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Prevention of Infective Endocarditis: Guidelines From the American Heart Association: A Guideline From the American Heart Association Rheumatic Fever, Endocarditis, and Kawasaki Disease Committee, Council on Cardiovascular Disease in the Young, and the Council on Clinical Cardiology, Council on Cardiovascular Surgery and Anesthesia, and the Quality of Care and Outcomes Research Interdisciplinary Working Group

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Prevention of Infective Endocarditis

Guidelines From the American Heart Association

A Guideline From the American Heart Association Rheumatic Fever, Endocarditis, and Kawasaki Disease Committee, Council on Cardiovascular Disease in the Young, and the Council on Clinical Cardiology, Council on Cardiovascular Surgery and Anesthesia, and the Quality of Care and Outcomes Research Interdisciplinary Working Group

Walter Wilson, MD, Chair; Kathryn A. Taubert, PhD, FAHA; Michael Gewitz, MD, FAHA; Peter B. Lockhart, DDS; Larry M. Baddour, MD; Matthew Levison, MD; Ann Bolger, MD, FAHA; Christopher H. Cabell, MD, MHS; Masato Takahashi, MD, FAHA; Robert S. Baltimore, MD; Jane W. Newburger, MD, MPH, FAHA; Brian L. Strom, MD; Lloyd Y. Tani, MD; Michael Gerber, MD; Robert O. Bonow, MD, FAHA; Thomas Pallasch, DDS, MS; Stanford T. Shulman, MD, FAHA; Anne H. Rowley, MD; Jane C. Burns, MD; Patricia Ferrieri, MD; Timothy Gardner, MD, FAHA; David Goff, MD, PhD, FAHA; David T. Durack, MD, PhD

The Council on Scientific Affairs of the American Dental Association has approved the guideline as it relates to dentistry. In addition, this guideline has been endorsed by the American Academy of Pediatrics, Infectious Diseases Society of America, the International Society of Chemotherapy for Infection and Cancer, and the Pediatric Infectious Diseases Society.*

Background—The purpose of this statement is to update the recommendations by the American Heart Association (AHA) for the prevention of infective endocarditis that were last published in 1997.

Methods and Results—A writing group was appointed by the AHA for their expertise in prevention and treatment of infective endocarditis, with liaison members representing the American Dental Association, the Infectious Diseases Society of America, and the American Academy of Pediatrics. The writing group reviewed input from national and international experts on infective endocarditis. The recommendations in this document reflect analyses of relevant literature regarding procedure-related bacteremia and infective endocarditis, in vitro susceptibility data of the most common microorganisms that cause infective endocarditis, results of prophylactic studies in animal models of experimental endocarditis, and retrospective and prospective studies of prevention of infective endocarditis. MEDLINE database searches from 1950 to 2006 were done for English-language papers using the following search terms: endocarditis, infective endocarditis, prophylaxis, prevention, antibiotic, antimicrobial, pathogens, organisms, dental, gastrointestinal, genitourinary, streptococcus, enterococcus, staphylococcus, respiratory, dental surgery, pathogenesis, vaccine, immunization, and bacteremia. The reference lists of the identified papers were also searched. We also searched the AHA online library. The American College of Cardiology/AHA classification of recommendations and levels of

*If these guidelines are applied outside of the United States of America, adaptation of the recommended antibiotic agents may be considered with respect to the regional situation.

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evidence for practice guidelines were used. The paper was subsequently reviewed by outside experts not affiliated with the writing group and by the AHA Science Advisory and Coordinating Committee.

Conclusions—The major changes in the updated recommendations include the following: (1) The Committee concluded that only an extremely small number of cases of infective endocarditis might be prevented by antibiotic prophylaxis for dental procedures even if such prophylactic therapy were 100% effective. (2) Infective endocarditis prophylaxis for dental procedures is reasonable only for patients with underlying cardiac conditions associated with the highest risk of adverse outcome from infective endocarditis. (3) For patients with these underlying cardiac conditions, prophylaxis is reasonable for all dental procedures that involve manipulation of gingival tissue or the periapical region of teeth or perforation of the oral mucosa. (4) Prophylaxis is not recommended based solely on an increased lifetime risk of acquisition of infective endocarditis. (5) Administration of antibiotics solely to prevent endocarditis is not recommended for patients who undergo a genitourinary or gastrointestinal tract procedure. These changes are intended to define more clearly when infective endocarditis prophylaxis is or is not recommended and to provide more uniform and consistent global recommendations. **(*Circulation*. 2007;116:1736-1754.)**

Key Words: AHA Scientific Statements ■ cardiovascular diseases ■ endocarditis ■ prevention ■ antibiotic prophylaxis

Infective endocarditis (IE) is an uncommon but life-threatening infection. Despite advances in diagnosis, antimicrobial therapy, surgical techniques, and management of complications, patients with IE still have high morbidity and mortality rates related to this condition. Since the last American Heart Association (AHA) publication on prevention of IE in 1997,[1] many authorities and societies, as well as the conclusions of published studies, have questioned the efficacy of antimicrobial prophylaxis to prevent IE in patients who undergo a dental, gastrointestinal (GI), or genitourinary (GU) tract procedure and have suggested that the AHA guidelines should be revised.[2–5] Members of the Rheumatic Fever, Endocarditis, and Kawasaki Disease Committee of the AHA Council on Cardiovascular Disease in the Young ("the Committee") and a national and international group of experts on IE extensively reviewed data published on the prevention of IE. The Committee is especially grateful to a group of international experts on IE who provided content review and input on this document (see Acknowledgments). The revised guidelines for IE prophylaxis are the subject of this report.

The writing group was charged with the task of performing an assessment of the evidence and giving a classification of recommendations and a level of evidence (LOE) to each recommendation. The American College of Cardiology (ACC)/AHA classification system was used as follows.

Classification of Recommendations:

Class I: Conditions for which there is evidence and/or general agreement that a given procedure or treatment is beneficial, useful, and effective.

Class II: Conditions for which there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of a procedure or treatment.

Class IIa: Weight of evidence/opinion is in favor of usefulness/efficacy.

Class IIb: Usefulness/efficacy is less well established by evidence/opinion.

Class III: Conditions for which there is evidence and/or general agreement that a procedure/treatment is not useful/effective and in some cases may be harmful.

Level of Evidence:

Level of Evidence A: Data derived from multiple randomized clinical trials or meta-analyses.

Level of Evidence B: Data derived from a single randomized trial or nonrandomized studies.

Level of Evidence C: Only consensus opinion of experts, case studies, or standard of care.

History of AHA Statements on Prevention of IE

The AHA has made recommendations for the prevention of IE for more than 50 years. In 1955, the first AHA document on this subject was published in *Circulation*.[6] Table 1 shows a summary of the documents published from 1955 to 1997.[1,6–13] The 1960 document called attention to the possible emergence of penicillin-resistant oral microflora as a result of prolonged therapy for prevention of IE, and pediatric patients were included for the first time.[8] Chloramphenicol was recommended for patients who were allergic to penicillin. In 1965, the Committee published for the first time a document devoted solely to the prophylaxis of IE and recognized the importance of enterococci after GI or GU tract procedures.[9] The revised recommendations published in 1972 were endorsed for the first time by the American Dental Association (ADA) and emphasized the importance of maintenance of good oral hygiene.[10] This version introduced a recommendation for ampicillin in patients undergoing a GI or GU tract procedure. The 1977 revisions categorized both patients and procedures into high- and low-risk groups.[11] This resulted in complex tables with many footnotes. The 1984 recommendations attempted to simplify prophylactic regimens by providing clear lists of procedures for which prophylaxis was and was not recommended and reduced postprocedure prophylaxis for dental, GI, and GU tract procedures to only 1 oral or parenteral dose.[12] In 1990, a more complete list of cardiac conditions and dental or surgical procedures for which prophylaxis was and was not recommended was provided.[13] These previous recommendations recognized the potential medical-legal risks associated with IE prophylaxis and suggested that the recommendations were

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Table 1. Summary of 9 Iterations of AHA-Recommended Antibiotic Regimens From 1955 to 1997 for Dental/Respiratory Tract Procedures*

Year (Reference)	Primary Regimens for Dental Procedures
1955 (6)	Aqueous penicillin 600 000 U and procaine penicillin 600 000 U in oil containing 2% aluminum monostearate administered IM 30 minutes before the operative procedure
1957 (7)	For 2 days before surgery, penicillin 200 000 to 250 000 U by mouth 4 times per day. On day of surgery, penicillin 200 000 to 250 000 U by mouth 4 times per day and aqueous penicillin 600 000 U with procaine penicillin 600 000 U IM 30 to 60 minutes before surgery. For 2 days after, 200 000 to 250 000 U by mouth 4 times per day.
1960 (8)	Step I: prophylaxis 2 days before surgery with procaine penicillin 600 000 U IM on each day
	Step II: day of surgery: procaine penicillin 600 000 U IM supplemented by crystalline penicillin 600 000 U IM 1 hour before surgical procedure
	Step III: for 2 days after surgery: procaine penicillin 600 000 U IM each day
1965 (9)	Day of procedure: procaine penicillin 600 000 U, supplemented by crystalline penicillin 600 000 U IM 1 to 2 hours before the procedure
	For 2 days after procedure: procaine penicillin 600 000 U IM each day
1972 (10)	Procaine penicillin G 600 000 U mixed with crystalline penicillin G 200 000 U IM 1 hour before procedure and once daily for the 2 days after the procedure
1977 (11)	Aqueous crystalline penicillin G (1 000 000 U IM) mixed with procaine penicillin G (600 000 U IM) 30 minutes to 1 hour before procedure and then penicillin V 500 mg orally every 6 hours for 8 doses.
1984 (12)	Penicillin V 2 g orally 1 hour before, then 1 g 6 hours after initial dose
1990 (13)	Amoxicillin 3 g orally 1 hour before procedure, then 1.5 g 6 hours after initial dose
1997 (1)	Amoxicillin 2 g orally 1 hour before procedure

IM indicates intramuscularly.

*These regimens were for adults and represented the initial regimen listed in each version of the recommendations. In some versions, >1 regimen was included.

intended to serve as a guideline, not as established standard of care. The most recent AHA document on IE prophylaxis was published in 1997.[1] The 1997 document stratified cardiac conditions into high-, moderate-, and low-risk (negligible risk) categories, with prophylaxis not recommended for the low-risk group.[1] An even more detailed list of dental, respiratory, GI, and GU tract procedures for which prophylaxis was and was not recommended was provided. The 1997 document was notable for its acknowledgment that most cases of IE are not attributable to an invasive procedure but rather are the result of randomly occurring bacteremias from routine daily activities and for its acknowledgment of possible IE prophylaxis failures.

Rationale for Revising the 1997 Document

It is clear from the above chronology that the AHA guidelines for IE prophylaxis have been in a process of evolution more than 50 years. The rationale for prophylaxis was based largely on expert opinion and what seemed to be a rational and prudent attempt to prevent a life-threatening infection. On the basis of the ACC and AHA Task Force on Practice Guidelines' evidence-based grading system for ranking recommendations, the recommendations in the AHA documents published during the past 50 years would be Class IIb, LOE C. Accordingly, the basis for recommendations for IE prophylaxis was not well established, and the quality of evidence was limited to a few case-control studies or was based on expert opinion, clinical experience, and descriptive studies that utilized surrogate measures of risk.

Over the years, other international societies have published recommendations and guidelines for the prevention of IE.[14,15] Recently, the British Society for Antimicrobial Chemotherapy issued new IE prophylaxis recommendations.[15] This group now recommends prophylaxis before dental procedures only for patients who have a history of previous IE or who have had cardiac valve replacement or surgically constructed pulmonary shunts or conduits.

The fundamental underlying principles that drove the formulation of the AHA guidelines and the 9 previous AHA documents were that (1) IE is an uncommon but life-threatening disease, and prevention is preferable to treatment of established infection; (2) certain underlying cardiac conditions predispose to IE; (3) bacteremia with organisms known to cause IE occurs commonly in association with invasive dental, GI, or GU tract procedures; (4) antimicrobial prophylaxis was proven to be effective for prevention of experimental IE in animals; and (5) antimicrobial prophylaxis was thought to be effective in humans for prevention of IE associated with dental, GI, or GU tract procedures. The Committee believes that of these 5 underlying principles, the first 4 are valid and have not changed during the past 30 years. Numerous publications have questioned the validity of the fifth principle and suggested revision of the guidelines, primarily for reasons as shown in Table 2.

Another reason that led the Committee to revise the 1997 document was that over the past 50 years, the AHA guidelines on prevention of IE became overly complicated, making it difficult for patients and healthcare providers to interpret or remember specific details, and they contained ambiguities and some inconsistencies in the recommendations. The decision to substantially revise the 1997 document was not taken lightly. The present revised document was not based on the results of a single study but rather on the collective body of evidence published in numerous studies over the past 2 decades. The Committee sought to construct the present recommendations such that they would be in the best interest

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Table 2. Primary Reasons for Revision of the IE Prophylaxis Guidelines

IE is much more likely to result from frequent exposure to random bacteremias associated with daily activities than from bacteremia caused by a dental, GI tract, or GU tract procedure.
Prophylaxis may prevent an exceedingly small number of cases of IE, if any, in individuals who undergo a dental, GI tract, or GU tract procedure.
The risk of antibiotic-associated adverse events exceeds the benefit, if any, from prophylactic antibiotic therapy.
Maintenance of optimal oral health and hygiene may reduce the incidence of bacteremia from daily activities and is more important than prophylactic antibiotics for a dental procedure to reduce the risk of IE.

of patients and providers, would be reasonable and prudent, and would represent the conclusions of published studies and the collective wisdom of many experts on IE and relevant national and international societies.

Potential Consequences of Substantive Changes in Recommendations

Substantive changes in recommendations could (1) violate long-standing expectations and practice patterns; (2) make fewer patients eligible for IE prophylaxis; (3) reduce malpractice claims related to IE prophylaxis; and (4) stimulate prospective studies on IE prophylaxis. The Committee and others[16] recognize that substantive changes in IE prophylaxis guidelines may violate long-standing expectations and practice patterns by patients and healthcare providers. The Committee recognizes that these new recommendations may cause concern among patients who have previously received antibiotic prophylaxis to prevent IE before dental or other procedures and are now advised that such prophylaxis is unnecessary. Table 2 includes the main talking points that may be helpful for clinicians in reeducating their patients about these changes. To recommend such changes demands due diligence and critical analysis. For 50 years, since the publication of the first AHA guidelines on the prevention of IE,[6] patients and healthcare providers assumed that antibiotics administered in association with a bacteremia-producing procedure effectively prevented IE in patients with underlying cardiac risk factors. Patients were educated about bacteremia-producing procedures and risk factors for IE, and they expected to receive antibiotic prophylaxis; healthcare providers, especially dentists, were expected to administer them. Patients with underlying cardiac conditions that carry a lifetime risk of acquisition of IE, such as mitral valve prolapse (MVP), had a sense of reassurance and comfort that antibiotics administered in association with a dental procedure were effective and usually safe to prevent IE. Healthcare providers, especially dentists, felt a sense of obligation and professional and legal responsibility to protect their patients from IE that might result from a procedure. On the basis of recommendations in this revised document, substantially fewer patients will be recommended for IE prophylaxis.

Cases of IE either temporally or remotely associated with an invasive procedure, especially a dental procedure, have frequently been the basis for malpractice claims against healthcare providers. Unlike many other infections for which there is conclusive evidence for the efficacy of preventive therapy, the prevention of IE is not a precise science. Because previously published AHA guidelines for the prevention of IE contained ambiguities and inconsistencies and were often based on minimal published data or expert opinion, they were subject to conflicting interpretations among patients, healthcare providers, and the legal system about patient eligibility for prophylaxis and whether there was strict adherence by healthcare providers to AHA recommendations for prophylaxis. This document is intended to identify which, if any, patients may possibly benefit from IE prophylaxis and to define, to the extent possible, which dental procedures should have prophylaxis in this select group of patients. Accordingly, the Committee hopes that this document will result in greater clarity for patients, healthcare providers, and consulting professionals.

The Committee believes that recommendations for IE prophylaxis must be evidence based. A placebo-controlled, multicenter, randomized, double-blinded study to evaluate the efficacy of IE prophylaxis in patients who undergo a dental, GI, or GU tract procedure has not been done. Such a study would require a large number of patients per treatment group and standardization of the specific invasive procedures and the patient populations. This type of study would be necessary to definitively answer long-standing unresolved questions regarding the efficacy of IE prophylaxis. The Committee hopes that this revised document will stimulate additional studies on the prevention of IE. Future published data will be reviewed carefully by the AHA, the Committee on Rheumatic Fever, Endocarditis, and Kawasaki Disease, and other societies, and further revisions to the present document will be based on relevant studies.

Pathogenesis of IE

The development of IE is the net result of the complex interaction between the bloodstream pathogen with matrix molecules and platelets at sites of endocardial cell damage. In addition, many of the clinical manifestations of IE emanate from the host's immune response to the infecting microorganism. The following sequence of events is thought to result in IE: formation of nonbacterial thrombotic endocarditis (NBTE) on the surface of a cardiac valve or elsewhere that endothelial damage occurs, bacteremia, adherence of the bacteria in the bloodstream to NBTE, and proliferation of bacteria within a vegetation.

Formation of NBTE

Turbulent blood flow produced by certain types of congenital or acquired heart disease, such as flow from a high- to a low-pressure chamber or across a narrowed orifice, traumatizes the endothelium. This creates a predisposition for deposition of platelets and fibrin on the surface of the endothelium, which results in NBTE. Invasion of the bloodstream with a microbial species that has the pathogenic potential to colonize this site can then result in IE.

Transient Bacteremia

Mucosal surfaces are populated by a dense endogenous microflora. Trauma to a mucosal surface, particularly the

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gingival crevice around teeth, oropharynx, GI tract, urethra, and vagina, releases many different microbial species transiently into the bloodstream. Transient bacteremia caused by viridans group streptococci and other oral microflora occurs commonly in association with dental extractions or other dental procedures or with routine daily activities. Although controversial, the frequency and intensity of the resulting bacteremias are believed to be related to the nature and magnitude of the tissue trauma, the density of the microbial flora, and the degree of inflammation or infection at the site of trauma. The microbial species entering the circulation depends on the unique endogenous microflora that colonizes the particular traumatized site.

Bacterial Adherence

The ability of various microbial species to adhere to specific sites determines the anatomic localization of infection caused by these microorganisms. Mediators of bacterial adherence serve as virulence factors in the pathogenesis of IE. Numerous bacterial surface components present in streptococci, staphylococci, and enterococci have been shown in animal models of experimental endocarditis to function as critical adhesins. Some viridans group streptococci contain a FimA protein that is a lipoprotein receptor antigen I (LraI) that serves as a major adhesin to the fibrin platelet matrix of NBTE.[17] Staphylococcal adhesins function in at least 2 ways. In one, microbial surface components recognizing adhesive matrix molecules facilitate the attachment of staphylococci to human extracellular matrix proteins and to medical devices that become coated with matrix proteins after implantation. In the other, bacterial extracellular structures contribute to the formation of biofilm that forms on the surface of implanted medical devices. In both cases, staphylococcal adhesins are important virulence factors.

Both FimA and staphylococcal adhesins are immunogenic in experimental infections. Vaccines prepared against FimA and staphylococcal adhesins provide some protective effect in experimental endocarditis caused by viridans group streptococci and staphylococci.[18,19] The results of these experimental studies are highly intriguing, because the development of an effective vaccine for use in humans to prevent viridans group streptococcal or staphylococcal IE would be of major importance.

Proliferation of Bacteria Within a Vegetation

Microorganisms adherent to the vegetation stimulate further deposition of fibrin and platelets on their surface. Within this secluded focus, the buried microorganisms multiply as rapidly as bacteria in broth cultures to reach maximal microbial densities of 10^8 to 10^{11} colony-forming units per gram of vegetation within a short time on the left side of the heart, apparently uninhibited by host defenses in left-sided lesions. Right-sided vegetations have lower bacterial densities, which may be the consequence of host defense mechanisms active at this site, such as polymorphonuclear activity or platelet-derived antibacterial proteins. More than 90% of the microorganisms in mature left- or right-sided valvular vegetations are metabolically inactive rather than in an active growth phase and are therefore less responsive to the bactericidal effects of antibiotics.[20]

Rationale for or Against Prophylaxis of IE

Historical Background

Viridans group streptococci are part of the normal skin, oral, respiratory, and GI tract flora, and they cause at least 50% of cases of community-acquired native valve IE not associated with intravenous drug use.[21] More than a century ago, the oral cavity was recognized as a potential source of the bacteremia that caused viridans group streptococcal IE. In 1885, Osler[22] noted an association between bacteremia from surgery and IE. Okell and Elliott[23] in 1935 reported that 11% of patients with poor oral hygiene had positive blood cultures with viridans group streptococci and that 61% of patients had viridans group streptococcal bacteremia with dental extraction.

As a result of these early studies and subsequent studies, during the past 50 years, the AHA guidelines recommended antimicrobial prophylaxis to prevent IE in patients with underlying cardiac conditions who underwent bacteremia-producing procedures on the basis of the following factors: (1) bacteremia causes endocarditis; (2) viridans group streptococci are part of the normal oral flora, and enterococci are part of the normal GI and GU tract flora; (3) these microorganisms were usually susceptible to antibiotics recommended for prophylaxis; (4) antibiotic prophylaxis prevents viridans group streptococcal or enterococcal experimental endocarditis in animals; (5) a large number of poorly documented case reports implicated a dental procedure as a cause of IE; (6) in some cases, there was a temporal relationship between a dental procedure and the onset of symptoms of IE; (7) an awareness of bacteremia caused by viridans group streptococci associated with a dental procedure exists; (8) the risk of significant adverse reactions to an antibiotic is low in an individual patient; and (9) morbidity and mortality from IE are high. Most of these factors remain valid, but collectively, they do not compensate for the lack of published data that demonstrate a benefit from prophylaxis.

Bacteremia-Producing Dental Procedures

The large majority of published studies have focused on dental procedures as a cause of IE and the use of prophylactic antibiotics to prevent IE in patients at risk. Few data exist on the risk of or prevention of IE associated with a GI or GU tract procedure. Accordingly, the Committee undertook a critical analysis of published data in the context of the historical rationale for recommending antibiotic prophylaxis for IE before a dental procedure. The following factors were considered: (1) frequency, nature, magnitude, and duration of bacteremia associated with dental procedures; (2) impact of dental disease, oral hygiene, and type of dental procedure on bacteremia; (3) impact of antibiotic prophylaxis on bacteremia from a dental procedure; and (4) the exposure over time of frequently occurring bacteremia from routine daily activities compared with bacteremia from various dental procedures.

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Frequency, Nature, Magnitude, and Duration of Bacteremia Associated With a Dental Procedure

Transient bacteremia is common with manipulation of the teeth and periodontal tissues, and there is a wide variation in reported frequencies of bacteremia in patients resulting from dental procedures: tooth extraction (10% to 100%), periodontal surgery (36% to 88%), scaling and root planing (8% to 80%), teeth cleaning (up to 40%), rubber dam matrix/wedge placement (9% to 32%), and endodontic procedures (up to 20%).[24–30] Transient bacteremia also occurs frequently during routine daily activities unrelated to a dental procedure, such as tooth brushing and flossing (20% to 68%), use of wooden toothpicks (20% to 40%), use of water irrigation devices (7% to 50%), and chewing food (7% to 51%).[26–29,31–36] Considering that the average person living in the United States has fewer than 2 dental visits per year, the frequency of bacteremia from routine daily activities is far greater.

There has been a disproportionate focus on the frequency of bacteremia associated with dental procedures rather than on the species of bacteria recovered from blood cultures. Studies suggest that more than 700 species of bacteria, including aerobic and anaerobic Gram-positive and Gram-negative microorganisms, may be identified in the human mouth, particularly on the teeth and in the gingival crevices.[24,37–40] Approximately 30% of the flora of the gingival crevice is streptococci, predominantly of the viridans group. Of the more than 100 oral bacterial species recovered from blood cultures after dental procedures, the most prevalent are viridans group streptococci, the most common microbiological cause of community-acquired native valve IE in non–intravenous drug users.[21] In healthy mouths, a thin surface of mucosal epithelium prevents potentially pathogenic bacteria from entering the bloodstream and lymphatic system. Anaerobic microorganisms are commonly responsible for periodontal disease and frequently enter the bloodstream but rarely cause IE, with fewer than 120 cases reported.[41] Viridans group streptococci are antagonistic to periodontal pathogens and predominate in a clean, healthy mouth.[42]

Few published studies exist on the magnitude of bacteremia after a dental procedure or from routine daily activities, and most of the published data used older, often unreliable microbiological methodology. There are no published data that demonstrate that a greater magnitude of bacteremia, compared with a lower magnitude, is more likely to cause IE in humans. The magnitude of bacteremia resulting from a dental procedure is relatively low ($<10^4$ colony-forming units of bacteria per milliliter), similar to that resulting from routine daily activities, and is less than that used to cause experimental IE in animals (10^6 to 10^8 colony-forming units of bacteria per milliliter).[20,43,44] Although the infective dose required to cause IE in humans is unknown, the number of microorganisms present in blood after a dental procedure or associated with daily activities is low. Cases of IE caused by oral bacteria probably result from the exposures to low inocula of bacteria in the bloodstream that result from routine daily activities and not from a dental procedure. Additionally, the vast majority of patients with IE have not had a dental procedure within 2 weeks before the onset of symptoms of IE.[2–4]

The role of duration of bacteremia on the risk of acquisition of IE is uncertain.[45,46] Early studies reported that sequential blood cultures were positive for up to 10 minutes after tooth extraction and that the number of positive blood cultures dropped sharply after 10 to 30 minutes.[24,45–51] More recent studies support these data but report a small percentage of positive blood cultures from 30 to 60 minutes after tooth extraction.[43,52,53] Intuitively, it seems logical to assume that the longer the duration of bacteremia, the greater the risk of IE, but no published studies support this assumption. Given the preponderance of published data, there may not be a clinically significant difference in the frequency, nature, magnitude, and duration of bacteremia associated with a dental procedure compared with that resulting from routine daily activities. Accordingly, it is inconsistent to recommend prophylaxis of IE for dental procedures but not for these same patients during routine daily activities. Such a recommendation for prophylaxis for routine daily activities would be impractical and unwarranted.

Impact of Dental Disease, Oral Hygiene, and Type of Dental Procedure on Bacteremia

It is assumed that a relationship exists between poor oral hygiene, the extent of dental and periodontal disease, the type of dental procedure, and the frequency, nature, magnitude, and duration of bacteremia, but the presumed relationship is controversial.[23,29,30,38,45,54–61] Nevertheless, available evidence supports an emphasis on maintaining good oral hygiene and eradicating dental disease to decrease the frequency of bacteremia from routine daily activities.[45,56–58,62,63] In patients with poor oral hygiene, the frequency of positive blood cultures just before dental extraction may be similar to that after extraction.[62,63]

More than 80 years ago, it was suggested that poor oral hygiene and dental disease were more important as a cause of IE than were dental procedures.[64] Most studies since that time have focused instead on the risks of bacteremia associated with dental procedures. For example, tooth extraction is thought to be the dental procedure most likely to cause bacteremia, with an incidence ranging from 10% to 100%.* However, numerous other dental procedures have been reported to be associated with risks of bacteremia that are similar to that resulting from tooth extraction.† A precise determination of the relative risk of bacteremia that results from a specific dental procedure in patients with or without dental disease is probably not possible.[27,72,73]

Bleeding often occurs during a dental procedure in patients with or without periodontal disease. Previous AHA guidelines recommended antibiotic prophylaxis for dental procedures in which bleeding was anticipated but not for procedures for which bleeding was not anticipated.[1] However, no data show that visible bleeding during a dental procedure is a reliable predictor of bacteremia.[62] These ambiguities in the previous AHA guidelines led to further uncertainties among healthcare providers about which dental procedures should be covered by prophylaxis.

*References 23, 24, 27, 29, 45, 48, 52, 54, 57, and 65–67.
†References 27, 28, 47, 51, 54, 56, 58, and 68–71.

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These factors complicated recommendations in previous AHA guidelines on prevention of IE that suggested antibiotic prophylaxis for some dental procedures but not for others. The collective published data suggest that the vast majority of dental office visits result in some degree of bacteremia; however, there is no evidence-based method to decide which procedures should require prophylaxis, because no data show that the incidence, magnitude, or duration of bacteremia from any dental procedure increase the risk of IE. Accordingly, it is not clear which dental procedures are more or less likely to cause a transient bacteremia or result in a greater magnitude of bacteremia than that which results from routine daily activities such as chewing food, tooth brushing, or flossing.

In patients with underlying cardiac conditions, lifelong antibiotic therapy is not recommended to prevent IE that might result from bacteremias associated with routine daily activities.[5] In patients with dental disease, the focus on the frequency of bacteremia associated with a specific dental procedure and the AHA guidelines for prevention of IE have resulted in an overemphasis on antibiotic prophylaxis and an underemphasis on maintenance of good oral hygiene and access to routine dental care, which are likely more important in reducing the lifetime risk of IE than the administration of antibiotic prophylaxis for a dental procedure. However, no observational or controlled studies support this contention.

Impact of Antibiotic Therapy on Bacteremia From a Dental Procedure

The ability of antibiotic therapy to prevent or reduce the frequency, magnitude, or duration of bacteremia associated with a dental procedure is controversial.[24,74] Some studies reported that antibiotics administered before a dental procedure reduced the frequency, nature, and/or duration of bacteremia,[53,75,76] whereas others did not.[24,66,77,78] Recent studies suggest that amoxicillin therapy has a statistically significant impact on reducing the incidence, nature, and duration of bacteremia from dental procedures, but it does not eliminate bacteremia.[52,53,76] However, no data show that such a reduction as a result of amoxicillin therapy reduces the risk of or prevents IE. Hall et al[78] reported that neither penicillin V nor amoxicillin therapy was effective in reducing the frequency of bacteremia compared with untreated control subjects. In patients who underwent a dental extraction, penicillin or ampicillin therapy compared with placebo diminished the percentage of viridans group streptococci and anaerobes in culture, but there was no significant difference in the percentage of patients with positive cultures 10 minutes after tooth extraction.[24,66] In a separate study, Hall et al[77] reported that cefaclor-treated patients did not have a reduction of postprocedure bacteremia compared with untreated control subjects. Contradictory published results from 2 studies showed reduction of postprocedure bacteremia by erythromycin in one[75] but lack of efficacy for erythromycin or clindamycin in another.[78] Finally, results are contradictory with regard to the efficacy of the use of topical antiseptics in reducing the frequency of bacteremia associated with dental procedures, but the preponderance of evidence suggests that there is no clear benefit. One study reported that chlorhexidine and povidone iodine mouth rinse were effective,[79] whereas others showed no statistically significant benefit.[52,80] Topical antiseptic rinses do not penetrate beyond 3 mm into the periodontal pocket and therefore do not reach areas of ulcerated tissue where bacteria most often gain entrance to the circulation. On the basis of these data, it is unlikely that topical antiseptics are effective to significantly reduce the frequency, magnitude, and duration of bacteremia associated with a dental procedure.

Cumulative Risk Over Time of Bacteremias From Routine Daily Activities Compared With the Bacteremia From a Dental Procedure

Guntheroth[81] estimated a cumulative exposure of 5370 minutes of bacteremia over a 1-month period in dentulous patients resulting from random bacteremia from chewing food and from oral hygiene measures, such as tooth brushing and flossing, and compared that with a duration of bacteremia lasting 6 to 30 minutes associated with a single tooth extraction. Roberts[62] estimated that tooth brushing 2 times daily for 1 year had a 154 000 times greater risk of exposure to bacteremia than that resulting from a single tooth extraction. The cumulative exposure during 1 year to bacteremia from routine daily activities may be as high as 5.6 million times greater than that resulting from a single tooth extraction, the dental procedure reported to be most likely to cause a bacteremia.[62]

Data exist for the duration of bacteremia from a single tooth extraction, and it is possible to estimate the annual cumulative exposure from dental procedures for the average individual. However, calculations for the incidence, nature, and duration of bacteremia from routine daily activities are at best rough estimates, and it is therefore not possible to compare precisely the cumulative monthly or annual duration of exposure for bacteremia from dental procedures compared with routine daily activities. Nevertheless, even if the estimates of bacteremia from routine daily activities are off by a factor of 1000, it is likely that the frequency and cumulative duration of exposure to bacteremia from routine daily events over 1 year are much higher than those that result from dental procedures.

Results of Clinical Studies of IE Prophylaxis for Dental Procedures

No prospective, randomized, placebo-controlled studies exist on the efficacy of antibiotic prophylaxis to prevent IE in patients who undergo a dental procedure. Data from published retrospective or prospective case-control studies are limited by the following factors: (1) the low incidence of IE, which requires a large number of patients per cohort for statistical significance; (2) the wide variation in the types and severity of underlying cardiac conditions, which would require a large number of patients with specific matched control subjects for each cardiac condition; and (3) the large variety of invasive dental procedures and dental disease states, which would be difficult to standardize for control groups. These and other limitations complicate the interpretation of the results of published studies of the efficacy of IE prophylaxis in patients who undergo dental procedures.

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Although some retrospective studies suggested that there was a benefit from prophylaxis, these studies were small in size and reported insufficient clinical data. Furthermore, in a number of cases, the incubation period between the dental procedure and the onset of symptoms of IE was prolonged.[80,82–84]

van der Meer and colleagues[85] published a study of dental procedures in the Netherlands and the efficacy of antibiotic prophylaxis to prevent IE in patients with native or prosthetic cardiac valves. They concluded that dental or other procedures probably caused only a small fraction of cases of IE and that prophylaxis would prevent only a small number of cases even if it were 100% effective. These same authors[86] performed a 2-year case-control study. Among patients for whom prophylaxis was recommended, 5 of 20 cases of IE occurred despite receiving antibiotic prophylaxis. The authors concluded that prophylaxis was not effective. In a separate study,[87] these authors reported poor awareness of recommendations for prophylaxis among both patients and healthcare providers.

Strom and colleagues[2] evaluated dental prophylaxis and cardiac risk factors in a multicenter case-control study. These authors reported that MVP, congenital heart disease (CHD), rheumatic heart disease (RHD), and previous cardiac valve surgery were risk factors for the development of IE. In that study, control subjects without IE were more likely to have undergone a dental procedure than were those with cases of IE ($P=0.03$). The authors concluded that dental treatment was not a risk factor for IE even in patients with valvular heart disease and that few cases of IE could be prevented with prophylaxis even if it were 100% effective.

These studies are in agreement with a recently published French study of the estimated risk of IE in adults with predisposing cardiac conditions who underwent dental procedures with or without antibiotic prophylaxis.[88] These authors concluded that a "huge number of prophylaxis doses would be necessary to prevent a very low number of IE cases."

Absolute Risk of IE Resulting From a Dental Procedure

No published data accurately determine the absolute risk of IE that results from a dental procedure. One study reported that 10% to 20% of patients with IE caused by oral flora underwent a preceding dental procedure (within 30 or 180 days of onset).[85] The evidence linking bacteremia associated with a dental procedure with IE is largely circumstantial, and the number of cases related to a dental procedure is overestimated for a number of reasons. For 60 years, noted opinion leaders in medicine suggested a link between bacteremia-causing dental procedures and IE,[23] and for 50 years, the AHA published regularly updated guidelines that emphasized the association between dental procedures and IE and recommended antibiotic prophylaxis.[1] Additionally, bacteremia-producing dental procedures are common; it is estimated that at least 50% of the population in the United States visits a dentist at least once a year. Furthermore, there are numerous poorly documented case reports that implicate dental procedures associated with the development of IE, but these reports did not prove a direct causal relationship. Even in the event of a close temporal relationship between a dental procedure and IE, it is not possible to determine with certainty whether the bacteremia that caused IE originated from a dental procedure or from a randomly occurring bacteremia as a result of routine daily activities during the same time period. Many case reports and reviews have included cases with a remote preceding dental procedure, often 3 to 6 months before the diagnosis of IE. Studies suggest that the time frame between bacteremia and the onset of symptoms of IE is usually 7 to 14 days for viridans group streptococci or enterococci. Reportedly, 78% of such cases of IE occur within 7 days of bacteremia and 85% within 14 days.[89] Although the upper time limit is not known, it is likely that many cases of IE with incubation periods longer than 2 weeks after a dental procedure were incorrectly attributed to the procedure. These and other factors have led to a heightened awareness among patients and healthcare providers of the possible association between dental procedures and IE, which likely has led to substantial overreporting of cases attributable to dental procedures.

Although the absolute risk for IE from a dental procedure is impossible to measure precisely, the best available estimates are as follows: If dental treatment causes 1% of all cases of viridans group streptococcal IE annually in the United States, the overall risk in the general population is estimated to be as low as 1 case of IE per 14 million dental procedures.[41,90,91] The estimated absolute risk rates for IE from a dental procedure in patients with underlying cardiac conditions are as follows: MVP, 1 per 1.1 million procedures; CHD, 1 per 475 000; RHD, 1 per 142 000; presence of a prosthetic cardiac valve, 1 per 114 000; and previous IE, 1 per 95 000 dental procedures.[41,91] Although these calculations of risk are estimates, it is likely that the number of cases of IE that result from a dental procedure is exceedingly small. Therefore, the number of cases that could be prevented by antibiotic prophylaxis, even if 100% effective, is similarly small. One would not expect antibiotic prophylaxis to be near 100% effective, however, because of the nature of the organisms and choice of antibiotics.

Risk of Adverse Reactions and Cost-Effectiveness of Prophylactic Therapy

Nonfatal adverse reactions, such as rash, diarrhea, and GI upset, occur commonly with the use of antimicrobials; however, only single-dose therapy is recommended for dental prophylaxis, and these common adverse reactions are usually not severe and are self-limited. Fatal anaphylactic reactions were estimated to occur in 15 to 25 individuals per 1 million patients who receive a dose of penicillin.[92,93] Among patients with a prior penicillin use, 36% of fatalities from anaphylaxis occurred in those with a known allergy to penicillin compared with 64% of fatalities among those with no history of penicillin allergy.[94] These calculations are at best rough estimates and may overestimate the true risk of death caused by fatal anaphylaxis from administration of a penicillin. They are based on retrospective reviews or surveys of patients or on healthcare providers' recall of events. A prospective study is necessary to accurately determine the risk of fatal anaphylaxis resulting from administration of a penicillin.

For 50 years, the AHA has recommended a penicillin as the preferred choice for dental prophylaxis for IE. During these

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50 years, the Committee is unaware of any cases reported to the AHA of fatal anaphylaxis resulting from the administration of a penicillin recommended in the AHA guidelines for IE prophylaxis. The Committee believes that a single dose of amoxicillin or ampicillin is safe and is the preferred prophylactic agent for individuals who do not have a history of type I hypersensitivity reaction to a penicillin, such as anaphylaxis, urticaria, or angioedema. Fatal anaphylaxis from a cephalosporin is estimated to be less common than from penicillin, at approximately 1 case per 1 million patients.[95] Fatal reactions to a single dose of a macrolide or clindamycin are extremely rare.[96,97] There has been only 1 case report of documented *Clostridium difficile* colitis after a single dose of prophylactic clindamycin.[98]

Summary

Although it has long been assumed that dental procedures may cause IE in patients with underlying cardiac risk factors and that antibiotic prophylaxis is effective, scientific proof is lacking to support these assumptions. The collective published evidence suggests that of the total number of cases of IE that occur annually, it is likely that an exceedingly small number are caused by bacteremia-producing dental procedures. Accordingly, only an extremely small number of cases of IE might be prevented by antibiotic prophylaxis even if it were 100% effective. The vast majority of cases of IE caused by oral microflora most likely result from random bacteremias caused by routine daily activities, such as chewing food, tooth brushing, flossing, use of toothpicks, use of water irrigation devices, and other activities. The presence of dental disease may increase the risk of bacteremia associated with these routine activities. There should be a shift in emphasis away from a focus on a dental procedure and antibiotic prophylaxis toward a greater emphasis on improved access to dental care and oral health in patients with underlying cardiac conditions associated with the highest risk of adverse outcome from IE and those conditions that predispose to the acquisition of IE.

Cardiac Conditions and Endocarditis

Previous AHA guidelines categorized underlying cardiac conditions associated with the risk of IE as those with high risk, moderate risk, and negligible risk and recommended prophylaxis for patients in the high- and moderate-risk categories.[1] For the present guidelines on prevention of IE, the Committee considered 3 distinct issues: (1) What underlying cardiac conditions over a lifetime have the highest predisposition to the acquisition of endocarditis? (2) What underlying cardiac conditions are associated with the highest risk of adverse outcome from endocarditis? (3) Should recommendations for IE prophylaxis be based on either or both of these 2 conditions?

Underlying Conditions Over a Lifetime That Have the Highest Predisposition to the Acquisition of Endocarditis

In Olmsted County, Minnesota, the incidence of IE in adults ranged from 5 to 7 cases per 100 000 person-years.[99] This incidence has remained stable during the past 4 decades and is similar to that reported in other studies.[100–103] Previously, RHD was the most common underlying condition predisposing to endocarditis, and RHD is still common in developing countries.[99] In developed countries, the frequency of RHD has declined, and MVP is now the most common underlying condition in patients with endocarditis.[104]

Few published data quantitate the lifetime risk of acquisition of IE associated with a specific underlying cardiac condition. Steckelberg and Wilson[90] reported the lifetime risk of acquisition of IE, which ranged from 5 per 100 000 patient-years in the general population with no known cardiac conditions to 2160 per 100 000 patient-years in patients who underwent replacement of an infected prosthetic cardiac valve. In that study,[90] the risk of IE per 100 000 patient-years was 4.6 in patients with MVP without an audible cardiac murmur and 52 in patients with MVP with an audible murmur of mitral regurgitation. Per 100 000 patient-years, the lifetime risk (380 to 440) for RHD was similar to that (308 to 383) for patients with a mechanical or bioprosthetic cardiac valve. The highest lifetime risks per 100 000 patient-years were as follows: cardiac valve replacement surgery for native valve IE, 630; previous IE, 740; and prosthetic valve replacement done in patients with prosthetic valve endocarditis, 2160. In a separate study, the risk of IE per 100 000 patient-years was 271 in patients with congenital aortic stenosis and 145 in patients with ventricular septal defect.[105] In that same study, the risk of IE before closure of a ventricular septal defect was more than twice that after closure. Although these data provide useful ranges of risk in large populations, it is difficult to utilize them to define accurately the lifetime risk of acquisition of IE in an individual patient with a specific underlying cardiac risk factor. This difficulty is based in part on the fact that each individual cardiac condition, such as RHD or MVP, represents a broad spectrum of pathology from minimal to severe, and the risk of IE would likely be influenced by the severity of valvular disease.

CHD is another underlying condition with multiple different cardiac abnormalities that range from relatively minor to severe, complex cyanotic heart disease. During the past 25 years, there has been an increasing use of various intracardiac valvular prostheses and intravascular shunts, grafts, and other devices for repair of valvular heart disease and CHD. The diversity and nature of these prostheses and procedures likely present different levels of risk for acquisition of IE. These factors complicate an accurate assessment of the true lifetime risk of acquisition of IE in patients with a specific underlying cardiac condition.

On the basis of the data from Steckelberg and Wilson[91] and others,[2] it is clear that the underlying conditions discussed above represent a lifetime increased risk of acquisition of IE compared with individuals with no known underlying cardiac condition. Accordingly, when utilizing previous AHA guidelines in the decision to recommend IE prophylaxis for a patient scheduled to undergo a dental, GI tract, or GU tract procedure, healthcare providers were required to base their decision on population-based studies of risk of acquisition of IE that may or may not be relevant to their specific patient. Furthermore, practitioners had to weigh the potential efficacy of IE prophylaxis in a patient who may neither need nor

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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 IE
Congenital heart disease (CHD)*
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 months after the procedure†
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

*Except for the conditions listed above, antibiotic prophylaxis is no longer recommended for any other form of CHD.

†Prophylaxis is reasonable because endothelialization of prosthetic material occurs within 6 months after the procedure.

benefit from such therapy against the risk of adverse reaction to the antibiotic prescribed. Finally, healthcare providers had to consider the potential medicolegal risk of not prescribing IE prophylaxis. For dental procedures, there is a growing body of evidence that suggests that IE prophylaxis may prevent only an exceedingly small number of cases of IE, as discussed in detail above.

Cardiac Conditions Associated With the Highest Risk of Adverse Outcome From Endocarditis

Endocarditis, irrespective of the underlying cardiac condition, is a serious, life-threatening disease that was always fatal in the preantibiotic era. Advances in antimicrobial therapy, early recognition and management of complications of IE, and improved surgical technology have reduced the morbidity and mortality of IE. Numerous comorbid factors, such as older age, diabetes mellitus, immunosuppressive conditions or therapy, and dialysis, may complicate IE. Each of these comorbid conditions independently increases the risk of adverse outcome from IE, and they often occur in combination, which further increases morbidity and mortality rates. Additionally, there may be long-term consequences of IE. Over time, the cardiac valve damaged by IE may undergo progressive functional deterioration that may result in the need for cardiac valve replacement.

In native valve viridans group streptococcal or enterococcal IE, the spectrum of disease may range from a relatively benign infection to severe valvular dysfunction, dehiscence, congestive heart failure, multiple embolic events, and death; however, the underlying conditions shown in Table 3 virtually always have an increased risk of adverse outcome. For example, patients with viridans group streptococcal prosthetic valve endocarditis have a mortality rate of ≈20% or greater,[106–109] whereas the mortality from patients with viridans group streptococcal native valve IE is 5% or less.[108,110–116] Similarly, the mortality of enterococcal prosthetic valve endocarditis is higher than that of native valve enterococcal IE.[107,108,114,117] Moreover, patients with prosthetic valve endocarditis are more likely than those with native valve endocarditis to develop heart failure, the need for cardiac valve replacement surgery, perivalvular extension of infection, and other complications.

Patients with relapsing or recurrent IE are at greater risk of congestive heart failure and increased need for cardiac valve replacement surgery, and they have a higher mortality rate than patients with a first episode of native valve IE.[118–124] Additionally, patients with multiple episodes of native or prosthetic valve IE are at greater risk of additional episodes of endocarditis, each of which is associated with the risk of more serious complications.[90]

Published series regarding endocarditis in patients with CHD are underpowered to determine the extent to which a specific form of CHD is an independent risk factor for morbidity and mortality. Nevertheless, most retrospective case series suggest that patients with complex cyanotic heart disease and those who have postoperative palliative shunts, conduits, or other prostheses have a high lifetime risk of acquiring IE, and these same groups appear at highest risk for morbidity and mortality among all patients with CHD.[125–129] In addition, multiple series and reviews reported that the presence of prosthetic material[130,131] and complex cyanotic heart disease in patients of very young age (newborns and infants <2 years of age)[132,133] are 2 factors associated with the worst prognoses from IE. Some types of CHD may be repaired completely without residual cardiac defects. As shown in Table 3, the Committee concludes that prophylaxis is reasonable for dental procedures for these patients during the first 6 months after the procedure. In these patients, endothelialization of prosthetic material or devices occurs within 6 months after the procedure.[134] The Committee does not recommend prophylaxis for dental procedures more than 6 months after the procedure provided that there is no residual defect from the repair. In most instances, treatment of patients who have infected prosthetic materials requires surgical removal in addition to medical therapy with associated high morbidity and mortality rates.

Should IE Prophylaxis Be Recommended for Patients With the Highest Risk of Acquisition of IE or for Patients With the Highest Risk of Adverse Outcome From IE?

In a major departure from previous AHA guidelines, the Committee no longer recommends IE prophylaxis based solely on an increased lifetime risk of acquisition of IE. It is noteworthy that patients with the conditions listed in Table 3 with a prosthetic cardiac valve, those with a previous episode of IE, and some patients with CHD are also among those patients with the highest lifetime risk of acquisition of endocarditis. No published data demonstrate convincingly that the administration of prophylactic antibiotics prevents IE associated with bacteremia from an invasive procedure. We cannot exclude the possibility that there may be an exceedingly small number of cases of IE that could be prevented by prophylactic antibiotics in patients who undergo an invasive procedure. However, if prophylaxis is effective, such therapy should be restricted to those patients with the highest risk of adverse outcome from IE who would derive the greatest benefit from prevention of IE. In patients with underlying cardiac conditions associated with the highest risk of adverse outcome from IE (Table 3), IE prophylaxis for dental proce-

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dures is reasonable, even though we acknowledge that its effectiveness is unknown (***Class IIa, LOE B***).

Compared with previous AHA guidelines, under these revised guidelines, many fewer patients would be candidates to receive IE prophylaxis. We believe that these revised guidelines are in the best interest of patients and healthcare providers and are based on the best available published data and expert opinion. Additionally, the change in emphasis to restrict prophylaxis for only those patients with the highest risk of adverse outcome should reduce the uncertainties among patients and providers about who should receive prophylaxis. MVP is the most common underlying condition that predisposes to acquisition of IE in the Western world; however, the absolute incidence of endocarditis is extremely low for the entire population with MVP, and it is not usually associated with the grave outcome associated with the conditions identified in Table 3. Thus, IE prophylaxis is no longer recommended for this group of individuals.

Finally, the administration of prophylactic antibiotics is not risk free, as discussed above. Additionally, the widespread use of antibiotic therapy promotes the emergence of resistant microorganisms most likely to cause endocarditis, such as viridans group streptococci and enterococci. The frequency of multidrug-resistant viridans group streptococci and enterococci has increased dramatically during the past 2 decades. This increased resistance has reduced the efficacy and number of antibiotics available for the treatment of IE.

Antibiotic Regimens

General Principles

An antibiotic for prophylaxis should be administered in a single dose before the procedure. If the dosage of antibiotic is *inadvertently* not administered before the procedure, the dosage may be administered up to 2 hours after the procedure. However, administration of the dosage after the procedure should be considered only when the patient did not receive the pre-procedure dose. Some patients who are scheduled for an invasive procedure may have a coincidental endocarditis. The presence of fever or other manifestations of systemic infection should alert the provider to the possibility of IE. In these circumstances, it is important to obtain blood cultures and other relevant tests before administration of antibiotics intended to prevent IE. Failure to do so may result in delay in diagnosis or treatment of a concomitant case of IE.

Regimens for Dental Procedures

Previous AHA guidelines on prophylaxis listed a substantial number of dental procedures and events for which antibiotic prophylaxis was recommended and those procedures for which prophylaxis was not recommended. On the basis of a critical review of the published data, it is clear that transient viridans group streptococcal bacteremia may result from any dental procedure that involves manipulation of the gingival or periapical region of teeth or perforation of the oral mucosa. It cannot be assumed that manipulation of a healthy-appearing mouth or a minimally invasive dental procedure reduces the likelihood of a bacteremia. Therefore, antibiotic prophylaxis is reasonable for patients with the conditions listed in Table 3 who undergo any dental procedure that involves the gingival tissues or periapical region of a tooth and for those procedures that perforate the oral mucosa (Table 4). Although IE prophylaxis is reasonable for these patients, its effectiveness is unknown (***Class IIa, LOE C***). This includes procedures such as biopsies, suture removal, and placement of orthodontic bands, but it does not include routine anesthetic injections through noninfected tissue, the taking of dental radiographs, placement of removable prosthodontic or orthodontic appliances, placement of orthodontic brackets, or adjustment of orthodontic appliances. Finally, there are other events that are not dental procedures and for which prophylaxis is not recommended, such as shedding of deciduous teeth and trauma to the lips and oral mucosa.

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*

*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.

In this limited patient population, prophylactic antimicrobial therapy should be directed against viridans group streptococci. During the past 2 decades, there has been a significant increase in the percentage of strains of viridans group streptococci resistant to antibiotics recommended in previous AHA guidelines for the prevention of IE. Prabhu et al[135] studied susceptibility patterns of viridans group streptococci recovered from patients with IE diagnosed during a period from 1971 to 1986 and compared these susceptibilities with those of viridans group streptococci from patients with IE diagnosed from 1994 to 2002. In that study, none of the strains of viridans group streptococci were penicillin resistant in the early time period compared with 13% of strains that were intermediately or fully penicillin resistant during the later time period. In that study, macrolide resistance increased from 11% to 26% and clindamycin resistance from 0% to 4%.

Among 352 blood culture isolates of viridans group streptococci, resistance rates were 13% for penicillin, 15% for amoxicillin, 17% for ceftriaxone, 38% for erythromycin, and 96% for cephalexin.[136] The rank order of decreasing level of activity of cephalosporins in that study was cefpodoxime equal to ceftriaxone, greater than cefprozil, and equal to cefuroxime, and cephalexin was the least active. In other studies, resistance of viridans group streptococci to penicillin ranged from 17% to 50%[137–142] and resistance to ceftriaxone ranged from 22% to 42%.[131,140] Ceftriaxone was 2 to 4 times more active in vitro than cefazolin.[131,140] Similarly high rates of resistance were reported for macrolides, ranging from 22% to 58%[137,141,143,144]; resistance to clindamycin ranged from 13% to 27%.[128,129,131,137,138,140]

Most of the strains of viridans group streptococci in the above-cited studies were recovered from patients with serious underlying illnesses, including malignancies and febrile neutropenia. These patients are at increased risk of infection and colonization by multiple-drug–resistant microorganisms, including viridans group streptococci. Accordingly, these

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Table 5. Regimens for a Dental Procedure

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*†	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†	1 g IM or IV	50 mg/kg IM or IV
	OR		
	Clindamycin	600 mg IM or IV	20 mg/kg IM or IV

IM indicates intramuscular; IV, intravenous.

*Or other first- or second-generation oral cephalosporin in equivalent adult or pediatric dosage.

†Cephalosporins should not be used in an individual with a history of anaphylaxis, angioedema, or urticaria with penicillins or ampicillin.

strains may not be representative of susceptibility patterns of viridans group streptococci recovered from presumably normal individuals who undergo a dental procedure. Diekema et al[137] reported that 32% of strains of viridans group streptococci were resistant to penicillin in patients without cancer. King et al[144] reported erythromycin resistance in 41% of streptococci recovered from throat cultures in otherwise healthy individuals who presented with mild respiratory tract infections. In that study, after treatment with either azithromycin or clindamycin, the percentage of resistant streptococci increased to 82% and 71%, respectively. Accordingly, the resistance rates of viridans group streptococci are similarly high in otherwise healthy individuals and in patients with serious underlying diseases.

The impact of viridans group streptococcal resistance on antibiotic prevention of IE is unknown. If resistance in vitro is predictive of lack of clinical efficacy, the high resistance rates of viridans group streptococci provide additional support for the assertion that prophylactic therapy for a dental procedure is of little, if any, value. It is impractical to recommend prophylaxis with only those antibiotics, such as vancomycin or a fluoroquinolone, that are highly active in vitro against viridans group streptococci. There is no evidence that such therapy is effective for prophylaxis of IE, and their use might result in the development of resistance of viridans group streptococci and other microorganisms to these and other antibiotics.

In Table 5, amoxicillin is the preferred choice for oral therapy because it is well absorbed in the GI tract and provides high and sustained serum concentrations. For individuals who are allergic to penicillins or amoxicillin, the use of cephalexin or another first-generation oral cephalosporin, clindamycin, azithromycin, or clarithromycin is recommended. Even though cephalexin was less active against viridans group streptococci than other first-generation oral cephalosporins in 1 study,[136] cephalexin is included in Table 5. No data show superiority of 1 oral cephalosporin over another for prevention of IE, and generic cephalexin is widely available and relatively inexpensive. Because of possible cross-reactions, a cephalosporin should not be administered to patients with a history of anaphylaxis, angioedema, or urticaria after treatment with any form of penicillin, including ampicillin or amoxicillin. Patients who are unable to tolerate an oral antibiotic may be treated with ampicillin, ceftriaxone, or cefazolin administered intramuscularly or intravenously. For ampicillin-allergic patients who are unable to tolerate an oral agent, therapy is recommended with parenteral cefazolin, ceftriaxone, or clindamycin.

Regimens for Respiratory Tract Procedures

A variety of respiratory tract procedures reportedly cause transient bacteremia with a wide array of microorganisms[1]; however, no published data conclusively demonstrate a link between these procedures and IE. Antibiotic prophylaxis with a regimen listed in Table 5 is reasonable (***Class IIa, LOE C***) for patients with the conditions listed in Table 3 who undergo an invasive procedure of the respiratory tract that involves incision or biopsy of the respiratory mucosa, such as tonsillectomy and adenoidectomy. We do not recommend antibiotic prophylaxis for bronchoscopy unless the procedure involves incision of the respiratory tract mucosa. For patients listed in Table 3 who undergo an invasive respiratory tract procedure to treat an established infection, such as drainage of an abscess or empyema, we recommend that the antibiotic regimen administered to these patients contain an agent active against viridans group streptococci (Table 5). If the infection is known or suspected to be caused by *Staphylococcus aureus*, the regimen should contain an agent active against *S aureus*, such as an antistaphylococcal penicillin or cephalosporin, or vancomycin in patients unable to tolerate a β-lactam. Vancomycin should be administered if the infection is known or suspected to be caused by a methicillin-resistant strain of *S aureus*.

Recommendations for GI or GU Tract Procedures

Enterococci are part of the normal flora of the GI tract. These microorganisms may cause intra-abdominal infection or infection of the hepatobiliary system. Such infections are often polymicrobial, with a mix of aerobic and anaerobic Gram-negative and Gram-positive microorganisms, but among these varied bacteria, only enterococci are likely to cause IE. Enterococci may cause urinary

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tract infections, particularly in older males with prostatic hypertrophy and obstructive uropathy or prostatitis.

The administration of prophylactic antibiotics solely to prevent endocarditis is not recommended for patients who undergo GU or GI tract procedures, including diagnostic esophagogastroduodenoscopy or colonoscopy (***Class III, LOE B***). This is in contrast to previous AHA guidelines that listed GI or GU tract procedures for which IE prophylaxis was recommended and those for which prophylaxis was not recommended.[1] A large number of diagnostic and therapeutic procedures that involve the GI, hepatobiliary, or GU tract may cause transient enterococcal bacteremia. The possible association between GI or GU tract procedures and IE has not been studied as extensively as the possible association with dental procedures.[145] The cases of IE temporally associated with a GI or GU tract procedure are anecdotal, with either a single or very small number of cases reported.[83] No published data demonstrate a conclusive link between procedures of the GI or GU tract and the development of IE.[145] Moreover, no studies exist that demonstrate that the administration of antimicrobial prophylaxis prevents IE in association with procedures performed on the GI or GU tract.

There has been a dramatic increase in the frequency of antimicrobial-resistant strains of enterococci to penicillins, vancomycin, and aminoglycosides.[146–151] These antibiotics were recommended for IE prophylaxis in previous AHA guidelines.[1] The significance of the increased frequency of multiresistant strains of enterococci on prevention of IE in patients who undergo GI or GU tract procedures is unknown. The high prevalence of resistant strains of enterococci adds further doubt about the efficacy of prophylactic therapy for GI or GU tract procedures.

Patients with infections of the GI or GU tract may have intermittent or sustained enterococcal bacteremia. For patients with the conditions listed in Table 3 who have an established GI or GU tract infection or for those who receive antibiotic therapy to prevent wound infection or sepsis associated with a GI or GU tract procedure, it may be reasonable that the antibiotic regimen include an agent active against enterococci, such as penicillin, ampicillin, piperacillin, or vancomycin (***Class IIb, LOE B***); however, no published studies demonstrate that such therapy would prevent enterococcal IE.

For patients with the conditions listed in Table 3 scheduled for an elective cystoscopy or other urinary tract manipulation who have an enterococcal urinary tract infection or colonization, antibiotic therapy to eradicate enterococci from the urine before the procedure may be reasonable (***Class IIb, LOE B***). If the urinary tract procedure is not elective, it may be reasonable that the empiric or specific antimicrobial regimen administered to the patient contain an agent active against enterococci (***Class IIb, LOE B***).

Amoxicillin or ampicillin is the preferred agent for enterococcal coverage for these patients. Vancomycin may be administered to patients unable to tolerate ampicillin. If infection is caused by a known or suspected strain of resistant enterococcus, consultation with an infectious diseases expert is recommended.

Table 6. Summary of Major Changes in Updated Document

We concluded that bacteremia resulting from daily activities is much more likely to cause IE than bacteremia associated with a dental procedure.
We concluded that only an extremely small number of cases of IE might be prevented by antibiotic prophylaxis even if prophylaxis is 100% effective.
Antibiotic prophylaxis is not recommended based solely on an increased lifetime risk of acquisition of IE.
Limit recommendations for IE prophylaxis only to those conditions listed in Table 3.
Antibiotic prophylaxis is no longer recommended for any other form of CHD, except for the conditions listed in Table 3.
Antibiotic prophylaxis is reasonable for all dental procedures that involve manipulation of gingival tissues or periapical region of teeth or perforation of oral mucosa only for patients with underlying cardiac conditions associated with the highest risk of adverse outcome from IE (Table 3).
Antibiotic prophylaxis is reasonable for procedures on respiratory tract or infected skin, skin structures, or musculoskeletal tissue only for patients with underlying cardiac conditions associated with the highest risk of adverse outcome from IE (Table 3).
Antibiotic prophylaxis solely to prevent IE is not recommended for GU or GI tract procedures.
Although these guidelines recommend changes in indications for IE prophylaxis with regard to selected dental procedures (see text), the writing group reaffirms that those medical procedures listed as not requiring IE prophylaxis in the 1997 statement remain unchanged and extends this view to vaginal delivery, hysterectomy, and tattooing. Additionally, the committee advises against body piercing for patients with conditions listed in Table 3 because of the possibility of bacteremia, while recognizing that there are minimal published data regarding the risk of bacteremia or endocarditis associated with body piercing.

Regimens for Procedures on Infected Skin, Skin Structure, or Musculoskeletal Tissue

These infections are often polymicrobial, but only staphylococci and β-hemolytic streptococci are likely to cause IE. For patients with the conditions listed in Table 3 who undergo a surgical procedure that involves infected skin, skin structure, or musculoskeletal tissue, it may be reasonable that the therapeutic regimen administered for treatment of the infection contain an agent active against staphylococci and β-hemolytic streptococci, such as an antistaphylococcal penicillin or a cephalosporin (Table 5 for dosage; ***Class IIb, LOE C***). Vancomycin or clindamycin may be administered to patients unable to tolerate a β-lactam or who are known or suspected to have an infection caused by a methicillin-resistant strain of staphylococcus.

A summary of the major changes in these updated recommendations for prevention of IE compared with previous AHA recommendations is shown in Table 6.

Specific Situations and Circumstances

Patients Already Receiving Antibiotics

If a patient is already receiving long-term antibiotic therapy with an antibiotic that is also recommended for IE prophylaxis for a dental procedure, it is prudent to select an antibiotic from a different class rather than to increase the dosage of the current antibiotic. For example, antibiotic regimens used to prevent the recurrence of acute rheumatic fever are administered in dosages lower than those recommended for the prevention of IE. Individuals who take an oral

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penicillin for secondary prevention of rheumatic fever or for other purposes are likely to have viridans group streptococci in their oral cavity that are relatively resistant to penicillin or amoxicillin. In such cases, the provider should select either clindamycin, azithromycin, or clarithromycin for IE prophylaxis for a dental procedure, but only for patients shown in Table 3. Because of possible cross-resistance of viridans group streptococci with cephalosporins, this class of antibiotics should be avoided. If possible, it would be preferable to delay a dental procedure until at least 10 days after completion of the antibiotic therapy. This may allow time for the usual oral flora to be reestablished.

Patients receiving parenteral antibiotic therapy for IE may require dental procedures during antimicrobial therapy, particularly if subsequent cardiac valve replacement surgery is anticipated. In these cases, the parenteral antibiotic therapy for IE should be continued and the timing of the dosage adjusted to be administered 30 to 60 minutes before the dental procedure. This parenteral antimicrobial therapy is administered in such high doses that the high concentration would overcome any possible low-level resistance developed among mouth flora (unlike the concentration that would occur after oral administration).

Patients Who Receive Anticoagulants

Intramuscular injections for IE prophylaxis should be avoided in patients who are receiving anticoagulant therapy (***Class I, LOE A***). In these circumstances, orally administered regimens should be given whenever possible. Intravenously administered antibiotics should be used for patients who are unable to tolerate or absorb oral medications.

Patients Who Undergo Cardiac Surgery

A careful preoperative dental evaluation is recommended so that required dental treatment may be completed whenever possible before cardiac valve surgery or replacement or repair of CHD. Such measures may decrease the incidence of late prosthetic valve endocarditis caused by viridans group streptococci.

Patients who undergo surgery for placement of prosthetic heart valves or prosthetic intravascular or intracardiac materials are at risk for the development of infection.[152] Because the morbidity and mortality of infection in these patients are high, perioperative prophylactic antibiotics are recommended (***Class I, LOE B***). Early-onset prosthetic valve endocarditis is most often caused by *S aureus*, coagulase-negative staphylococci, or diphtheroids. No single antibiotic regimen is effective against all these microorganisms. Prophylaxis at the time of cardiac surgery should be directed primarily against staphylococci and should be of short duration. A first-generation cephalosporin is most often used, but the choice of an antibiotic should be influenced by the antibiotic susceptibility patterns at each hospital. For example, a high prevalence of infection by methicillin-resistant *S aureus* should prompt the consideration of the use of vancomycin for perioperative prophylaxis. The majority of nosocomial coagulase-negative staphylococci are methicillin-resistant. Nonetheless, surgical prophylaxis with a first-generation cephalosporin may be recommended for these patients (***Class I, LOE A***).[107] In hospitals with a high prevalence of methicillin-resistant strains of *S epidermidis*, surgical prophylaxis with vancomycin may be reasonable but has not been shown to be superior to prophylaxis with a cephalosporin (***Class IIb, LOE C***). Prophylaxis should be initiated immediately before the operative procedure, repeated during prolonged procedures to maintain serum concentrations intraoperatively, and continued for no more than 48 hours postoperatively to minimize emergence of resistant microorganisms (***Class IIa, LOE B***). The effects of cardiopulmonary bypass and compromised renal function on antibiotic concentrations in serum should be considered and dosages adjusted as necessary before and during the procedure.

Other Considerations

There is no evidence that coronary artery bypass graft surgery is associated with a long-term risk for infection. Therefore, antibiotic prophylaxis for dental procedures is not needed for individuals who have undergone this surgery. Antibiotic prophylaxis for dental procedures is not recommended for patients with coronary artery stents (***Class III, LOE C***). The treatment and prevention of infection for these and other endovascular grafts and prosthetic devices are addressed in a separate AHA publication.[152] There are insufficient data to support specific recommendations for patients who have undergone heart transplantation. Such patients are at risk of acquired valvular dysfunction, especially during episodes of rejection. Endocarditis that occurs in a heart transplant patient is associated with a high risk of adverse outcome (Table 3).[153] Accordingly, the use of IE prophylaxis for dental procedures in cardiac transplant recipients who develop cardiac valvulopathy is reasonable, but the usefulness is not well established (***Class IIa, LOE C***; Table 4). The use of prophylactic antibiotics to prevent infection of joint prostheses during potentially bacteremia-inducing procedures is not within the scope of this document.

Future Considerations

Prospective placebo-controlled, double-blinded studies of antibiotic prophylaxis of IE in patients who undergo a bacteremia-producing procedure would be necessary to evaluate accurately the efficacy of IE prophylaxis. Additional prospective case-control studies are needed. The AHA has made substantial revisions to previously published guidelines on IE prophylaxis. Given our current recommendations, we anticipate that significantly fewer patients will receive IE prophylaxis for a dental procedure. Studies are necessary to monitor the effects, if any, of these recommended changes in IE prophylaxis. The incidence of IE could change or stay the same. Because the incidence of IE is low, small changes in incidence may take years to detect. Accordingly, we urge that such studies be designed and instituted promptly so that any change in incidence may be detected sooner rather than later. Subsequent revisions of the AHA guidelines on the preven-tion of IE will be based on the results of these studies and other published data.

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*Modest.

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*Modest.

†Significant.

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Correction

In the AHA Guideline by Wilson et al, "Prevention of Infective Endocarditis: Guidelines From the American Heart Association: A Guideline From the American Heart Association Rheumatic Fever, Endocarditis, and Kawasaki Disease Committee, Council on Cardiovascular Disease in the Young, and the Council on Clinical Cardiology, Council on Cardiovascular Surgery and Anesthesia, and the Quality of Care and Outcomes Research Interdisciplinary Working Group," that published online on April 19, 2007 (DOI: 10.1161/CIRCULATIONAHA.106.183095), several changes are needed. After online publication of these guidelines, the writing group was made aware that there was confusion among the readership regarding the use of the language "Recommended" in the title of Tables 3 and 4 and "may be reasonable" or "may be considered" in the text when referring to our Class IIb recommendations. The writing group has clarified this by revising the wording in the tables and changing the language in the text to "is reasonable." According to existing American Heart Association policy for wording of classes of recommendations, this change in language is accompanied by a shift in the class of recommendation from IIb to IIa as detailed in the errata.

1. Since the online publication of this article, the American Academy of Pediatrics and the International Society of Chemotherapy for Infection and Cancer* have added their endorsements.
2. On page 1736, in the footnotes section, the following footnote applies to the endorsement by the International Society of Chemotherapy for Infection and Cancer: "*If these guidelines are applied outside of the United States of America, adaptation of the recommended antibiotic agents may be considered with respect to the regional situation."
3. On page 1737, in the Conclusions part of the abstract, the following items have been modified: "(2) Infective endocarditis prophylaxis for dental procedures is reasonable only for patients with underlying cardiac conditions associated with the highest risk of adverse outcome from infective endocarditis. (3) For patients with these underlying cardiac conditions, prophylaxis is reasonable for all dental procedures that involve manipulation of gingival tissue or the periapical region of teeth or perforation of the oral mucosa."
4. In Table 3 on page 1745, the following items have been modified:
   a. The title now reads: "Cardiac Conditions Associated With the Highest Risk of Adverse Outcome From Endocarditis for Which Prophylaxis With Dental Procedures Is Reasonable"
   b. The first entry now reads: "Prosthetic cardiac valve or prosthetic material used for cardiac valve repair"
   c. The second footnote now reads: "†Prophylaxis is reasonable because endothelialization of prosthetic material occurs within 6 months after the procedure."
5. On page 1745, second column, second paragraph, the fifth sentence has been modified to read: "As shown in Table 3, the Committee concludes that prophylaxis is reasonable for dental procedures for these patients during the first 6 months after the procedure."
6. On page 1745, second column, third paragraph, the last sentence has been modified to read: "In patients with underlying cardiac conditions associated with the highest risk of adverse outcome from IE (Table 3), IE prophylaxis for dental procedures is reasonable, even though we acknowledge that its effectiveness is unknown (***Class IIa, LOE B***)."
7. On page 1746, first column, first full paragraph, the third sentence has been modified to read: "Additionally, the change in emphasis to restrict prophylaxis for only those patients with the highest risk of adverse outcome should reduce the uncertainties among patients and providers about who should receive. . .."
8. On page 1746, first column, the section heading has been modified from "Regimens Recommended" to "Antibiotic Regimens."

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9. On page 1746, first column, fourth paragraph, the fourth and fifth sentences have been modified to read: "Therefore, antibiotic prophylaxis is reasonable for patients with the conditions listed in Table 3 who undergo any dental procedure that involves the gingival tissues or periapical region of a tooth and for those procedures that perforate the oral mucosa (Table 4). Although IE prophylaxis is reasonable for these patients, its effectiveness is unknown (***Class IIa, LOE C***)."
10. For Table 4 on page 1746, the title has been changed to: "Dental Procedures for Which Endocarditis Prophylaxis Is Reasonable for Patients in Table 3."
11. On page 1747, second column, under the "Regimens for Respiratory Tract Procedures" heading, the second sentence has been modified to read: "Antibiotic prophylaxis with a regimen listed in Table 5 is reasonable (***Class IIa, LOE C***) for patients with the conditions listed in Table 3 who undergo an invasive procedure of the respiratory tract that involves incision or biopsy of the respiratory mucosa, such as tonsillectomy and adenoidectomy."
12. In Table 6 on page 1748, the following items have been updated:
    a. The sixth entry should read: "Antibiotic prophylaxis is reasonable for all dental procedures that involve manipulation of gingival tissues. . . ."
    b. The seventh entry should read: "Antibiotic prophylaxis is reasonable for procedures on respiratory tract or infected skin, skin structures, or musculoskeletal. . .."
    c. The last entry should read: "Although these guidelines recommend changes in indications for IE prophylaxis with regard to selected dental procedures (see text), the writing group reaffirms that those medical procedures listed as not requiring IE prophylaxis in the 1997 statement remain unchanged and extends this view to vaginal delivery and hysterectomy and tattooing. Additionally, the committee advises against body piercing for patients in Table 3 because of the possibility of bacteremia, while recognizing there are minimal published data regarding the risk of bacteremia or endocarditis associated with body piercing."
13. On page 1748, second column, the heading at the top of the column has been modified to read: "Regimens for Procedures on Infected Skin, Skin Structure, or Musculoskeletal Tissue".
14. On page 1748, second column, first paragraph, the second sentence has been modified to read: "For patients with the conditions listed in Table 3 who undergo a surgical procedure that involves infected skin, skin structure, or musculoskeletal tissue, it may be reasonable that the therapeutic regimen administered for treatment of the infection contain an agent active against staphylococci. . . ."
15. On page 1749, first column, last paragraph, the last sentence has been modified to read: "In hospitals with a high prevalence of methicillin-resistant strains of *S epidermidis*, surgical prophylaxis with vancomycin may be reasonable but has not been shown to be superior to prophylaxis. . .."
16. On page 1749, second column, under the heading "Other Considerations", the penultimate sentence has been modified to read: "Accordingly, the use of IE prophylaxis for dental procedures in cardiac transplant recipients who develop cardiac valvulopathy is reasonable, but the usefulness is not well established (***Class IIa, LOE C***; Table 4)."

These changes have been made in the current print (*Circulation*. 2007;116:1736–1754) and online versions of the article.

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