicillin V	250-1000 mg orally twice daily[f]
	or Penicillin G benzathine	1.2 million U IM every 2 to 4 wk
	Penicillin allergy	
	Erythromycin	250-500 mg orally twice daily
Recurrent pyogenic or staphylococcal soft tissue infection[8-10]	Etiology unknown or methicillin-susceptible *Staphylococcus aureus* suspected	
	Dicloxacillin	500 mg orally twice daily
	or Clindamycin	150 mg orally once daily
	MRSA	
	Oral antimicrobial prophylaxis has not been studied[8]	
Meningococcal disease (close contacts of sporadic cases)[11]	Rifampin	600 mg orally every 12 h for 2 d
	or Ciprofloxacin	500 mg orally for 1 dose (adults)
	or Ceftriaxone	250 mg IM once
Travelers' diarrhea[12]		Daily oral dose[g]
	Bismuth subsalicylate	2 tablets (262 mg/tablet) chewed 4 times daily
	Norfloxacin[h]	400 mg
	Ciprofloxacin[h]	500 mg
	Rifaximin[i]	200 mg once or twice daily
Recurrent uncomplicated urinary tract infections in nonpregnant women[13-15]	Continuous prophylaxis	Daily oral dose (at bedtime)
	Trimethoprim-sulfamethoxazole	½ SS tablet (or 3 times/wk)
	Trimethoprim	100 mg
	Norfloxacin	200 mg
	Ciprofloxacin	125 mg
	Nitrofurantoin	50-100 mg
	Cephalexin	125-250 mg
	Postcoital regimens	Single oral dose
	Trimethoprim-sulfamethoxazole	½-1 SS tablet
	Cephalexin	125-250 mg
	Nitrofurantoin	50-100 mg
	Ciprofloxacin	125 mg
	Norfloxacin	200 mg
	Intermittent self-treatment	Oral dose
	Trimethoprim-sulfamethoxazole	1 DS tablet twice daily for 3 d
	Ciprofloxacin	250 mg twice daily for 3 d
	Ofloxacin	200 mg twice daily for 3 d
Spontaneous bacterial peritonitis[16]	Ascites and upper GI bleeding	
	Preferred (if taking a quinolone for long-term SBP prophylaxis)	
	Ceftriaxone	2 g IV initially, then 1 g daily for 7 d
	Alternative	
	Norfloxacin	400 mg orally twice daily for 7 d
	Primary or secondary prophylaxis, non–upper GI bleeding[j]	
	Trimethoprim-sulfamethoxazole	1 DS tablet orally every day
	or Norfloxacin	400 mg orally every day
	or Ciprofloxacin	500 mg orally every day

(continued on next page)

TABLE 1. **Continued**[a,b]

Condition	Antimicrobial agent	Dose
High-risk dog, cat, or human bite[17-19]	Initial IV antibiotics[k]	
	Ampicillin-sulbactam	3 g IV every 6 h
	or Piperacillin-tazobactam	3.375 g IV every 6 h
	or Ertapenem	1 g IV once daily
	or Metronidazole	500 mg orally or IV every 8 h
	plus ceftriaxone,	1 g IV every 24 h
	levofloxacin,	500 or 750 mg IV once daily
	or ciprofloxacin	400 mg IV every 12 h
	Oral antibiotic for 3-5 d[l]	
	Preferred	
	Amoxicillin-clavulanate[m]	875 mg orally twice daily for 3-5 d
	Penicillin allergy	
	Moxifloxacin monotherapy	400 mg orally once daily
	or Clindamycin	300-450 mg orally 4 times daily
	plus ciprofloxacin or	500 mg orally daily
	levofloxacin	750 mg orally daily
Pertussis[20]	Primary agents[n]	
	Azithromycin	500 mg orally day 1, then 250 mg per day on days 2-5
	or Clarithromycin	500 mg orally twice daily for 7 d
	or Erythromycin	2000 mg orally in 4 divided doses for 14 d
	Alternative agent	
	Trimethoprim-sulfamethoxazole, DS	1 tablet orally twice daily for 14 d
Influenza[21,22]	Influenza A or B	
	Oseltamivir[o,p]	75 mg orally daily
	or Zanamivir[o,q]	5 mg/blister for inhalation: 2 inhalations (10 mg) daily
	Influenza A only	
	Rimanadines (amantadine and rimantadine) are no longer recommended[r]	

[a] DS = double-strength; GI = gastrointestinal; IM = intramuscularly; IV = intravenously; MRSA = methicillin-resistant *Staphylococcus aureus*; SBP = spontaneous bacterial peritonitis; SS = single-strength; Tdap = tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis vaccine, adsorbed.

[b] Antibiotic doses assume normal renal and hepatic function; the choice of therapy should be guided by the patient's history of allergy or intolerance to a specific agent.

[c] See Table 2 and text for duration of prophylaxis.

[d] Administration of benzathine penicillin every 3 wk is recommended in the United States only for those who have recurrent acute rheumatic fever despite adherence to a once-monthly regimen.

[e] Dosing of these agents was not specified in the recently published guidelines.[4] However, a clarithromycin dose of 250 mg twice daily was proposed to us by one of the authors of those guidelines, Stanford T. Schulman, MD (written communication, January 5, 2011).

[f] There is a wide range of recommended penicillin V dosing for this purpose; 250-500 mg twice daily would be a reasonable starting point.

[g] Duration of prophylaxis for travelers' diarrhea should be limited to 2-3 wk and should be stopped 2 d after returning from travel.

[h] Other fluoroquinolones are likely to be effective but have not been studied for use in prophylaxis for travelers' diarrhea.

[i] Rifaximin prophylaxis has only been studied in travelers to Mexico.[23]

[j] Primary prophylaxis for SBP is indicated in patients with ascitic fluid protein <1.5 g/dL and at least 1 of the following criteria: serum creatinine level, ≥1.2 mg/dL (to convert to μmol/L, multiply by 88.4); blood urea nitrogen level, ≥25 mg/dL (to convert to mmol/L, multiply by 0.357); serum sodium level, ≤130 mEq/L (to convert to mmol/L, multiply by 1); or Child-Pugh score, ≥9 points with bilirubin level ≥3 mg/dL (to convert to μmol/L, multiply by 17.104).[16]

[k] Consider IV antibiotics for animal bites as initial dose in the emergency department and with hospitalized patients. Consider hospitalization and IV antibiotics as an initial therapy for human bites and in patients with fever, sepsis, spread of cellulitis, significant edema or crush injury, or loss of function and in those who are immunocompromised or nonadherent to treatment.

[l] Use oral antibiotics if treatment occurs soon after a dog or cat bite and only mild to moderate signs of infection are present.

[m] Avoid penicillins in patients with a history of severe penicillin allergy.

[n] Vaccinate with Tdap if indicated.

[o] Choice of therapy should be dictated by resistance patterns of the circulating influenza virus; see text for discussion of treatment duration.

[p] Common adverse effects include nausea, vomiting, and headaches. Taking oseltamivir with food may reduce the likelihood of nausea and vomiting.

[q] Adverse effects include cough, nasal and throat discomfort, and (rarely) bronchospasm and decreased lung function. Zanamivir should be avoided in patients with asthma or chronic obstructive lung disease.

[r] The high prevalence of adamantane (rimantadine and amantadine) resistance in circulating influenza A viruses indicates that these agents have no current role outside of clinical trials.[24]

about the rare but serious complications associated with this agent, including hepatitis, pulmonary reactions, and neuropathy. Cranberries contain 2 substances that prevent fimbriated *Escherichia coli* from adhering to uroepithelial cells.[36] Clinical studies have shown that cranberry juice and cranberry products may reduce the recurrence of UTIs in women. A recent Cochrane review noted limitations in these studies, including variable cranberry products and dosing used in the various studies, as well as high study participant dropout rates.[37] Other patients who may be considered for prophylaxis of frequent UTIs include pregnant women, persons with spinal cord injuries, persons with

TABLE 2. **Duration of Secondary Rheumatic Fever Prophylaxis**[a]

Category	Duration after last attack
Rheumatic fever with carditis and residual heart disease (persistent valvular disease[b])	10 years or until 40 years of age (whichever is longer), sometimes lifelong prophylaxis[a]
Rheumatic fever with carditis but no residual heart disease (no valvular disease[b])	10 years or until 21 years of age (whichever is longer)
Rheumatic fever without carditis	5 years or until 21 years of age (whichever is longer)

[a] See text and Gerber et al[4] for discussion.
[b] Clinical or echocardiographic evidence.
Adapted from *Circulation*,[4] with permission from the American Heart Association.

neurogenic bladders, renal transplant recipients, and men with chronic bacterial prostatitis.[13,34] Postcoital regimens may be appropriate for female patients with UTIs temporally related to sexual intercourse.[15,38] Patients who use postcoital regimens should be informed that only 1 dose per day is recommended, regardless of the frequency of intercourse. Postcoital AP in pregnancy can be managed with a single dose of either cephalexin (250 mg) or nitrofurantoin (50 mg).[34] Tetracyclines and fluoroquinolones should be avoided during pregnancy, and sulfonamides should be avoided during the last weeks of gestation to minimize the risk of hyperbilirubinemia and kernicterus in the newborn. Topical vaginal estrogen therapy has been shown to reduce the risk of recurrent UTIs in postmenopausal women; it may be a consideration for postmenopausal women who are not receiving estrogen replacement therapy and who have no contraindications to estrogen therapy.[39]

Spontaneous Bacterial Peritonitis

Spontaneous bacterial peritonitis (SBP) in patients with cirrhosis is associated with increased morbidity and mortality. Aerobic gram-negative organisms and streptococci are the most frequent causes of this infection. In a recent Cochrane review of 12 treatment trials, empirical oral or parenteral antimicrobial treatment of patients with cirrhosis and upper gastrointestinal (UGI) bleeding reduced the incidence of bacterial infections and was associated with shortened hospital stays and reduced rates of overall mortality, mortality from bacterial infections, and rebleeding.[40] No one antibiotic regimen or route of administration was found to be superior. On the basis of these data, 7 days of empirical antibiotics are recommended for patients with ascites and UGI bleeding[16] (Table 1). In prospective randomized clinical trials, primary prophylaxis in high-risk patients and secondary prophylaxis after an initial episode of SBP have been shown to be effective in preventing SBP.[41-44] A recent Cochrane review of 7 trials of empirical AP to prevent SBP in cirrhotic patients with ascites without UGI bleeding revealed a pooled reduction in SBP and mortality but noted issues with trial methodology and findings suggestive of systematic bias in publication and design.[45] A 1998 analysis concluded that prophylaxis in high-risk patients (serum bilirubin level >2.5 mg/dL [to convert to μmol/L, multiply by 17.104]; ascitic fluid protein level, <1 g/dL) is cost-effective.[46] The American Association for the Study of Liver Diseases has published guidelines that recommend long-term daily AP for patients with previous SBP and for primary prophylaxis in those with an ascitic fluid protein level of less than 1.5 g/dL and at least 1 of the following criteria: a serum creatinine level of 1.2 mg/dL or higher (to convert to μmol/L, multiply by 88.4), a blood urea nitrogen level of 25 mg/dL or higher (to convert to mmol/L, multiply by 0.357), a serum sodium level of 130 mEq/L or less (to convert to mmol/L, multiply by 1), or a Child-Pugh score of 9 points or higher with a bilirubin level of 3 mg/dL or higher[16] (Table 1). Before initiation of AP, SBP should be ruled out in all patients with ascites at hospital admission and in cirrhotic patients with ascites with signs, symptoms, or laboratory abnormalities suggestive of infection.[16]

Acute Necrotizing Pancreatitis

Severe pancreatitis with necrosis is associated with an overall mortality rate of 17% and a mortality rate of 25% to 30% with infected necrosis. Debate is ongoing as to whether AP in the setting of acute necrotizing pancreatitis (ANP) leads to improved outcomes (some consider the use of antibiotics in this setting preemptive).[47] A recent Cochrane database review of 7 randomized studies concluded that patients randomized to receive AP for ANP had no statistically significant reduction in infections.[48] Recent practice guidelines published by the American College of Gastroenterology do not recommend AP for ANP.[49] If AP is initiated, a broad-spectrum β-lactam such as imipenem-cilastatin is often recommended and should be limited to computed tomography–documented pancreatic necrosis involving 30% or more of the pancreas for 14 days or less.[50]

Bite Wound Infection

Five percent of dog bites and 30% of cat bites become secondarily infected because these wounds are highly contaminated by microorganisms present in the oral cavity of these animals. These infections can lead to septic arthritis, tenosynovitis, severe soft tissue infection, or sepsis.[51] The microbiology of dog and cat bite infections is typically polymicrobial and includes *Pasteurella* species as the most common isolate, followed by staphylococci, streptococci, and anaerobes.[52] Although AP for animal bites remains controversial, a meta-analysis of 8 clinical trials by Cummings[53] found that AP significantly protects against subsequent wound infection. Antimicrobial prophylaxis of a

contaminated wound may be more accurately considered *expectant therapy* to prevent the development of a wound infection in a contaminated but not yet infected wound. No clinical trials have shown superiority of one antibiotic regimen over another; choices should be based on the likely microbiology of dog and cat bite infections.[54] Antimicrobial prophylaxis for bite wounds has recently been reviewed and should be offered to all patients who are thought to have an increased risk of infection[17] (Table 1). High-risk situations include, but are not limited to, bites to body areas where deeper structures (tendons and bones) can become easily injured, bites to the hand(s) or close to a bone or joint, crush injuries, puncture wounds (difficult to clean), bites in which treatment is delayed more than 8 to 10 hours, wounds requiring closure, bites in compromised persons (diabetic patients, persons with no spleen, immunocompromised patients), bites in persons with indwelling prosthetic devices, and all cat bites.[17,18] Consideration for hospitalization and intravenous antibiotics may be reasonable for patients in the setting of fever, sepsis, spread of cellulitis, significant edema or crush injury, loss of function, compromised immunity, or patient nonadherence to treatment.[19] All dog and cat bites should be appropriately irrigated and débrided, and rabies prophylaxis should be administered, if indicated. Delayed primary closure of heavily contaminated wounds should be considered to decrease the risk of wound infection.

Human bite wounds, including clenched fist injuries, are considered to be at high-risk of infection with organisms such as *Streptococcus anginosus*, *S aureus*, *Eikenella corrodens*, and anaerobes. Recommended AP is similar to that for animal bite wounds[17,55] (Table 1). Patients who have sustained human bites should be assessed for human immunodeficiency virus (HIV) and hepatitis B infection risk, and prophylaxis should be offered as indicated according to published guidelines. Tetanus immune globulin and tetanus toxoid should be administered to patients who have not been immunized or tetanus toxoid alone to any patient who has not received a tetanus booster within the past 5 years.

Pertussis

Pertussis (whooping cough), an upper respiratory tract infection caused by *Bordetella pertussis*, is associated with prolonged bouts of coughing that may last 1 to 6 weeks. Numerous pertussis outbreaks have occurred in the United States during the past 6 years among adolescents and adults as immunity from childhood vaccination has waned. Because pertussis is spread by aerosolized respiratory droplets, it is recommended that all household and other close contacts of infected patients who did not use respiratory precautions while in contact with an infected patient receive AP, regardless of age or immunization status[20] (Table 1).

The first tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis vaccine, adsorbed (Tdap) licensed for adults was approved by the FDA in 2005 (ADACEL; Sanofi Pasteur; Swiftwater, PA [US Headquarters]; Lyon, France [Global Headquarters]) as a single-dose booster vaccine for persons aged 11 to 64 years to provide protection against tetanus, diphtheria, and pertussis. Tdap was initially recommended to replace the next adult booster dose of tetanus- and diphtheria-toxoid vaccines in patients whose last tetanus booster was 10 years or more earlier. The interval between the most recent tetanus vaccination and Tdap for persons with contact with infants, child care providers, or health care professionals with direct patient contact could be as short as 2 years or less.[56] Given the poor adult pertussis vaccine coverage (5.9% in 2008[57]), and in the setting of increasing numbers of pertussis cases in the United States (16,858 cases in 2009, including 14 infant deaths[58]), the Pertussis Vaccine Working Group of the Advisory Committee on Immunization Practices[59] recommends the administration of a single Tdap (either ADACEL or BOOSTRIX [GlaxoSmithKline Biologicals; Morrisville, NC]), when indicated, for any adult, at any interval since the previous tetanus-diphtheria vaccination. A single Tdap should be considered for adults 65 years or older who have or anticipate having close contact with an infant younger than 12 months as well as for children aged 7 through 10 years who are not fully vaccinated against pertussis. Tdap is not licensed for revaccination. A provisional recommendation from the Advisory Committee on Immunization Practices (February 23, 2011) states that the data on the need for postexposure AP for Tdap-vaccinated health care professionals are inconclusive.[60] In view of this, Tdap-vaccinated health care professionals may still be at risk of acquiring pertussis and should be considered for chemoprophylaxis (CP) after a significant pertussis exposure, particularly if they are likely to be exposed to a patient at risk of severe pertussis, such as hospitalized neonates and pregnant women.

Infective Endocarditis

Infective endocarditis is a relatively rare endocardial infection that can lead to catastrophic complications and death. Guidelines for the prevention of IE have been published by the American Heart Association for more than 50 years. The first 9 guidelines (1955-1997) were based on low-level evidence; more recently, guidelines have been stratified according to the lifetime risk of IE. The recommendations of the most recent (2007) guidelines reflected a new reticence about using AP for IE based on the following premises: (1) cumulative bacteremia risk is much greater with daily activities than dental procedures; (2) antibiotics do not eliminate bacteremia or clearly reduce IE risk; (3) there are no prospective, placebo-controlled AP trials; and (4) even if

TABLE 3. **Cardiac Conditions Associated With the Highest Risk of Adverse Outcome From Endocarditis for Which Prophylaxis With Dental Procedures Is Reasonable**

Prosthetic cardiac valve or prosthetic material used for cardiac valve repair
Previous infective endocarditis
Congenital heart disease (CHD)[a]
Unrepaired cyanotic CHD, including palliative shunts and conduits
Completely repaired congenital heart defect with prosthetic material or device, whether placed by surgery or by catheter intervention, during the first 6 mo after the procedure[b]
Repaired CHD with residual defects at the site or adjacent to the site of a prosthetic patch or prosthetic device (which inhibit endothelialization)
Cardiac transplantation recipients who develop cardiac valvulopathy

[a] Except for the conditions listed above, antimicrobial prophylaxis is no longer recommended for any other form of CHD.
[b] Prophylaxis is reasonable because endothelialization of prosthetic material occurs within 6 mo after the procedure.
From *Circulation*,[61] with permission from the American Heart Association.

100% effective, antibiotics would prevent only rare cases of IE.[61] The 2007 AP guidelines for IE from the American Heart Association and the Infectious Diseases Society of America (IDSA) recommend AP only for patients at highest risk of complications of IE (Table 3) and only for selected dental procedures (Table 4). Administration of prophylactic antibiotics is no longer stratified according to lifetime IE risk. The antibiotics that are recommended for IE prophylaxis before dental procedures are listed in Table 5. Patients receiving a penicillin for RF prophylaxis should not receive a penicillin for IE dental prophylaxis.

Prophylaxis is no longer recommended for uncomplicated gastrointestinal bronchoscopy without incision of the respiratory mucosa and for urinary procedures. If the urine is colonized or infected before an elective cystoscopy, antibiotic therapy to eradicate the infection before the urologic manipulation is recommended. If an urgent cystoscopy is to be performed in the setting of colonized or infected urine, then an antibiotic with activity against enterococci should be administered. Ampicillin or amoxicillin are the preferred agents in this setting; vancomycin should be used in the setting of severe penicillin intolerance. Urinary tract colonization or infection with enterococci known or suspected to be resistant (including those resistant to vancomycin) may require a consultation with an infectious diseases expert.[61]

TABLE 4. **Dental Procedures for Which Endocarditis Prophylaxis Is Reasonable for Patients in Table 3**

All dental procedures that involve manipulation of gingival tissue or the periapical region of teeth or perforation of the oral mucosa[a]

[a] The following procedures and events do not need prophylaxis: routine anesthetic injections through noninfected tissue, taking dental radiographs, placement of removable prosthodontic or orthodontic appliances, adjustment of orthodontic appliances, placement of orthodontic brackets, shedding of deciduous teeth, and bleeding from trauma to the lips or oral mucosa.
From *Circulation*,[61] with permission from the American Heart Association.

Although many respiratory tract procedures reportedly cause bacteremia involving a wide variety of microorganisms, no published data conclusively demonstrate a link between these procedures and IE. Antimicrobial prophylaxis (for regimens, see Table 5) is thought to be reasonable for patients at highest risk of complications from IE (Table 3) who undergo invasive procedures of the respiratory tract that involve incision or biopsy of the respiratory mucosa (eg, tonsillectomy, adenoidectomy). Patients at highest risk of complications from IE who undergo an invasive respiratory tract procedure to treat an established infection, such as drainage of an abscess or empyema, should receive an antibiotic that is active against the viridans group streptococci. If an infection is known or suspected to be caused by *S aureus*, the antibiotic regimen should contain an antistaphylococcal penicillin or a cephalosporin for patients who are unable to tolerate a penicillin. Vancomycin should be used in those in whom an infection is known or suspected to be caused by a methicillin-resistant strain of *S aureus* or in those who have a history of a severe reaction to β-lactam antibiotics.[61]

Prosthetic Joint Infections

By 2030, an estimated 4 million total knee or hip arthroplasties will be performed annually in the United States.[62] Prosthetic joint infections (PJIs), which are rare but serious complications of prosthetic joint replacements (PJRs), occur in 0.3% to 1.0% of patients after primary total hip replacement and 1.0% to 2.0% of patients after primary total knee replacements, with the greatest risk occurring during the first 2 postoperative years (6.5, 3.2, and 1.4 infections per 1000 patient-years during the first year, second year, and after the second year, respectively).[63,64] These infections may be associated with devastating financial and personal consequences. Most PJIs are acquired in the operating room as a result of colonization of the prosthesis at the time of implantation or airborne contamination of the wound.[63] Infection of a prosthesis via hematogenous seeding is a less common cause of PJI. Among PJIs occurring via the hematogenous route, most are the result of *S aureus* bacteremia, skin infections, or urosepsis.[65-67] The development of a PJI due to hematogenous seeding after dental procedures is thought to be a rare event. According to a recent literature review, this occurred in 0.04% to 0.20% of reported PJR case series; many of these infections were seen in patients with dental disease.[68] Pins, plates, and screws not within the synovial joint are not thought to be at increased risk of hematogenous seeding by microorganisms. No studies have shown that AP before dental procedures prevents PJI.[69] A recently published prospective case-control study concluded that dental procedures were not risk factors for subsequent total hip or knee infection. Additionally, the use

TABLE 5. **Regimens for a Dental Procedure**[a]

Situation	Agent	Regimen: single dose 30 to 60 min before procedure	
		Adults	Children
Oral	Amoxicillin	2 g	50 mg/kg
Unable to take oral medication	Ampicillin	2 g IM or IV	50 mg/kg IM or IV
	OR		
	Cefazolin or ceftriaxone	1 g IM or IV	50 mg/kg IM or IV
Allergic to penicillins or ampicillin—oral	Cephalexin[b,c]	2 g	50 mg/kg
	OR		
	Clindamycin	600 mg	20 mg/kg
	OR		
	Azithromycin or clarithromycin	500 mg	15 mg/kg
Allergic to penicillins or ampicillin and unable to take oral medication	Cefazolin or ceftriaxone[c]	1 g IM or IV	50 mg/kg IM or IV
	OR		
	Clindamycin	600 mg IM or IV	20 mg/kg IM or IV

[a] IM = intramuscularly; IV = intravenously.
[b] Or other first- or second-generation oral cephalosporin in equivalent adult or pediatric dosage.
[c] Cephalosporins should not be used in an individual with a history of anaphylaxis, angioedema, or urticaria with penicillins or ampicillin.
Adapted from *Circulation*,[61] with permission from the American Heart Association.

of AP before dental procedures did not decrease the risk of subsequent total hip or knee infection.[70]

Despite the lack of data supporting AP before dental procedures, many surveys of health care professionals have shown that a substantial number of them recommend AP before dental procedures in patients with a PJR.[71,72] Antimicrobial prophylaxis for patients with a prosthetic joint undergoing a dental procedure or other invasive medical procedure has been controversial for decades.[67,71,73-75] Consensus guidelines for this practice were initially published in 1997 and affirmed in 2003 by the American Dental Association (ADA) and the American Association of Orthopedic Surgeons (AAOS) on the basis of low-level evidence.[69,76] It was proposed that AP be administered before dental procedures thought most likely to be associated with bacteremia for patients who were considered to be at highest risk of bacteremia-associated PJI. High-risk patients are thought to include all patients during the first 2 years after joint replacement, immunocompromised or immunosuppressed patients, patients with comorbid conditions (eg, diabetes, obesity, HIV infection, smoking), and patients with inflammatory arthropathies (eg, rheumatoid arthritis), systemic lupus erythematosus, medication- or radiation-induced immunosuppression, previous PJI, malnourishment, hemophilia, HIV infection, insulin-dependent (type 1) diabetes, megaprosthesis, or malignancy. More recently (February 2009), the Patient Safety Committee of the AAOS posted an Information Statement (IS) advising that "clinicians consider antibiotic prophylaxis for…all total joint replacement patients prior to any invasive procedure that may cause bacteremia."[77] The ADA no longer supports the 2003 AAOS/ADA Guidelines and refers patients and health care professionals to the AAOS IS (Karen London, American Dental Association, written communication, March 28, 2011).[77] Although specific dental procedures that may cause bacteremia are not listed in the AAOS IS, the ADA lists the dental procedures that may cause bacteremia in the AAOS/ADA 2003 guidelines.[76,77] The antibiotics recommended in the AAOS IS to be administered to patients with PJR before dental procedures include 2 g of oral cephalexin, cephradine, or amoxicillin 1 hour before dental procedures. The AAOS IS makes no mention of parenteral antibiotic options or antibiotic alternatives for penicillin-allergic patients. The 2003 AAOS/ADA advisory statement recommended 1 g of intravenous cefazolin or ampicillin as parenteral antibiotic alternatives or 600 mg of clindamycin (intravenous or oral) for penicillin-allergic patients, to be administered 1 hour before the dental procedure; in our opinion, these remain valid antibiotic alternatives.[76]

A panel that included representatives from the ADA, AAOS, and IDSA was recently convened with the goal of producing an evidence-based antimicrobial guideline for patients with PJR before dental procedures (D.R.O. is a member of the working group). It is hoped that this will lead to a simpler consensus guideline for patients and health care professionals. Good dental health before and after total joint replacement and prompt treatment of active oral infection should be encouraged for all patients with PJR.

Antimicrobial prophylaxis in patients undergoing invasive gastrointestinal procedures is not recommended by the American Society of Colon and Rectal Surgeons[78] or the American Society for Gastrointestinal Endoscopy.[79] If clinicians elect to recommend AP for the prevention of he-

matogenous PJI in these patients, they should discuss with them the possibility of life-threatening adverse reactions (rare) and the more common drug toxicities. If used, antimicrobial agents should be chosen on the basis of the expected flora at the site of the procedure.

The American Urological Association (AUA) and the AAOS first published consensus- and expert opinion–based AP guidelines in 2003 for patients with total joint replacement who were undergoing urologic procedures.[80] Antimicrobial prophylaxis is recommended for patients at increased risk of hematogenous PJI who undergo urologic procedures associated with an increased risk of bacteremia. The details of these recommendations can be found in the 2007 AUA Best Practice Policy Statement on Urologic Surgery Antimicrobial Prophylaxis, which is available on the AUA Web site.[80,81] The guidelines assume that the urine is sterile preoperatively. If bacteriuria is present, it should be treated with appropriate antibacterial agents before manipulation of the urinary tract.

Travelers' Diarrhea

Antibacterial agents have been shown to decrease the risk of travelers' diarrhea by up to 84%.[82-84] Antimicrobial agents are not routinely recommended for the prevention of travelers' diarrhea because antibiotic self-treatment is so rapidly effective. The traveler may be instructed to carry a supply of an antibiotic (often a 1- to 3-day course of a fluoroquinolone for travel to Central or South America or Africa or of azithromycin when traveling to Asia or the Indian subcontinent) to be taken on an as-needed basis.[12] In certain circumstances (risk-averse travelers, athletes, persons taking antacids, or persons with diabetes, an elevated gastric pH, or inflammatory bowel disease), a daily oral antibiotic regimen may be considered on a short-term basis (ideally <2-3 weeks) to prevent travelers' diarrhea. Fluoroquinolones may be less effective in areas with quinolone-resistant *Campylobacter* species infections (eg, India, Southeast Asia), so an agent such as azithromycin (250 mg once daily) may be considered, although this has not been studied. In a 14-day study among travelers to Mexico, rifaximin (200 mg 1-3 times daily) was 72% effective in preventing travelers' diarrhea.[23] Bismuth subsalicylate prophylaxis (Pepto-Bismol [Proctor & Gamble; Cincinnati, OH]: two 262-mg chewable tablets 4 times daily, with meals and once in the evening) is less effective (62%-65% effective) than antibiotics, is inconvenient to take, contains a salicylate (to be avoided if receiving anticoagulant therapy or high-dose salicylates), causes a black tongue, and may interfere with the absorption of medications such as doxycycline.[12] Probiotics containing *Lactobacillus* GG or *Saccharomyces boulardii* are of limited efficacy (0%-60% effective) in the prevention of travelers' diarrhea and generally are not recommended for this purpose.[85,86]

Open Fractures

Open fractures, particularly Gustilo grade 3 fractures, are at an increased risk of infection.[87] The key to infection avoidance of open class III fractures is wound irrigation, surgical débridement of devitalized tissue, and delayed wound closure. A recent Surgical Infection Society Guideline recommended AP with a first-generation cephalosporin after open fracture until 24 to 48 hours after wound closure.[88] Some groups recommend adding gram-negative coverage for class III open fractures.[89]

Herpes Simplex Viral Infection

Frequent recurrent genital herpes simplex viral infections (>5-6 episodes per year) are amenable to prophylaxis with continuous acyclovir (400 mg twice daily), famciclovir (250 mg twice daily), or valacyclovir (500-1000 mg once daily).[90,91] Famciclovir may be less effective for suppression of viral shedding, and 500 mg of valacyclovir once daily might be less effective than other valacyclovir or acyclovir dosing regimens in patients who have very frequent recurrences (ie, ≥10 episodes per year).[91] Patients should be counseled regarding consistent condom use and avoidance of sexual activity during recurrences in addition to suppressive antiviral therapy.

Influenza

Chemoprophylaxis of influenza A and B infection with a neuraminidase inhibitor (zanamivir [inhaled] or oseltamivir [oral]) is 70% to 90% effective[92,93] (Table 1). These agents are particularly useful for prophylaxis after exposure in unvaccinated high-risk patients and unvaccinated health care professionals in an outbreak setting in a medical institution or community. Chemoprophylaxis is recommended for persons who are at high risk of influenza complications (Table 6) and those who are hospitalized or have severe, complicated, or progressive illness.[94] Low-risk, healthy persons who are not in contact with high-risk patients do not typically require CP. Adults for whom antiviral CP should be considered during periods of increased influenza activity in the community are listed in Table 7. Zanamivir and oseltamivir are classified as category C (risk cannot be ruled out) for use during pregnancy. Influenza CP should be considered as an adjunct to influenza vaccination. Chemoprophylaxis should not be administered 48 hours before or 2 weeks after administration of the intranasal live-attenuated FluMist influenza vaccine (MedImmune, Gaithersburg, MD); CP has no effect on the inactivated influenza vaccine.[21] Chemoprophylaxis may be stopped 10 days after exposure for household contacts and 7 days after other exposures.[94] For control of outbreaks in long-term care facilities and hospitals, the Centers for Disease Control and Prevention recommends CP for a mini-

TABLE 6. **Persons at High Risk of Influenza Complications**[a,b,c]

Children aged <5 y (especially <2 y)
Adults aged >65 y[c]
Persons with chronic disorders, including the following: Pulmonary (including asthma) Cardiovascular (except hypertension alone) Renal Hepatic Hematologic (including sickle cell disease) Metabolic (including diabetes mellitus)
Persons with neurologic and neurodevelopment conditions,[d] including the following: Cerebral palsy Epilepsy Stroke Intellectual disability (mental retardation) Moderate to severe developmental delay Muscular dystrophy Spinal cord injury
Persons who are immunosuppressed as a result of medication or HIV infection
Women who are pregnant or postpartum (within 2 wk after delivery)
Persons aged ≤18 y who are receiving long-term aspirin therapy
American Indians and Alaska Natives
Persons who are morbidly obese (ie, BMI ≥40)
Residents of nursing homes and other long-term care facilities

[a] BMI = body mass index; HIV = human immunodeficiency virus.
[b] Influenza vaccination is the primary tool to prevent influenza; antiviral chemoprophylaxis is not a substitute for vaccination. Chemoprophylaxis should be administered in conjunction with inactivated vaccination.
[c] Highest risks for morbidity and mortality include the very elderly (aged >85 y) residents of nursing homes and those severely immunosuppressed (eg, allogenic stem cell transplant recipients).
[d] Affecting brain, spinal cord, peripheral nerve, or muscle.
Adapted from *Clin Infect Dis*,[22] with permission from Oxford University Press, and from *MMWR Recomm Rep*.[94]

mum of 2 weeks, even for vaccinated persons, up to 1 week after the last known case was identified.[22,94] In patients who are unable to receive influenza vaccination and who are at high risk of complications, treatment should be continued for the duration of the influenza season in the community. Oseltamivir- and zanamivir-resistant influenza A strains have been reported; one should monitor the Centers for Disease Control and Prevention influenza Web site (http://www.cdc.gov/flu) for seasonal updates. The adamantanes (amantadine and rimantadine) are active only against influenza A; with the emergence of adamantane resistance in most seasonal A H3N2 and pandemic 2009-2010 A H1N1 strains, these agents are no longer recommended for CP.

SURGICAL AP

Surgical site infections account for 14% to 18% of all health care infections and are the third most frequently reported nosocomial infection.[96,97] Factors that may increase the risk of surgical site infection include those related to the patient (age, nutritional status, diabetes, smoking status, obesity, coexisting infections at a remote site, colonization with a pathogenic microorganism, altered immune response, and length of preoperative stay) and the operative procedure (duration of surgical scrub, skin antisepsis, preoperative shaving, preoperative skin preparation, duration of operation, AP, operating room ventilation, inadequate sterilization of instruments, foreign material at the surgical site, surgical drains, and surgical technique).[98] The risk of surgical site infection also depends on whether the surgical procedure is clean, clean-contaminated, contaminated, or dirty-infected based on standard definitions of these terms.[98] Improvements in operating room ventilation, sterilization methods, barriers, and surgical technique as well as the use of perioperative topical, oral, and intravenous AP have been important in decreasing the incidence of surgical site infection.[98,99]

Perioperative antimicrobial surgical prophylaxis is recommended for operative procedures that have a high rate of postoperative wound infection, when foreign material is implanted, or when the wound infection rate is low but the development of a wound infection results in a disastrous event.[98-100] Prophylactic antimicrobial agents should be bactericidal, nontoxic, and inexpensive and

TABLE 7. **Adults for Whom Antiviral Chemoprophylaxis Should Be Considered During Periods of Increased Influenza Activity in the Community**[a,b,c]

Persons at high risk during the 2 wk after influenza vaccination[a]
Persons at highest risk of influenza complications for whom influenza vaccine is contraindicated, unavailable, or a poor match (at particularly high risk are recipients of hematopoietic stem cell transplants, pregnant women, and those infected with the human immunodeficiency virus)
Family members or health care professionals who are unvaccinated and are likely to have ongoing, close exposure to persons at high risk, unvaccinated persons, or infants aged <6 mo
Persons at high risk, their family members and close contacts, and health care professionals, when circulating strains of influenza virus in the community are not matched with the vaccine strains
Persons with immune deficiencies or those who might not respond to vaccination (eg, persons who are infected with the human immunodeficiency virus, who have other immunosuppressed conditions, or who are receiving immunosuppressive medications)
Vaccinated and unvaccinated staff and other persons during response to an outbreak in a closed institutional setting with residents at high risk (eg, extended-care facilities)

[a] Chemoprophylaxis should be administered in conjunction with inactivated vaccination.
[b] Chemoprophylaxis does not need to be limited to these people.
[c] Updates or supplements to these recommendations might be required. Health care professionals should be alert to the announcement of recommendation updates and should check the Centers for Disease Control and Prevention influenza Web site periodically for additional information.
Adapted from *Clin Infect Dis*,[22] with permission from Oxford University Press, and from *MMWR Recomm Rep*.[95]

TABLE 8. **Antimicrobial Prophylaxis for Surgery**[a,b]

Nature of operation	Common pathogens	Recommended antimicrobial agents	Adult dosage before surgery[c]
Cardiac[d] (prosthetic valve, coronary artery bypass, open heart surgery)[103,104]	*Staphylococcus aureus*, coagulase-negative staphylococci	Cefazolin *or* Cefuroxime[102] *or* Vancomycin[d,f]	1-2 g IV every 8 h[e] 1.5 g IV every 12 h 15 mg/kg IV every 12 h
Thoracic (noncardiac)	*S aureus*, coagulase-negative staphylococci, enteric gram-negative bacilli	Cefazolin *or* Cefuroxime *or* Vancomycin	1-2 g IV every 8 h 1.5 g IV every 12 h 15 mg/kg IV every 12 h
Pacemaker or defibrillator implant[10,105,106]	*S aureus*, coagulase-negative staphylococci	Cefazolin *or* Vancomycin	1-2 g IV every 8 h 15 mg/kg IV every 12 h
Gastrointestinal			
Esophageal, gastroduodenal	Enteric gram-negative bacilli, gram-positive cocci	High-risk patients only[g] Cefazolin[h]	 1-2 g IV every 8 h
Biliary tract[107-109]	Enteric gram-negative bacilli, enterococci, clostridia	High-risk patients[i] only Cefazolin[h]	 1-2 g IV every 8 h
Colorectal[110b]	Enteric gram-negative bacilli, enterococci, anaerobes	Oral Neomycin sulfate *plus* Erythromycin base[j] *or plus* Metronidazole[j] Parenteral Cefoxitin[h] or cefotetan[h] *or* Cefazolin *plus* Metronidazole *or* Ampicillin-sulbactam[h]	 NA 1-2 g IV 1-2 g IV 0.5 g IV 3 g IV
Appendectomy, nonperforated[k]	Enteric gram-negative bacilli, enterococci, anaerobes	Cefoxitin[h] or cefotetan[h] *or* Cefazolin *plus* Metronidazole *or* Ampicillin-sulbactam[h]	1-2 g IV 1-2 g IV 0.5 g IV 3 g IV
Genitourinary[81]	Enteric gram-negative bacilli,		
Cystoscopy alone	enterococci	High-risk patients only[l] Ciprofloxacin *or* Trimethoprim-sulfamethoxazole	 500 mg orally or 400 mg IV 1 DS tablet
Cystoscopy with manipulation or upper tract instrumentation[m]		Ciprofloxacin	500 mg orally or 400 mg IV
Open or laparoscopic surgery[n]		Cefazolin[h]	1-2 g IV
Gynecologic and obstetric[111]			
Vaginal, abdominal, or laparoscopic hysterectomy	Gram-negative bacilli, enterococci, group B streptococci, anaerobes	Cefoxitin,[h] or cefotetan,[h] or cefazolin[h] *or* Ampicillin-sulbactam[h]	1-2 g IV 3 g IV
Cesarean section[112]	Same as for hysterectomy	Cefazolin[h]	1-2 g IV
Abortion[111]	Same as for hysterectomy	Doxycycline	300 mg orally[o]
Head and neck[113,114]	*S aureus*, oropharyngeal anaerobes, enteric gram-negative bacilli	Clindamycin *or* Cefazolin *plus* Metronidazole	600-900 mg IV 1-2 g IV 0.5 g IV
Incision through oral or pharyngeal mucosa			
Neurosurgical	*S aureus*, coagulase-negative		
Craniotomy/spine[115-117]	staphylococci	Cefazolin	1-2 g IV
Cerebrospinal fluid shunting[118-121]		*or* Vancomycin[f]	15 mg/kg IV
Ophthalmic[122,123p]	*S aureus*, coagulase-negative staphylococci, streptococci, enteric gram-negative bacilli, *Pseudomonas* species	Gentamicin, tobramycin, ciprofloxacin, ofloxacin, gatifloxacin, levofloxacin, moxifloxacin *or* Neomycin-gramicidin-polymyxin B Cefazolin	Multiple drops topically over 2 to 24 h 100 mg subconjunctivally

(continued on next page)

have in vitro activity against the common organisms that cause postoperative wound infection after a specific surgical procedure. Consensus panels most often recommend cefazolin and other cephalosporins because they meet the aforementioned criteria.[98,100] Broad-spectrum antibiotics (eg, ertapenem) should be avoided for surgical prophylaxis.[100,101] Perioperative antimicrobial surgical prophylaxis regimens for various surgical procedures adapted from the published recommendations of 2 consensus panels are summarized in Table 8.[99,100,102] The use of vancomycin

TABLE 8. **Continued**[a,b]

Nature of operation	Common pathogens	Recommended antimicrobial agents	Adult dosage before surgery[c]
Orthopedic[124,125]	*S aureus*, coagulase-negative staphylococci	Cefazolin[q] or cefuroxime[q]	1-2 g IV every 8 h for 24 h
Total joint replacement[r]			1.5 g IV every 12 h
Implantation of internal fixation device		*or* Vancomycin[f,q]	15 mg/kg IV every 12 h for 2 doses
Vascular[126,127]	*S aureus*, coagulase-negative staphylococci, enteric gram-negative bacilli		
Arterial surgery involving a prosthesis, the abdominal aorta, or a groin incision		Cefazolin *or* Vancomycin[f]	1-2 g IV every 8 h for 24 h; 15 mg/kg IV every 12 h for 2 doses
Lower extremity amputation due to ischemia	*S aureus*, coagulase-negative staphylococci, enteric gram-negative bacilli, clostridia	Cefazolin *or* Vancomycin[f]	1-2 g IV; 1 g IV (or 15 mg/kg)

[a] DS = double-strength; IV = intravenously; NA = not available.

[b] We agree with the *Medical Letter* consultants who do not recommend the use of broad-spectrum drugs (eg, ertapenem), third-generation cephalosporins (eg, cefotaxime, ceftriaxone, cefoperazone, ceftizoxime), or fourth-generation cephalosporins (eg, cefepime) for routine surgical prophylaxis because they are expensive, the activity of some against staphylococci is less than first- or second-generation cephalosporins, and their spectrum of activity includes organisms rarely encountered in elective surgery. These drugs should be reserved for treatment of serious infections, particularly those likely to be caused by organisms resistant to other antimicrobial agents.[100]

[c] Parenteral prophylactic antimicrobial agents can be given as a single IV dose begun ≤60 min before the operation. For prolonged operations (>4 h) or those with major blood loss, additional intraoperative doses should be given at intervals 1 to 2 times the half-life of the drug: ampicillin-sulbactam, every 2-4 h; cefazolin, every 2-5 h; cefuroxime, every 3-4 h; cefoxitin, every 2-3 h; clindamycin, every 3-6 h; vancomycin, every 6-12 h; and metronidazole, every 6-8 h[102] for the duration of the procedure in patients with normal renal function. If vancomycin or a fluoroquinolone is used, the infusion should be started 60-120 min before the initial incision to minimize the possibility of an infusion reaction close to the time of induction of anesthesia and to have adequate tissue levels at the time of incision.

[d] The Society of Thoracic Surgeons recommends vancomycin plus cefazolin in patients not allergic to penicillins who are at increased risk of methicillin-resistant staphylococcal surgical site infections and nasal mupirocin in all patients who are nasally colonized with *S aureus* or in whom nasal *S aureus* colonization status is unavailable.[104] Adjunctive decolonization of *S aureus* carriers may also decrease the incidence of surgical site infection.[128,129] Duration of prophylaxis up to 48 h may be appropriate.

[e] Some consultants recommend an additional dose when patients are removed from bypass during open heart surgery.

[f] Vancomycin can be used in hospitals in which methicillin-resistant *S aureus* (MRSA) and *Staphylococcus epidermidis* are a frequent cause of postoperative wound infections, in patients previously colonized with MRSA, or in those who are allergic to penicillins or cephalosporins. Rapid IV administration may cause hypotension, which could be especially dangerous during induction of anesthesia. Even when the drug is administered for a period of 60 min, hypotension may occur; treatment with diphenhydramine and further slowing of the infusion rate may be helpful. Some experts would give 15 mg/kg of vancomycin to patients weighing more than 75 kg, up to a maximum of 1.5 g, with a slower infusion rate (1.5 g for 90 min). For operations in which enteric gram-negative bacilli are common pathogens, adding another drug, such as an aminoglycoside (gentamicin, tobramycin, or amikacin), may be reasonable.

[g] Patients with morbid obesity, esophageal obstruction, decreased gastric acidity, decreased gastrointestinal motility, hemorrhage, gastric cancer, gastric bypass, or percutaneous endoscopic gastrostomy are at high risk, as are those being treated with an H_2 blocker or a proton pump inhibitor.[130] Some experts recommend prophylaxis for all gastroduodenal operations in which there is entry into the lumen of the gastrointestinal tract.[99]

[h] For patients allergic to penicillins and cephalosporins, clindamycin with either gentamicin, ciprofloxacin, levofloxacin, or aztreonam is a reasonable alternative.

[i] Risk factors for infection resulting from biliary procedures, including laparoscopic cholecystectomy: emergency procedures, diabetes, longer procedure duration, intraoperative gallbladder rupture, age >70 y, open cholecystectomy, conversion of laparoscopic to open cholecystectomy, higher American Society of Anesthesiologists (ASA) score, episode of colic within 30 d before surgery, reintervention in <1 mo for noninfectious complications, acute cholecystitis, bile spillage, jaundice, pregnancy, nonfunctioning gallbladder, immunosuppression, obstructive jaundice, common duct stones, or insertion of a prosthetic device. Some experts recommend prophylaxis for all biliary operations.[99]

[j] 1 g of neomycin plus 1 g of erythromycin at 1 PM, 2 PM, and 11 PM or 2 g of neomycin plus 2 g of metronidazole at 7 PM and 11 PM the day before an 8 AM operation.

[k] For a ruptured viscus, therapy is often continued for about 5 d (therapeutic course).

[l] Preoperative urine culture positive or unavailable, preoperative catheter, transrectal prostatic biopsy, or placement of prosthetic material.

[m] Shockwave lithotripsy, ureteroscopy.

[n] Including percutaneous renal surgery, procedures with entry into the urinary tract, and those involving implantation of a prosthesis. If manipulation of the bowel is involved, prophylaxis is given according to colorectal guidelines.

[o] Divided into 100 mg an hour before the abortion and 200 mg a half hour after.

[p] There is no consensus supporting a particular choice, route, or duration of antimicrobial prophylaxis for ophthalmic surgeries.[122]

[q] If a tourniquet is to be used in the procedure, the entire dose of antibiotic must be infused before its inflation.

[r] Antibiotic containing polymethyl methacrylate cement in addition to cefazolin or vancomycin may be appropriate for high-risk procedures, including revision arthroplasty.[73] Adjunctive decolonization of *S aureus* carriers may also decrease the incidence of surgical site infection.[131]

for prophylaxis is appropriate in the event of true type I hypersensitivity or other serious reaction to penicillin or when the incidence of surgical site infection is high due to methicillin-resistant staphylococci.[132] Adherence to this practice will help to avoid the emergence of vancomycin-resistant organisms and vancomycin-related toxicity.[133-136] Prophylactic antimicrobial agents should be administered not more than 30 to 60 minutes before surgery, including cesarian sections.[100,112,137,138] Exceptions to this include oral administration of antimicrobial agents before colonic and urologic procedures (Table 8). Infusions should be completed before the tourniquet is placed with orthopedic surgeries. Vancomycin and fluoroquinolone infusions should be started 90 to 120 minutes before surgical incision because these require at least 1 hour to infuse. Therapeutic concentrations of antimicrobial agents should be present in the tissue throughout the period that the wound is open. Additional antibiotic doses may need to be administered intraoperatively for prolonged procedures or with antimicrobial agents with short half-lives.[102,139] Initiating intravenous antimicrobial therapy before the perioperative period provides no benefit. Prolonged postoperative AP should be discouraged because of the possibility of added antimicrobial toxicity, selection of resistant organisms, and unnecessary expense. The duration of AP for most procedures should not exceed 24 hours, with the exception of cardiac surgeries, in which antibiotics may be continued for up to 48 hours.[99,100,102,103,140] The duration of antibiotic therapy for ophthalmic procedures has not been established. An advisory statement for AP in dermatologic surgery has been published recently.[141] The IDSA, American Society of Health-System Pharmacists (ASHP), Society for Healthcare Epidemiology of America, and Surgical Infection Society are currently in the process of revising the 1999 ASHP Antimicrobial Prophylaxis in Surgery Guideline.[99]

In 2002, the Center for Medicaid and Medicare Services implemented a quality initiative project, currently entitled the Surgical Care Improvement Project (SCIP), in an attempt to decrease postoperative surgical site infections.[140] As part of the SCIP, medical institutions are being graded on 3 surgical AP performance measures with cardiothoracic, vascular, colon, hip/knee, and vaginal or abdominal hysterectomy surgeries: (1) the proportion of patients who have parenteral AP initiated within 1 hour before surgical incision, (2) the proportion of patients who are provided an antibiotic agent that is consistent with currently published guidelines, and (3) the proportion of patients whose prophylactic antibiotic is discontinued within 24 hours after the end of the operation (48 hours for cardiothoracic surgery). The most up-to-date list of approved antibiotics for various surgeries is posted on the SCIP Web site.[140]

CONCLUSION

The use of AP has led to the prevention of a large number and variety of infections and to substantial declines in surgical site infections. Antimicrobial prophylaxis should be limited to specific, well-accepted indications to avoid excess cost, toxicity, and antimicrobial resistance. Patients should understand the potential risks and benefits of any AP regimen. Although some AP practices are evidence-based, many are based on low-level evidence or expert opinion. More studies in the area of AP are needed.

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