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Antibiotic prophylaxis for endocarditis, prosthetic joints, and surgery

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Antibiotics are prescribed in dentistry for two main reasons: to treat infections and to prevent infections. It is the latter that can be regarded as prophylactic use of these drugs. For the perspective of this article, we consider the main indications (or controversies) relating to prophylactic use of antibiotics in dentistry, notably the prevention of infective endocarditis, infections in patients with hip and joint prostheses, and the prevention of infection following various dental surgical procedures.

Antibiotic prophylaxis to prevent infective endocarditis

Infective endocarditis (IE) is a microbial infection involving the cardiac valves. The condition is uncommon, with a prevalence of 15–30 cases per 1 million per year [1]. The prevalence of IE has remained consistent even after the introduction of antibiotic prophylaxis in the 1940s [2].

Dental procedures, especially those that result in a bacteremia, are frequently blamed for IE and hence result in the need for antibiotic prophylaxis to cover such procedures in at-risk patients. This has been the clinical doctrine and teaching for the past 60 years. Evidence from the United States [3] and studies from the Netherlands [1,4] have presented further data that challenge the practice of antibiotic prophylaxis to prevent IE. Thus there exist several controversial areas surrounding the association between dentistry and IE. These can be broadly classified as follows:

1. Is infective endocarditis caused by a dental procedure-induced bacteremia or from spontaneous bacteremia?

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2. Which patients are at risk for infective endocarditis?
3. Which procedures require antibiotic coverage?
4. Are the risks of providing such coverage greater than the risks for contracting infective endocarditis?
5. Are the antibiotic regimens effective?

A major pitfall in trying to address these questions is the lack of a randomized controlled clinical trial to evaluate the efficacy of antibiotic coverage. Such a study would require at least 6000 at-risk patients and raise considerable ethical issues.

Is infective endocarditis caused by a dental procedure-induced bacteremia or from spontaneous bacteremia?

Poor oral health, especially periodontal status, is an important risk factor for infective endocarditis. Gingival inflammation correlates positively with the prevalence and magnitude of bacteremia [5]. Bleeding per se, however, is a poor indicator of odontogenic bacteremia.

Certain periodontal procedures are associated with bacteremia, although the magnitude varies. The prevalence of such bacteremia and the associated procedures is shown in Table 1. Also, by contrast, is the prevalence of bacteremia arising after various oral hygiene practices and after chewing. In many instances their magnitudes are comparable with the listed procedures. It has been suggested that oral hygiene practices and chewing are responsible for so-called ''random'' or ''spontaneous'' cases of bacteremia. Such bacteremia, either from periodontal procedures or oral hygiene practices, is of low-grade intensity ($1 \leftrightarrow 10^1$–$2 \leftrightarrow 10^2$ cfu ml^{-1} of blood) and of short duration [6].

Table 1
Prevalence of bacteremia arising after various types of dental procedures and oral activity

Procedure	Prevalence of bacteremia
Extractions (single)	51%
Extractions (multiple)	68–100%
Endodontics (intracanal instrumentation)	0–31%
Endodontics (extracanal instrumentation)	0–54%
Periodontal surgery (flap procedure)	36–88%
Periodontal surgery (gingivectomy)	83%
Scaling and root planing	8–80%
Periodontal prophylaxis	0–40%
Toothbrushing	0–26%
Dental flossing	20–58%
Interproximal cleaning with toothpicks	20–40%
Irrigation devices	7–50%
Chewing	17–51%

Dental treatment is often regarded as the cause of infective endocarditis. In many instances, the occurrence of endocarditis does not relate to the so-called "dental-induced" bacteremia. It may well transpire that random or spontaneous bacteremia may be more causative in infective endocarditis than dental surgeons carrying out treatment.

Further evidence to support this hypothesis comes from an analysis of cases of infective endocarditis in which dental treatment has been implicated as the cause. Oral Streptococci cause approximately 50% of all infective endocarditis cases [7]. Similarly, only 15% of patients in whom infective endocarditis has been diagnosed reported medical or dental treatment within the previous 3 months [8]. It has been estimated that 4% or less of all infective endocarditis cases are related to dental-induced bacteremia [2,5]. Whether such bacteremias arise from dental treatment or were spontaneous is not discernible. It is suggested that if spontaneous, random bacteremias cause 96% of all cases of infective endocarditis, than these bacteremias as opposed to those arising from dental treatment also may have caused the remaining 4% [9].

Three major studies have investigated the link between dental procedures and infective endocarditis [1,3,4]. Of these 3 studies, one was a case study [1], and the remaining two were of case-control design [3,4]. The conclusion from the Dutch studies [1,3] suggest that strict adherence to generally accepted recommendations for prophylaxis might do little to decrease the total number of patients with endocarditis in the community. The Strom [4] study is more far-reaching in their findings. They found that dental treatment was no more frequent among patients with IE than control subjects (adjusted odds ratio 0.8), and that among patients with known cardiac lesions (the target of antibiotic coverage) dental treatment was significantly less common than among control subjects. Few participants received chemoprophylaxis. The authors concluded that the lack of a link between dental treatment and IE, together with the rare occurrence of this disease, does not justify the routine use of antibiotic prophylaxis.

Two of the studies [3,4] were of case-control design, and this may weaken their conclusions. Although such studies can demonstrate a risk, the addition of control subjects allows the risk to be quantified. Case control studies, however, are not first rate in hierarchies of evidence that reflect the degree to which different study designs are susceptible to bias, or how certain it is that the observed effects are attributable to the intervention and are not the results of other factors.

Other criticisms of the cited studies have been aired. For example, a letter published in the Lancet raises three points [10]. The first was that although the number of cases of endocarditis prevented was negligible in population terms, the effect on individual patients could not be ignored. Second, concern was expressed at the small numbers of cases eventually entered into the trial, and the even smaller number who received adequate prophylaxis. Finally, doubt was expressed over the feasibility of maintaining a sufficiently large trial to settle this question and comment was made that it might be

fruitless anyway. For these reasons, the authors did not see any good reason to waive current antibiotic prophylaxis practice for at-risk patients undergoing a high-risk dental procedure.

Yet this is the dilemma. Few are prepared to say that dental treatment and the resulting bacteremia do not cause IE, or even advocate for less prophylaxis to demonstrate that some cases of endocarditis follow dental treatment. So it might be impossible to devise a trial in which some individuals would be denied antibiotic coverage. In the meantime, clinicians and their patients will find it difficult to abandon such coverage while circumstantial evidence exists, on an individual level, that it confers some benefit (or more precisely, may reduce a theoretic risk). It might be difficult to change clinical practice, even if an unequivocal randomized controlled trial was done. Until such a trial can be completed, current regimens are likely to remain in place, even if subjected to review and modification.

Which patients are at risk from infective endocarditis?

The most detailed list of patients at risk for IE has been published by the American Heart Association (AHA) [11] (Table 2). They categorize their patients as high, moderate, and negligible risk based on their cardiac history. The negligible risk patients are at no greater risk than the rest of the general population. Differentiating between high and moderate risk does seem somewhat arbitrary, as these patients require antibiotic coverage for most procedures. The main problem relates to mitral valve prolapse (MVP), which is a common condition that affects approximately 5% of the adult population [12]. It is only those patients who have valvular prolapse with regurgitation or thickened leaflets, however, who are at risk for IE. MVP can only be diagnosed by angiography or from echocardiograms. In most cases neither the dental surgeon nor the patient is aware of any disorder of their mitral valves and will receive treatment without antibiotic coverage.

Guidelines on identifying patients at risk for IE vary from country to country. The consensus view is that antibiotic coverage is often overprescribed for many seemingly innocuous cardiac conditions.

Which procedures require coverage?

Again, the AHA is prescriptive in identifying those procedures that require coverage [11] (see box below). From the periodontal perspective, these include all types of periodontal surgery, the placement of implants, scaling and root planing, probing periodontal pockets, subgingival placement of antibiotic fibers or strips, and prophylactic cleaning of the teeth when bleeding is anticipated. There may be concern among dental surgeons over procedures such as probing periodontal pockets, placement of

Table 2
American Heart Association guideline for antibiotic prophylaxis

Cardiac conditions associated with endocarditis
- High risk category
  - Prosthetic heart valves, including bioprosthetic and homograft valves
  - Previous bacterial endocarditis
  - Complex cyanolic congenital heart disease (eg, single ventricle states, transposition of the great arteries, tetralogy of Fallot)
  - Surgically-constructed systemic pulmonary shunts or conduits
- Moderate risk category
  - Most other congenital cardiac malformations
  - Acquired valvular dysfunction (eg, rheumatic heart disease)
  - Hypertrophic cardiomyopathy
  - Mitral valve prolapse with valvular regurgitation or thickened leaflets
- Negligible risk category (no greater risk than the general population)
  - Isolated secundum atrial septal defect
  - Surgical repair of atrial septal defect, ventricular septal defect, or patent ductus arteriosis (without residue beyond 6 m)
  - Previous coronary artery bypass graft surgery
  - Mitral valve prolapse without valvular regurgitation
  - Physiologic, functional, or innocent heart murmurs
  - Previous Kawasaki disease without valvular dysfunction
  - Previous rheumatic fever without valvular dysfunction
  - Cardiac pacemakers and implanted defibrillators

Antibiotic regimes

Situation	Regimen
Standard general prophylaxis	Adults: amoxicillin 2 g, children: amoxicillin 50 mg/kg, oral 1 h before procedure
Unable to take oral medications	Adults: ampicillin 2 g IV or IM Children: ampicillin 50 mg/kg IM or IV, within 30 min before procedure
Allergic to penicillin	Adults: clindamycin 600 mg Children: clindamycin 20 mg/kg 1 h before procedure or Adults: azithromycin or clarithromycin 500 mg Children: azithromycin or clarithromycin 15 mg/kg orally 1 h before procedure
Allergic to penicillin and unable to take oral medication	Adults: clindamycin 600 mg IV or IM Children: 20 mg/kg IV within 30 min before procedure

subgingival antibiotic fibers, and prophylactic cleaning of the teeth. Although bacteremias arising from such procedures have not been quantified, they are likely to be similar in magnitude to the bacteremia arising from tooth-brushing or other oral hygiene practices. This issue brings into question whether such procedures require coverage, whereas those that the patient can generate on their own do not. Although the AHA guidelines for certain periodontal procedures may be an overstatement, they do need to be adhered to until evidence becomes available that refutes them.

Dental procedures for which antibiotic prophylaxis is recommended to prevent infective endocarditis (AHA recommendations)

Dental extractions
Periodontal procedures, including surgery, scaling, root planing, probing periodontal pockets, and recall maintenance
Dental implant placement and reimplantation of avulsed teeth
Endodontic (root canal) instrumentation or surgery beyond the apex
Subgingival placement of antibiotic fibers or strips
Initial placement of orthodontic bands, but not brackets
Intraligamentary local anesthetic injections
Prophylactic cleaning of teeth or implants in which bleeding is anticipated
Incision and drainage or other procedures involving infected tissues

Are the risks for providing antibiotic coverage greater than the risk for contracting IE?

When antibiotics are given prophylactically to prevent IE, the dental surgeon needs to consider the risk and cost benefit of such treatment. The most significant adverse event associated with amoxicillin is hypersensitivity reactions. These can range from a troublesome rash to a life-threatening anaphylactic reaction. One to ten percent of patients report a penicillin allergy [13], although many of these are not confirmed if subjected to the appropriate test. More importantly, the chance of an allergic reaction following administration of the drug is in the range of 0.7–5% [14]. This prevalence does vary with the route of drug administration, with the intramuscular route causing a 5% prevalence and oral penicillin a 0.3% prevalence. High doses of oral amoxicillin, however, can cause an allergic reaction rate similar to that of intramuscular penicillin [15].

Data from the United States show that 400–800 deaths are caused each year by anaphylactic reactions to penicillin, although only a portion of these arise from penicillin prophylaxis to prevent IE. To put the risk–benefit ratio into perspective, it has been estimated that 1.36 people per 1 million population are likely to die from penicillin anaphylaxis to prevent IE, whereas only 0.26 deaths per 1 million population are caused by dental procedure-induced endocarditis [16]. Put another way, patients receiving penicillin (amoxicillin) prophylaxis to prevent IE are five times more likely to die from an anaphylactic reaction to the drug than to die from contracting endocarditis. It would thus seem from these statistics that the risk for

providing antibiotic coverage to prevent IE is far greater than not providing coverage.

Are the antibiotic regimens effective?

One of the most telling statistics on the efficacy of antibiotic prophylaxis relates to the prevalence of the disease. The overall prevalence of IE is approximately 15 per 1 million patients per year. This figure has not changed with the advent of antibiotic prophylaxis. Thus, it could be inferred that the provision of such prophylaxis has had little impact on the occurrence of the disease. This would also question the value of providing such antibiotic coverage.

The efficacy of antibiotic prophylaxis to prevent IE has not been subjected to a randomized, placebo-controlled study. Evidence to date on efficacy has come from case-controlled studies, animal experiments, and antibiotic efficacy studies on bacteremia after tooth extractions. There is uncertainty as to whether prophylactic administration of penicillins has an impact on orally induced bacteremia. Parental penicillin has been shown to reduce bacteremia by 84–86% at 5 minutes and 95–97% at 30 minutes after a bacteremia induction. These figures compare with a reduction of 24–42% and 49–76% respectively, when no prophylaxis is used [17]. By contrast, otherworkers have shown that single doses of penicillin 2 g and amoxicillin 3 g fail to reduce bacteremia after dental extractions [18]. There is now a growing consensus that antibiotic prophylaxis may not prevent IE by a bactericidal blood activity but may do so by decreasing microbial adherence to damaged cardiac valves or by eliminating bacteria after their attachment to valves [19–21].

Although most attention has focused on antibiotic prophylaxis, there is evidence that antiseptic mouthwashes such as chlorhexidine and povidone-iodine used before certain dental procedures may reduce the prevalence of bacteremia [16,22]. The AHA recommends the use of local irrigation with chlorhexidine before any treatment that can result in a bacteremia. Whether such a procedure is sufficient to prevent IE in high or moderate risk patients has yet to be determined. One possible disadvantage is that regular use of chlorhexidine may lead to the selection of resistant streptococci such as *Streptococcus sanguis* and other gram-negative bacteria. An endocarditis from such resistant organisms would have a higher mortality rate than one caused by viridans streptococci [23,24].

Antibiotic prophylaxis in patients with hip and joint prostheses

The provision of joint prostheses is a common orthopedic procedure. In the late 1950s and early 1960s, there was a high prevalence (15–25%) of postoperative infections associated with such surgery. Infections that occurred within 2 months of surgery were categorized as early, whereas those that occurred after this time were considered late infections. Early infections were related to the surgical procedure, whereas late infections were believed

to be caused by hematogenous spread of bacteria from another site of infection elsewhere in the body. Antibiotic prophylaxis at the time of surgery reduced the prevalence of postoperative infection to approximately 1%. These findings suggest that most of the late infections were caused by wound contamination and not from hematogenous spread. Despite such evidence, many orthopedic surgeons insist that their patients receive antibiotic coverage before dental procedures that can induce bacteremia.

Microbiology of joint infections

Most joint infections (>66%) are caused by staphylococci and only 4.9% are related to viridans streptococci of possible oral origin [25]. Whether the *S viridans* infection arose directly from dental treatment or from other sources was not established. DNA fingerprinting techniques have not been used to confirm that isolates from infected joints are the same as those found in the mouth.

Is there evidence to suggest that dental-induced bacteremia causes joint infections?

There is little firm evidence to suggest that dental-induced bacteremia can cause hematogenous infection around a prosthetic joint [26]. By contrast, there are several studies that show the opposite. A review of 21 cases of prosthetic joint infections attributable to a dental procedure identified one patient in whom the same infecting organism was grown on culture from the mouth, blood, and prosthetic joint [27]. Whether the bacteremia arose from a dental procedure or occurred spontaneously was never ascertained. In a prospective 6-year study [28] on 1000 patients, only three developed joint infections. Of these 1000 patients, 224 had undergone an invasive dental procedure without antibiotic prophylaxis and there was no episode of late joint infections. Two further reviews of patients with joint infection [29,30] implicate skin and soft tissue infections as being the most likely primary cause. Four of 110 cases were reported to be attributable to *S viridans* [29]. All four patients had recent experience of an acute dental infection.

Guidelines from professional bodies

Despite the lack of evidence of an association between dental treatment and late joint infections, several professional bodies have produced guidelines on antibiotic prophylaxis before dental treatment. Most recent guidelines are those issued jointly by the American Dental Association (ADA) and the American Academy of Orthopaedic Surgeons (AAOS) [31]. They state that "antibiotic prophylaxis is not indicated for dental patients with pins, plates and screws, nor is it routinely indicated for most patients with total joint replacement." They do consider that certain immunocompromised patients undergoing high-risk procedures within 2 years of joint replacement or those patients with a previous history of joint infection

might be considered for antibiotic prophylaxis. A similar view is adopted by the British Orthopaedic Association, but they also advocate antibiotic prophylaxis when dental treatment is complex, extensive, and of long duration (>45 minutes). It is encouraging to see that both professional bodies advocate the establishment and maintenance of good oral health in patients with joint prostheses. The British Society for Antimicrobial Chemotherapy (BSAC) takes a different view than those expressed by Orthopaedic Associations [32]. The BSAC does not recommend prophylactic use of antibiotics, and further states that exposing patients to the risk for adverse reactions to antibiotics when there is no evidence that such prophylaxis is of any benefit is unacceptable. With these differing views, it is not surprising that the dental profession is confused. There does, however, seem to be some agreement between the various professional bodies that the otherwise healthy patient with a joint prosthesis does not require antibiotic prophylaxis for most dental procedures. Some of the guidelines do need challenging, in particular those involving immunocompromised patients, patients with a joint prosthesis fitted within 2 years, and for procedures lasting >45 minutes.

Patients who would be categorized as at-risk include patients with insulin-dependent diabetes, patients with previous joint infection (first 2 years following joint placement), hemophiliacs, patients with a history of rheumatoid arthritis, and patients with either drug- or disease-induced immunosuppression. An overview of these factors has been presented previously [26]. Their conclusions were that the evidence implicating rheumatoid arthritis and hemophilia as predisposing factors for late infection around prosthetic joints is persuasive. Use of corticosteroid may also predispose a patient to late infection, but this may be because many patients who have rheumatoid arthritis take corticosteroids. Immunosuppression, diabetes mellitus, the type of prosthesis used, the use of bone grafting, and previous complications (infections) related to a prosthetic joint have been reported to be predisposing factors for late infection; however, the data do not currently support such contentions.

Antibiotic regimens and efficacy

As with infective endocarditis, the efficacy of antibiotic prophylaxis to prevent hematogenous infection in patients with joint prostheses has not been evaluated in a randomized controlled trial.

The ADA/AAOS [31] recommendation for cases in which prophylaxis is indicated includes single doses of cephalexin, cephradine, or amoxicillin 2 g orally 1 hour before the dental procedure. Patients allergic to penicillin are prescribed clindamycin 600 mg orally.

Various studies have investigated the risk–benefit ratio for providing antibiotic prophylaxis to patients with prosthetic joints [33–35]. It has been estimated that for every 100,000 patients with joint replacements, approximately 30 (0.03%) would acquire an infection that would necessitate joint replacement. This additional surgery would cost approximately

$900,000. Providing these same 100,000 patients with antibiotic prophylaxis would cost $1,500,000. The risk for providing the coverage, however, would be 40 cases of anaphylaxis and four deaths. These figures would be lower for cephalosporins, but even with this antibiotic, the number of deaths from anaphylactic reactions would be greater than deaths from joint infections [33].

Overview

The need for antibiotic prophylaxis for patients with joint prostheses remains a contentious issue and is certainly an area of conflict between orthopedic surgeons and the dental profession. There is certainly a lack of evidence-based information to support some of the recommendations listed in various published guidelines. The following seems to be a synopsis of the evidence to date:

1. Most joint infections are of staphylococcal origin and not related to dental-induced bacteremia;
2. If an oral commensal has been implicated in causing a joint infection, then it is much more likely to have arisen spontaneously from the patient's oral hygiene practice than from a dental procedure;
3. There is no evidence from randomized controlled studies to support the efficacy of antibiotic prophylaxis before dental procedures to prevent hematogenous joint infections;
4. The risk for providing antibiotic prophylaxis is considerably greater than the risk for a joint infection;
5. Patients with joint prostheses should maintain a high standard of oral health and be rendered dentally fit before joint surgery;
6. There is limited evidence to suggest that patients with rheumatoid arthritis may be more susceptible to dental-induced bacteremia and hence may require antibiotic coverage.

As with infective endocarditis, there is the specter of litigation that often clouds the issue of antibiotic prophylaxis. In this era of evidence-based dentistry, however, it would seem difficult to support the cause of antibiotic prophylaxis for patients with joint prostheses.

The prevention of infection following dental surgical procedures

There are numerous local surgical procedures and medical conditions that are routinely covered by systemic antimicrobials in an attempt to prevent postoperative complications. These can be considered as follows:

- Local wound infection that may not jeopardize the procedure (eg, impacted third molar removal);
- Local infection that may jeopardize the procedure (eg, installation of endosseous implants);

- Distant metastatic infection (eg, infection of an in-dwelling vascular stent);
- Fulminant sepsis (eg, the severely immunocompromised patient).

Local surgical procedures

Antibiotic prophylaxis can generally be justified for surgical procedures when it may safely and cost-effectively reduce the risk for:

1. Exposing a sterile body area to infection;
2. Acquiring an infection likely to cause major morbidity, including the implantation of prostheses [36].

Considered against these criteria, there are few clear indications to provide antibiotic coverage for dental and oral surgical procedures in fit and healthy individuals [37].

Impacted third molars

Surgical removal of impacted third molars is a high-volume procedure in dental practice. The operation carries a low postoperative infection rate on the order of 1–5% [38–41], though procedures involving bone removal carry a higher risk than simple extraction [42]. Such infections are rarely serious or life threatening in healthy, immunocompetent patients. Antibiotic prescribing to prevent these infections is widespread and highly controversial. There is some evidence that antibiotics may further reduce the incidence and severity of postoperative infection [41,43], but others have strongly suggested otherwise [44–48].

It is difficult to support the routine, empirical use of antibiotics to cover such procedures with a low risk for minor morbidity [37,41]. Wise local precautions may include the avoidance of surgery in the presence of acute infection, ensuring optimal plaque control in the preoperative period, and supporting postoperative plaque control with a chemical antiplaque agent.

Orthognathic surgery

Infection is a complication of orthognathic surgery in 1–15% of cases [49,50]. Depending on the nature of the procedure, the consequences of infection may be serious. Numerous studies have revealed lower postoperative infection rates following the use of antibiotics [49,51–53], whereas at least one has demonstrated no benefit [54]. Responsible prescribing demands that the risks and consequences of wound infection are carefully assessed for each patient and procedure, and that antimicrobial drugs are not prescribed without thought. Certainly for intraoral procedures, local plaque control measures should probably be emphasized more strongly.

Implant surgery

The installation of intraoral endosseous implants fits the stated criteria for antibiotic prophylaxis [36]. We know little about the effects of prophylactic antibiotics on implant infection and failure [55], however, and clear indications for their use before implant surgery have not been established [56]. Although the incidence of infection seems to be low, most surgeons have used a prophylactic regimen, including preoperative and long-term postoperative antibiotic therapy [57].

A prospective multi-center study of 2641 implants [56] concluded that significantly fewer failed before the completion of stage II surgery if preoperative antibiotics were used. A following report showed that infectious complications were reduced by almost 50% if patients used chlorhexidine mouthwash perioperatively [58]. The correlation between chlorhexidine use and implant survival was not presented. Conversely, a retrospective, single-center study of 1454 implants in 279 patients followed for 1–6 years showed no significant difference in outcome if antibiotics were not used, and concluded that there was no advantage to the patient from antibiotic prophylaxis in routine implant cases [59].

More clinical audit and research is needed to clarify the position, but the case for routine prophylaxis is by no means clear [57].

Medical conditions

Patients with a lowered local or general resistance to infection may be placed at special risk by invasive dental treatment. It is probable that the risks to these patients are higher than those in the categories considered earlier, and that their relative rarity does not raise the same public health issues.

Immunosuppression

Immune function may be impaired by a range of conditions and medical treatments including leukemias, lymphomas, anti-cancer chemotherapy, immunosuppressive drugs following organ transplantation, poorly controlled insulin-dependant diabetes, loss of splenic function, and HIV infection.

Odontogenic infections may potentially be life threatening, and preventive dental care should be pursued aggressively.

High-risk, invasive dental procedures such as deep scaling and tooth extraction should be avoided whenever possible, but if they become necessary, they should be treated with antibiotics in patients with hematological cancers, bone marrow suppression, and those patients taking anti-cancer chemotherapy [37,60,61]. These are not procedures to be undertaken lightly or without proper collaboration with hematologic, oncologic, and microbiologic specialists. The risk, for example, for opportunistic fungal infection promoted by broad-spectrum antibiotic treatment should not be underestimated.

Organ transplant patients are generally not covered for dental procedures after the immediate postoperative period.

The vast majority of diabetics are controlled well enough to ensure that they are at no major threat from bacteremia caused by dental treatment. Patients with unstable insulin-controlled diabetes may be debilitated and at some risk from invasive dental interventions. Although clear evidence is lacking, these vulnerable patients may benefit from antibiotic prophylaxis for high-risk procedures such as extractions [60].

Splenectomized patients are certainly vulnerable to some forms of infection, particularly from encapsulated microorganisms such as *Staphylococcus pneumoniae* and *Haemophilus* spp [62,63]. The importance of oral microorganisms is less clear. Antibiotic prophylaxis is generally not recommended for dental treatment in these patients [37,61], and the status of post-splenectomy sepsis in an age of routine *S pneumoniae* immunization is under review [62].

Most people with HIV infection are generally well and do not require antibiotic coverage for dental procedures [64,65]. Those with full-blown AIDS become increasingly vulnerable to infection, and it is wise to consider covering patients undergoing invasive procedures with a high risk for bacteremia, such as the removal of an abscessed tooth [60,61]. The balance of risks between fulminant sepsis without antibiotic coverage and the precipitation of another opportunistic infection if a broad-spectrum agent is used should again be carefully reviewed. The best course for these patients is to limit the need for treatment by implementing an effective preventive approach.

Locally reduced resistance to infection

Irradiated bone is poorly vascularized and liable to necrose following trauma or infection. Historically, it was recommended that patients were rendered edentulous before radiotherapy to the head and neck [66] to eliminate dental disease or treatment as a cause of osteoradionecrosis. Osteoradionecrosis is a significant risk after dental extraction [67], but the relative risks for infection and trauma are not known. Some clinicians have reported that extractions can be accomplished with minimal risk under antibiotic coverage, combined with careful technique and effective oral hygiene [68]. Others have observed that antibiotic coverage alone is not sufficient to prevent delayed healing and osteoradionecrosis [69]. There is some consensus that patients who have received radiotherapy to the head and neck should receive antibiotic coverage for dental extractions, that antibiotics should continue until healing is complete, and that complications can be further reduced by hyperbaric oxygen therapy to enhance angiogenesis and perfusion [69–71].

Infection of other in-dwelling devices

Bacteremia from dental treatment may theoretically present an infection risk to a range of in-dwelling devices including vascular grafts, catheters and shunts, neurosurgical shunts, cardiac pacemakers, and defibrillators.

Cardiac pacemakers and defibrillators have not been shown to be at special risk from dentally induced bacteremia, and antibiotic prophylaxis is not recommended [11,72].

By contrast, patients with vascular grafts involving the major vessels [37] and renal impairment, especially those with arteriovenous shunts for hemodialysis [73–76] should be considered for antibiotic prophylaxis before invasive dental procedures. A recent review [60] added extracranial shunts for the drainage of cerebrospinal fluid to this list.

For many of these special situations, there is no clear evidence base. Treatment planning is often complex, involving a variety of specialists and care providers. The prevention of serious dental disease cannot be overemphasized in all of the patient groups considered, and dentists should play an important role in multidisciplinary teams.

Summary

It would seem from a review of the evidence that the need for antibiotic prophylaxis in dentistry is overstated. In simple mathematic terms, the risk for providing coverage is greater than the outcomes that could arise if coverage is withheld. In addition, there is the increasing problem of the development of resistant strains and their impact on medicine and dentistry. Yet despite these observations, the profession continues to put their patients at this greater risk. Medico-legal issues do cloud judgments in this area and many dentists err on the side of caution. The profession does require clear, uniform guidelines that are evidence-based. At present, there is still significant debate as to who is at risk from dental-induced bacteremia and what procedures require chemoprophylaxis.

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