Practice Guideline for Adult Antibiotic Prophylaxis during Vascular and Interventional Radiology Procedures

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Abbreviations: AHA = American Heart Association, GI = gastrointestinal, GU = genitourinary, IE = infective endocarditis, IR = interventional radiology, IV = intravenous, IVC = inferior vena cava, RF = radiofrequency, SIR = Society of Interventional Radiology, TIPS = transjugular intrahepatic portosystemic shunt, UAE = uterine artery embolization

PREAMBLE

There is a need for current, formal recommendations in the interventional radiology (IR) literature concerning the appropriate use of prophylactic antibiotics for IR procedures. This is particularly important given the increasing incidence of antibiotic resistance and complications from nosocomial infection. This document summarizes the findings from the available surgical and IR literature on this topic. Anticipated pathogens and corresponding antibiotic coverage (dose and duration) are enumerated for common vascular and nonvascular interventions in adults. Note that this document is intended to provide recommendations concerning only antibiotic prophylaxis, not treatment of infectious complications. It is beyond the scope of this article to discuss the management of infectious complications sustained during vascular and interventional radiology procedures.

The membership of the Society of Interventional Radiology (SIR) Standards of Practice Committee represents experts in a broad spectrum of interventional procedures from the private and academic sectors of medicine. Generally, Standards of Practice Committee members dedicate the vast majority of their professional time to performing interventional procedures; as such, they represent a valid broad expert constituency of the subject matter under consideration for standards production.

Technical documents specifying the exact consensus and literature review methodologies as well as the institutional affiliations and professional credentials of the authors of this document are available upon request from SIR, 3975 Fair Ridge Dr., Suite 400 N., Fairfax, VA 22033.

METHODOLOGY

SIR produces its Standards of Practice documents using the following process. Standards documents of relevance and timeliness are concep-

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tualized by the Standards of Practice Committee members. A recognized expert is identified to serve as the principal author for the standard. Additional authors may be assigned dependent upon the magnitude of the project.

An in-depth literature search is performed using electronic medical literature databases. Then a critical review of peer-reviewed articles is performed with regard to the study methodology, results, and conclusions. The qualitative weight of these articles is assembled into an evidence table, which is used to write the document such that it contains evidence-based data with respect to content, rates, and thresholds.

When the evidence of literature is weak, conflicting, or contradictory, consensus for the parameter is reached by a minimum of 12 Standards of Practice Committee members using a Modified Delphi Consensus Method (Appendix A) (1–3). For the purposes of these documents, consensus is defined as 80% Delphi participant agreement on a value or parameter.

The draft document is critically reviewed by the Standards of Practice Committee members, either by telephone conference calling or face-to-face meeting. The finalized draft from the Committee is sent to the SIR membership for further input/criticism during a 30-day comment period. These comments are discussed by the Standards of Practice Committee, and appropriate revisions made to create the finished standards document. Before its publication the document is endorsed by the SIR Executive Council.

The current guidelines were written to help determine appropriate antibiotic prophylaxis for vascular and IR procedures. The elements of care necessitate knowledge of the following: (i) the anticipated pathogens associated with the given intervention and (ii) pretreatment evaluation and patient-specific factors that may be associated with higher likelihood of periprocedural infection. The outcome measures or indicators for this process include (i) how often antibiotics are given when they should be given; (ii) how often antibiotics are given when they should not be given; and (iii) how often is antibiotic timing within recommended guidelines. Although practicing physicians should strive to achieve perfect outcomes, in practice all physicians will fall short of ideal outcomes to a variable extent. Therefore, in addition to quality improvement case reviews conducted after individual complications, outcome measure thresholds should be used to assess treatment safety and efficacy in ongoing quality improvement programs. For the purpose of these guidelines, a threshold is a specific level of an indicator that, when reached or exceeded, should prompt a review of departmental policies and procedures to determine causes and to implement changes, if necessary. Thresholds may vary from those listed here; for example, patient referral patterns and selection factors may dictate a different threshold value for a particular indicator at a particular institution. Therefore, setting universal thresholds is difficult, and each department is urged to adjust its thresholds as needed to meet its specific quality improvement program situation.

SIR is committed to the basic principles of outcome-focused, evidence-based medicine. Ideally, every Standards of Practice Committee recommendation would be based on evidence derived from multiple prospective randomized trials of adequate statistical power. Unfortunately, currently there are no published multicenter randomized trials that evaluate the clinical efficacy and indications for antibiotic prophylaxis during IR procedures. Within the existing publications, several major limitations are evident: (i) lack of randomized controlled trials concerning the efficacy of IR antibiotic prophylaxis and reliance on existing case series and retrospective analyses; (ii) extreme variation in the existing literature concerning patient selection parameters, definitions of short-term efficacy, and definitions of infectious complications; and (iii) absence of systematic assessment of long-term efficacy. SIR recognizes the potential pitfalls of developing evidence-based standards for antibiotic prophylaxis and of making recommendations regarding the use of drugs based on studies of suboptimal design. However, these difficulties are far outweighed by the potential improvements in safety and treatment efficacy that may be gained by implementing the key lessons learned from the existing peer-reviewed scientific literature that has evaluated antibiotic prophylaxis during surgical and IR procedures. Given the limited scientific foundation, most of the recommendations presented in this document are intended to guide clinical practice rather than to mandate the use of specific algorithms. The authors fully anticipate that these guidelines will be appropriately revised when future studies of greater scientific rigor are available. Levels of evidence have been assigned to the current recommendations within this clinical practice guideline that adhere to definitions created by the American College of Cardiology and American Heart Association (AHA) Guidelines Task Force (4,5). A summary of these definitions are provided in Appendix B.

INTRODUCTION

During the past two decades, several authors have reported on the use of prophylactic antibiotics for IR procedures (6–9). Spies et al (6) were the first to provide a critical review on antibiotic prophylaxis in IR. Their study underscored the lack of randomized controlled trials of antibiotic prophylaxis during IR procedures, indicating that the selection of antibiotics for IR prophylaxis was largely guided by the existing surgical literature (6,9). There has been a lack of randomized controlled trials in the radiology literature to provide scientific validation for the role and effectiveness of antibiotic prophylaxis during IR procedures. Nevertheless, antibiotic prophylaxis has become the perceived standard of care for selected procedures, making it possible that randomized controlled trials may never be performed (6,9). Extensive clinical data on the use of antimicrobial agents in

surgery exist. As noted by Spies et al (6), the analogous clinical considerations in surgery serve as a basis for developing an approach to the proper use of antibiotics in IR. Clinical case series and retrospective analyses in the IR literature concerning the occurrence, prevention, and management of infectious complications following specific IR procedures are also available to guide clinical practice (10–14). This document offers a logical basis for prophylactic use of antibiotics during IR procedures based on the literature available. Many current clinical and environmental factors mandate current recommendations for prophylaxis during IR procedures. These include the widening breadth of IR procedures and recent revisions to existing surgical practice guidelines from which many IR prophylaxis guidelines are derived (6,9,15–17). Additional factors include increasing antibiotic resistance, morbidity associated with nosocomial infection, and increasing health care costs (9,15–17).

The specific antibiotic agent doses provided herein are recommendations for normal adult patients. Although the doses and agents named here are suggestions meant to facilitate the care of IR patients, it is the ultimate responsibility of the individual interventional radiologist to pay close attention to individual patient factors, including advanced patient age, existing medications, reduced renal or hepatic function, medication allergy history, the intended procedure and its likely pathogens, and the dose and timing of the most recent antibiotic agent dose. Antibiotic choices have been listed as "first choice" if a specific antibiotic agent has been consistently described in the published literature in association with prophylaxis for a given procedure. When no single agent has been uniformly reported as the agent of choice for prophylaxis of a given procedure, no first-choice antibiotic is listed. Instead, a list of common antibiotic choices are provided, which are described in the literature. It is important to note that this document should not be considered a replacement for the close and careful evaluation of individual patients by their IR practitioners. The responsibility ultimately lies with the individual IR physician, who must determine for him- or herself the appropriateness of a specific antibiotic regimen for a specific patient and clinical scenario. As the antibiotic sensitivities of different pathogens vary based on time and region, the appropriate prophylactic antibiotic selection may differ depending on the institution at which the physician practices. The IR physician should therefore periodically consult with his or her local hospital-based infectious disease committee, consulting service, microbiology laboratory, and/or pharmacy for recommended medications.

DEFINITIONS

General Definitions

This document uses definitions as outlined by Spies et al (6) for colonization, infection, clinical infection, and prophylaxis, as follows:

Colonization is the presence of a microorganism without host response.

Infection is the presence of an organism with host response.

Clinical infection represents infections that produce local signs or symptoms (eg, fever, pain, leukocytosis).

Prophylaxis is the administration of an antimicrobial in the periprocedural period in the absence of clinical infection to prevent an infectious complication.

Bacteremia is the presence of bacteria within the bloodstream without clinical signs or symptoms of infection (eg, fever, pain, leukocytosis).

Septicemia is the presence of pathogenic organisms or their toxins in the bloodstream with concomitant systemic signs and symptoms of sepsis (6).

Procedure Classification

The National Academy of Sciences/National Research Council has divided surgical wounds into four classes—clean, clean-contaminated, contaminated, and dirty—each of which is associated with a different risk of infection (7,18). This classification may be used to guide antibiotic prophylaxis for IR procedures (6).

Clean.—A procedure is regarded as clean if the gastrointestinal (GI) tract, genitourinary (GU) tract, or respiratory tract is not entered, if inflammation is not evident, and if there is no break in aseptic technique (18). An example of a clean procedure is routine diagnostic angiography (7,18).

Clean-contaminated.—A procedure is regarded as clean-contaminated if the GI, biliary, or GU tract is entered; if inflammation is not evident; and there is no break in aseptic technique. An example of a clean-contaminated procedure is nephrostomy tube placement in a patient with sterile urine (7,18).

Contaminated.—A procedure is regarded as contaminated if there is entry into an inflamed or colonized GI or GU tract without frank pus, or if a major break in aseptic technique occurs (18).

Dirty.—A procedure is regarded as dirty if it involves entering an infected purulent site such as an abscess, a clinically infected biliary or GU site, or perforated viscus (18).

As noted later, antibiotic prophylaxis for IR procedures is generally recommended for procedures that are not clean, or for procedures that are considered clean but, as a result of which, a potentially significant volume of necrotic tissue is generated in potentially contaminated areas, eg, embolization with intent to create infarction. Although National Academy of Sciences/National Research Council surgical wound classification may be used as a guide, it should be noted that the infectious risks of open surgical procedures differ from those of IR procedures (19). As noted by Zarrinpar et al (19), surgical prophylaxis is typically directed at preventing infection of the wound by infected fluid or skin organisms. The small incision made during vascular and nonvascular IR procedures rarely serves as a site for clinically important infection (19). Prophylaxis in IR is more commonly done to prevent infection resulting from the communication that is created by a needle or catheter (19) between an infected space and the bloodstream. Data from studies of surgical wound prophylaxis may therefore not always be directly applicable to IR procedures performed on the same organ, and the interventional radiologist is encouraged to consider the appropriate-

ness of prophylaxis in accordance with the clinical circumstances of the individual patient and site-specific flora (19).

COMPLICATIONS

Complications can be grouped on the basis of outcome. Major complications from antibiotic therapy result in admission to a hospital for therapy (for outpatient procedures), an unplanned increase in the level of care, prolonged hospitalization, permanent adverse sequelae, or death. Minor complications result in no sequelae; they may require nominal therapy or a short hospital stay for observation (generally overnight; Appendix C). The complication rates described in the present document refer to major complications.

TIMING AND ADMINISTRATION OF PROPHYLAXIS

The basis for timing and duration of antibiotic prophylaxis of IR procedures is derived from the surgical literature. The rationale for current surgical antibiotic prophylaxis emerged from animal experiments performed in the 1960s by Burke (20), who demonstrated the greatest suppression of infection when antimicrobial agents were administered before inoculation. The likelihood of postprocedure infection increased the longer the delay between initiation of antibiotic prophylaxis and the procedure; an initial dose given 3 hours after a procedure resulted in no difference in the likelihood of infection in treated animals versus untreated controls (20). More recent clinical studies corroborate these findings, demonstrating a fivefold increased rate of infectious events when antibiotic administration occurs more than 3 hours after a procedure (7,21). In a randomized double-blinded study of patients undergoing colonic surgery, a 16% frequency of wound infection occurred when no prophylaxis was used; the incidences were 15% when prophylaxis was given after the procedure and only 6% when prophylaxis was given 1 hour before surgery (6,22). Overall, an almost fourfold greater incidence of incisional infection was demonstrated when antibiotic agent was withheld versus when it was given preoperatively (18). Initiation of antibiotic therapy postoperatively yielded similar results to those in which parenteral antibiotic treatment was completely withheld (6,22).

With respect to duration of administration, several studies have evaluated the efficacy of single versus multiple dose protocols for prophylaxis, demonstrating that a single appropriately timed dose is as effective as a multiple-dose protocol (9,23–26). Recommended IR practice for most procedures warranting prophylaxis involves administration of a single preprocedural dose of an antimicrobial agent just before commencement of a procedure. Exceptions include procedures when a patient undergoes instrumentation of an obstructed viscus, such as biliary or kidney obstruction, in which the risk of postprocedural bacteremia caused by intravasation of organisms into the bloodstream remains present until the organ is adequately drained (9). The antibiotic agent used in this setting admittedly spans the boundary between prophylaxis and treatment, and in such patients, treatment should be continued until satisfactory drainage of the viscus is achieved (9). In percutaneous drainage procedures, the risk of bacteremia is attributed to communication of the fluid cavity with the arterial, venous, and lymphatic systems (6,27). In the absence of data on this topic, Spies et al (6) have advocated continued antibiotic therapy for 48 hours after such a procedure to reduce the risk of bacteremia and its consequences. Other cases that may warrant prolonged prophylaxis include those that involve earlier surgical manipulation (eg, bilioenteric anastomosis before chemoembolization).

Additional factors to consider include patient condition and procedure duration (9). Investigators from the Centers for Disease Control (7,28) have described three risk factors associated with an increased risk of postoperative surgical wound infection, in addition to the level of wound contamination. These factors were derived from information collected on more than 58,000 operative patients. A simple multivariate risk index was created, which prospectively predicted surgical wound infection risk (28). Factors including a procedure lasting more than 2 hours, an abdominal operation, and the presence of multiple-organ disease, when included in a predictive model along with the level of wound contamination, allowed identification of a subgroup of patients who would sustain 90% of wound infections (28).

Prophylactic antibiotic agents should be administered immediately before transfer to the interventional suite, or by the IR nurse when the patient arrives in the interventional suite. The latter is optimal, particularly if there is a delay in the patient's arrival, as the time of antibiotic agent administration should not be altered (9). In keeping with the current Joint Commission on the Accreditation of Healthcare Organization 2009 Hospital Patient Safety Goals (29), which recapitulate the existing surgical literature, intravenous (IV) antimicrobial prophylaxis should be administered within 1 hour before incision, with 2 hours allowed for the administration of vancomycin and fluoroquinolones, and with discontinuation of the prophylactic antimicrobial agent within 24 hours after intervention, unless clinical circumstances (eg, obstructed viscus) warrant continuation of a prophylactic regimen as therapy. An accurate list of the patient's current medications and known allergies should also be reviewed to safely prescribe any setting-specific antibiotics and to assess for the potential allergic or adverse drug reactions (29–31). Appropriate antibiotic coverage should be selected by an experienced IR practitioner. When a patient is already receiving antibiotic drugs, the timing of the most recent dose of antibiotic agent should be reviewed, as well as the appropriateness of the antibiotic relative to the procedure and the likely pathogens (9). If indicated, an additional dose or different agent may be administered before the procedure. If a procedure is likely to be prolonged (ie, >2 h), a supplemental dose of antibiotic agent should be considered, depending on the half-life of the agent being administered (9).

Antibiotic Resistance

Patient morbidity and mortality resulting from infectious complications have been increasing during the past two decades (9). This, in large part, is related to the increasing frequency and spectrum of antibiotic resistant infections (9,32). Factors facilitating selection of antibiotic resistance include the over-

use of antibiotic agents by health care practitioners, the increased use of invasive devices, a greater number of susceptible hosts (ie, those in an immunocompromised condition), and lapses in appropriate infection control (9). When choosing an antibiotic agent for prophylaxis, one needs to consider the likely source and pathogen, and the prophylaxis should be specifically directed against these organisms. The routine use of broad spectrum antibiotics is not cost effective and promotes further antibiotic resistance (9,33).

PROPHYLAXIS FOR SPECIFIC IR PROCEDURES

Vascular Interventions: Angiography, Angioplasty, Thrombolysis, Arterial Closure Device Placement, Stent Placement

Diagnostic angiography, routine angioplasty, and thrombolysis are considered clean procedures, and with careful technique, antibiotic prophylaxis is unnecessary (34). Bacteremia occurs after 4%–8% of angiographic procedures and is typically asymptomatic (6,34,35). When it does occur, the source is usually an angiographic catheter that was contaminated before use (6,34). Repeated puncture of a site or repeated catheterization of an indwelling sheath is believed to increase the risk of periprocedural infection (7,36).

Percutaneous vascular closure devices, including collagen plug devices and suture-mediated closure devices, are increasingly used during cardiac and peripheral vascular interventions (37,38). Infectious complications have been reported after the use of these devices; these include groin cellulitis and femoral artery endarteritis (37–39). Comorbid factors described in patients with infectious complications include diabetes mellitus, obesity, and placement of a percutaneous suture closure device within the previous 6 months, warranting caution when considering the use of a percutaneous closure device in such patients (38). However, at the present time, there are insufficient data to suggest prophylaxis before placement of these devices.

Stent infection is an uncommon but serious complication of endovascular treatment (9). This is likely secondary to several factors, including the presence of a foreign body and the presence of inflammation at the site of stent implantation (7,40). Stent infection has been reported in the aorta, iliac, renal, coronary, and subclavian arteries (9,41–48). When reported, complications are major, usually involving arteritis with pseudoaneurysm formation (9,49). Risk factors have included repeat puncture of the same vessel during a short time interval or use of a vascular sheath that has been in place for more than 24 hours (9,49). Recommendations have been made in the literature for prophylactic antibiotic agent use if an arterial sheath is left in overnight after stent placement, or for patients undergoing multiple endovascular interventions (46). One advocated approach involves administration of prophylactic antibiotic agents before a second procedure to patients in whom repeat intervention is performed within 7 days (38). Although infection represents a statistically low-risk event, serious outcomes have been associated with this complication. At the present time, prophylactic antibiotic agents are not recommended for routine arterial stent placement. However, for those patients deemed to be at high risk (ie, cases of repeat intervention within 7 d, prolonged indwelling arterial sheath, or prolonged duration of procedure), prophylaxis may be given (9,46).

Procedure: clean
Organisms encountered: *Staphylococcus aureus, Staphylococcus epidermidis*
Routine prophylaxis recommended: no
Special considerations: 1 g cefazolin IV if there is a high risk of stent infection; or (ii) if the patient is allergic to penicillin, vancomycin or clindamycin
Level of evidence: 5, 8 (Appendix B)

Endograft Placement

Prophylactic antibiotic agents are given routinely for aortic endograft therapy at many institutions, although there is limited scientific evidence to support this approach (9,49). Prosthetic graft infection is an uncommon event, but when it occurs, it carries a high mortality rate (9,50,51). Prophylaxis is similarly recommended for peripheral endografts, including those for superficial femoral artery recanalization and dialysis access endografts, which are increasingly used in IR practice.

Procedure classification: clean
Organisms encountered: *S aureus, S epidermidis*
Routine prophylaxis recommended: yes
First-choice antibiotic agent: 1 g cefazolin IV
Alternate choices: (ii) if penicillin-allergic, vancomycin or clindamycin
Level of evidence: 5, 8

Lower-extremity Superficial Venous Insufficiency Treatment

Current therapies for treatment of lower-extremity superficial venous insufficiency—including varicose veins—include endovascular thermal ablation, sclerotherapy, and ambulatory phlebectomy (52). Although routine practice includes the use of sterile technique before these procedures, there are insufficient data in the literature to warrant routine antibiotic prophylaxis (52). Adverse events related to these therapies are typically minor, and include paresthesias and superficial phlebitis, with more serious adverse events—primarily pertaining to endovascular thermal ablation—including deep vein thrombosis, neurologic injury, and skin burns (52).

Procedure classification: clean
Organisms encountered: *S aureus, S epidermidis*
Routine prophylaxis recommended: no
Level of evidence: 8

Inferior Vena Cava Filter Placement

Infection after inferior vena cava (IVC) filter placement has not been a significant problem in clinical practice. One case of fatal septicemia after placement of an IVC filter has been reported in the IR literature (7). In this instance, the IVC filter (LGM VenaTech IVC Filter; L-G Medical, Evanston, Illinois) was placed through the site of an indwelling central venous catheter (53). When placing an IVC filter, a "fresh" venous access site is recommended (7,53). However, routine filter placement in an uninfected patient does not warrant prophylaxis (7,54).

Procedure classification: clean
Routine prophylaxis recommended: no
Level of evidence: 5, 6

Central Venous Access

The use of antibiotic prophylaxis for central venous catheter placement is controversial. Central venous catheter placement is classified as a clean procedure. Therefore, prophylaxis is not routinely recommended, although meticulous sterile technique and appropriate preprocedural preparation is mandatory (9). When catheter-related infections do occur, these are most commonly caused by coagulase negative *Staphylococcus* species (9). Migration of skin organisms into the catheter tract is the most common route of infection, with contamination of the catheter hub contributing to colonization of long-term catheters (9). Most infections in patients with long-term venous access are caused by Gram-positive bacteria (9).

A recent version of the Centers for Disease Control Guidelines for the Prevention of Intravascular Catheter-related Infections (9,55) underscored the importance of sterile technique, the use of 2% chlorhexidine skin preparation, avoidance of routine catheter change, and the use of antiseptic or antibiotic agent–impregnated catheters only if previous infection rates are high. van de Wetering et al (56) evaluated the efficacy of administration of antibiotic agents before insertion of a central venous catheter with or without vancomycin/heparin flush technique in the first 45 days after catheter placement to minimize Gram-positive catheter-related infections in oncology patients (9), and antibiotic agent administration before catheter insertion followed by vancomycin/heparin flush was associated with a decreased incidence of Gram-positive infections (56). Of note, this strategy was not advocated for general practice, but in the setting of recurrent catheter infection (9,56–58). Loo et al (59) reported a survey of 196 consecutive central venous catheters placed in the intensive care unit in 151 patients, in which an antiseptic agent–impregnated catheter was alternated on a bimonthly basis with a standard triple-lumen central venous catheter. There was no difference in the catheter-related bacteremia rates between the two groups, and although the impregnated catheter group had a lower cumulative infection rate for dwell times less than 5 days, the difference between the cumulative infection rates was not statistically significant for dwell times of 6, 7, or 8 days (59).

Some authors have suggested that routine antibiotic prophylaxis may be warranted before placement of tunneled catheters with implantable ports, given that these patients are often in an immunocompromised state, and given the severity of complications and difficulty in treating infected ports (9). The benefit of antibiotic prophylaxis for central venous access remains unproven, and therefore the routine use of antibiotic prophylaxis remains an area of controversy. Prevention is critical to minimize the likelihood of infections associated with implantable ports, as these are difficult to treat and potentially fatal (9). Preventive strategies include meticulous attention to sterile technique. The use of catheters with the fewest number of lumens necessary for management of the patient reduces portals for colonization (9). For patients who require intermittent long-term venous access, implantable devices are recommended, as these are more resistant to contamination (9). Such devices are now in use for dialysis access management in an attempt to reduce infection rates. Although the use of antibiotic prophylaxis may be considered in specific clinical scenarios (eg, immunocompromised patients who require catheter placement before chemotherapy and those with a history of catheter infection), routine prophylaxis for these procedures is not recommended.

Procedure classification: clean
Organisms encountered: *S aureus, S epidermidis*
Routine prophylaxis recommended: no consensus
Special considerations (eg, immunocompromised patients who require catheter placement before chemotherapy and those with a history of catheter infection): 1 g cefazolin IV; or in the case of penicillin allergy, vancomycin or clindamycin
Level of evidence: 8

Embolization and Chemoembolization

Historic IR data have reported a higher incidence of transient bacteremia after embolization compared with diagnostic angiography (60). In a prospective study of 45 patients undergoing embolization, 32% of patients who received no antibiotic treatment developed bacteremia, although none developed clinical sepsis. The organisms isolated included *S epidermidis, Streptococcus* species, and *Corynebacterium* species, all of which are normal in mucosal or skin flora (60). In contrast, no patients who received antibiotic prophylaxis had positive blood cultures (60). Findings from this study suggest that bacteremia is especially likely following embolization. Findings from additional studies support the use of antibiotic prophylaxis before embolization. Reed et al (61) reported the results of 494 hepatic chemoembolization procedures, among which 14 were performed without prophylactic antibiotics. One of these 14 cases resulted in fatal sepsis within 24 hours of intervention (7,61). In a patient-by-patient analysis of these data, of the 226 patients who received prophylaxis, six developed hepatic abscesses but no cases of fatal sepsis occurred (61). In a separate clinical series of 410 embolization cases (62), eight deaths were reported, of which seven were caused by infectious complications in patients who had not received antibiotic prophylaxis. Prophylaxis targeted against skin pathogens is recommended before performing tumor and/or solid organ embolization, including the liver, kidney, and spleen, when there is an intent to create infarction or a high likelihood of infarction, as this may result in a potentially significant volume of necrotic tissue in potentially contaminated areas (9,19,60). Routine prophylaxis remains controversial in the setting of embolization for the purposes of controlling bleeding from a viscus or solid organ, such as in the setting of trauma. Depending on the clinical setting and treatment goals,

the target organ, and likelihood of additional pathogens, the antibiotic regimen should be adjusted accordingly (9).

The IR literature regarding the use of antibiotic prophylaxis for chemoembolization is small. In the absence of randomized clinical trials, the effectiveness of prophylaxis in this setting is unproven, although several clinical series (9,11,12,63–66) have suggested that major infectious complications may be sustained in this population. Many operators routinely administer antibiotic prophylaxis for this procedure, including coverage for skin flora and for Gram-negative enteric organisms, even though this practice has not been prospectively proven to be of benefit for all patients (9,11,12,61,62–66). Some practitioners recommend continued administration of antibiotics for 3–7 days after chemoembolization to cover Gram-negative enteric pathogens, although this too lacks prospective validation (9,67). Patients without an intact sphincter of Oddi as a result of earlier surgery or sphincterotomy or biliary drainage are at increased risk for subsequent abscess formation (67). The risk of postembolization infection appears to be reduced by the performance of a bowel preparation the night before treatment and by ensuring coverage of Gram-positive and Gram-negative aerobic and anaerobic organisms (eg, tazobactam/piperacillin). However, it remains to be seen how high the infectious risks are, despite adoption of an aggressive regimen (12).

Even fewer reports exist concerning infectious complications of radioembolization. There have been individual reports of hepatic abscess after yttrium-90 radioembolization, but ongoing research is needed in this population to better assess the risks of infectious complications and to determine the efficacy of antibiotic prophylaxis (67–69).

Procedure classification: clean; clean-contaminated (bilioenteric surgery)
Organisms encountered: *S aureus*, *Streptococcus* species, *Corynebacterium* species with or without enteric flora (in cases of earlier sphincter of Oddi manipulation/bilioenteric surgery)
Routine prophylaxis recommended: yes (if intent to create infarction or high likelihood of solid organ infarction)
First-choice antibiotic agent: no consensus
Common antibiotic choices: (i) 1.5–3 g ampicillin/sulbactam IV (hepatic chemoembolization); (ii) 1 g cefazolin and 500 mg metronidazole IV (hepatic chemoembolization); (iii) 2 g ampicillin IV and 1.5 mg/kg gentamicin (hepatic chemoembolization); (iv) 1 g ceftriaxone IV (hepatic chemoembolization or renal or splenic embolization); (iv) if penicillin-allergic, vancomycin or clindamycin plus aminoglycoside
Special considerations: in patients for hepatic chemoembolization without an intact sphincter of Oddi (previous sphincterotomy, biliary drainage, history of bilioenteric anastomosis), consider tazobactam/piperacillin; also consider bowel preparation in this population
Level of evidence: 4, 7, 8

Uterine Artery Embolization

Uterine artery embolization (UAE) has become a desirable alternative to hysterectomy or myomectomy for the treatment of symptomatic leiomyomas (13,70). The risk of infection has been largely described in the literature as being low, and is reported to occur in 0.2%–1% of patients (9,13,71,72). However, several of the reported cases of fatal sepsis occurring after UAE have occurred in patients who did not receive prophylaxis (9,73–75). The most common organisms causing infection after UAE are common skin flora (*Staphylococcus* or *Streptococcus* species), as is the case for other solid organ embolization. At least one fatal case of sepsis after UAE has been reported in a patient who developed an *Escherichia coli* urinary tract infection after the procedure and fatal subsequent *E coli* sepsis (9,74).

The role of prophylactic antibiotics for patients undergoing UAE has been debated in the literature (13). The joint working party for the Royal College of Radiologists and the Royal College of Obstetricians and Gynecologists in the United Kingdom has recommended that prophylactic antibiotic treatment should not be given at the time of the embolization as infectious complications are generally delayed (as long as 2–3 weeks after the procedure) (13,76,77). In the Ontario Uterine Fibroid Embolization Trial (77), which included 555 patients, antibiotic prophylaxis (1 g cefazolin IV) was routinely administered at four hospitals and reserved for patients at increased risk of infection at an additional four hospitals. This trial reported only two infection-related hysterectomies in 570 UAE procedures, with one occurring in each cohort (13,77). A retrospective review by Rajan et al (78) of 410 patients undergoing UAE was performed to identify risk factors for the development of intrauterine infection after UAE (13,78). Multiple variables were analyzed as predictors for intrauterine infectious complications requiring medical and/or surgical therapy, including the use of preprocedural antibiotics, embolic agent used, quantity of embolic material, location of tumors (eg, submucosal, nonsubmucosal), and size and location of the dominant tumor (78). Intrauterine infectious complications requiring IV antibiotic therapy and/or surgery occurred in five patients (1.2%), with no specific risk factor for intrauterine infection after UAE identified (78). Rajan et al (78) concluded that infection after embolization is rare (13,78). In contrast to these studies, there has been a single clinical series from the United Kingdom (9,79) that described a 17% readmission rate for infection after UAE (seven of 42 patients). There was one infection-related hysterectomy. Three of the patients had urinary tract infection, most likely secondary to bladder catheterization; in the three remaining patients, no source of infection was identified (9,79). The antibiotic prophylaxis regimen used in this clinical series included amoxicillin/clavulanate three times daily and metronidazole twice daily on the day of the procedure, followed by a further 48-hour administration of the same antibiotic agent after the procedure. Patients were admitted to the hospital for 3 days (79). This multiple-day, multidrug approach to prophylaxis is largely the exception for UAE prophylaxis in the

IR literature; as in other clinical settings, multidrug regimens and prolonged antibiotic administration have been critiqued for eliminating normal Gram-positive organisms, thereby allowing Gram-negative organisms to proliferate (13,80). Notwithstanding little evidence from randomized controlled clinical trials, most clinical series reporting on UAE have routinely administered a single dose of preprocedural antibiotic drugs, with the current antibiotic of choice being 1 g of cefazolin (9). Cefazolin is inexpensive and has activity against the likely source of pathogens during solid organ embolization, ie, skin pathogens (*Staphylococcus* or *Streptococcus* species), as well as activity against *E coli* (9). Other options that have been described include gentamicin plus clindamycin, ampicillin, ampicillin/sulbactam, or vancomycin in the penicillin-allergic patient (9,72,80).

Patients with a history of hydrosalpinx may warrant special consideration before UAE, although there is no published consensus regarding which agents should be used. Practitioners experienced in performing UAE in patients with a history of hydrosalpinx recommend prophylaxis with doxycycline 100 mg twice daily for 7 days before the procedure (J. Spies, MD, personal communication, October 2009).

- *Procedure classification*: clean; clean-contaminated
- *Organisms encountered*: *S aureus, S epidermidis, Streptococcus* species with or without *E coli*
- *Routine prophylaxis recommended*: yes
- *First-choice antibiotic agent*: no consensus
- *Common antibiotic choices*: (i) 1 g cefazolin IV; (ii) 900 mg clindamycin IV plus 1.5 mg/kg gentamicin; (iii) 2 g ampicillin IV; (iv) 1.5–3 g ampicillin/sulbactam IV; (v) if penicillin-allergic, can use vancomycin
- *Special considerations*: if history of hydrosalpinx, 100 mg doxycycline twice daily for 7 days
- *Level of evidence*: 4, 5, 8

Transjugular Intrahepatic Portosystemic Shunt (TIPS) Creation

As noted by Beddy et al (13), transjugular intrahepatic portosystemic shunt (TIPS) creation was originally used as a bridge to transplantation in patients with severe complications of portal hypertension (13). With the introduction of covered stents and their improved long-term patency, the employment of TIPS has expanded (13,81). Two separate infectious complications from TIPS have been described: (i) periprocedural sepsis without stent infection and (ii) TIPS stent infection (9,13).

Periprocedural sepsis has been described since the early days of TIPS procedures and has been reported to occur in as many as 17% of patients (13,82). The causative organisms are usually skin flora (eg, *Staphylococcus* or *Streptococcus* species) (13). Deibert et al (83) studied the effectiveness of a single dose of a second-generation cephalosporin to prevent post-TIPS infection. Patients who underwent 105 transjugular interventions were randomized to receive no antibiotic treatment (46 interventions) or 2 g cefotiam (56 interventions), which was administered at the beginning of the procedure (9,82). Post-TIPS infection was defined by an increase in white blood cell count (>15,000/μL), fever (>38.5°C), or a positive blood culture result (83). Patients who did not receive cefotiam had an infection rate of 20%, versus an infection rate of 14% in patients treated with antibiotics (83). The difference in infection rate between the two groups did not reach statistical significance, suggesting that routine use of prophylactic antibiotics for TIPS creation may not be of value (9,83). As noted by Ryan et al (9), the effectiveness of cefotiam for TIPS prophylaxis may have been limited by its limited activity against enterococcal species. A more appropriate agent may have been one with enhanced coverage against *Enterococcus* species, which may have resulted in a different outcome in this study (9). As patients undergoing TIPS creation typically have multisystem disease and do not tolerate the sequelae of infection, many interventionalists administer antibiotic prophylaxis in this setting, despite a relative lack of evidence from randomized controlled clinical trials (8). The survey of IR prophylaxis regimens by Dravid et al (8) reported that a majority of respondents (69%) use antibiotic prophylaxis in patients undergoing TIPS creation; an infection rate of 13% was reported by respondents in this survey. The authors concluded that prophylaxis is indicated for TIPS procedures, and suggested a regimen of cefoxitin 1 g IV every 6 hours for 48 hours (8). As noted by Beddy et al (13), some interventionalists use ceftriaxone 1 g IV once daily for 48 hours rather than cefoxitin, given its enhanced activity against *E coli, Enterobacter* species, Gram-negative bacteria, anaerobes, and enterococci, and its once-daily dosing regimen. Ampicillin/sulbactam also has improved coverage against *Enterococcus* species and can be used for TIPS prophylaxis (13).

Infection of the TIPS stent itself been more recently described, reportedly occurring in 1.7%–5.1% of cases (9,82–86). Sanyal et al (82) were the first to describe the clinical picture of infection of the TIPS stent. Their diagnosis was based on the presence of fever with positive blood cultures and (i) the presence of stent thrombus or vegetations or (ii) persistent bacteremia in a patient with a TIPS and no other detectable source of infection (9,82). Clinical signs and symptoms reported in this setting included fever, tender hepatomegaly, hypoxemia, septic pulmonary emboli, septic shock, neutrophilia, and subsequent development of necrotizing fasciitis (9,82). The causative organisms included oral and enteric aerobic Gram-negative bacteria and *Candida* species (9). Most patients responded to antibiotic therapy (9,82). DeSimone et al (84) studied 99 TIPSs created during an 8-year period and identified five patients with no other alternative source of bacteremia who were presumed to have TIPS stent infections. Patients developed bacteremia a median of 100 days after TIPS placement (range, 6–732 d), well beyond the effective period of antibiotic prophylaxis. Bacteremia resolved in all cases after treatment with IV antibiotic agents (84). Although acute infection related to TIPS creation appears to be uncommon, and the value of prophylactic antibiotic agents has not been demonstrated via

randomized clinical trials, most investigators continue to administer antibiotic prophylaxis to patients before TIPS procedures (8,9,13).

Procedure classification: clean; clean-contaminated
Organisms encountered: skin flora (*S epidermidis*, *S aureus*), *Corynebacterium* species, biliary pathogens, enteric Gram-negative rods, anaerobes, *Enterococcus* species
Routine prophylaxis recommended: yes
First-choice antibiotic agent: no consensus
Common antibiotic choices: (i) 1 g ceftriaxone IV or (ii) 1.5–3 g ampicillin/sulbactam IV; (iii) if penicillin-allergic, can use vancomycin or clindamycin and aminoglycoside
Level of evidence: 2, 4, 5

NONVASCULAR INTERVENTIONS

Fluoroscopically Guided Gastrostomy and Gastrojejunostomy Tube Placement

Fluoroscopically guided percutaneous radiologic gastrostomy was first described in 1981 (14,85). Since that time, technical modifications have been made, including use of larger-bore tubes (20–24 F vs initial use of 9–16 F tubes) and the introduction of gastropexy devices in 1986 (13,14,86). At present, the two most common methods of gastrostomy tube placement are the "push" method, which involves percutaneous introducer technique through the anterior abdominal wall, and the more commonly performed "pull" method, which traverses the oropharynx. Infectious complications of gastrostomy tube placement are most commonly peristomal infections. The pull placement technique has been associated with a high incidence of peristomal infectious complications (4%–30%), resulting in recommendations for routine prophylactic antibiotics for this procedure (87–89). A prospective, randomized trial of prophylactic antibiotic agents (90) showed that cefazolin (1 g IV) reduced the rate of infection from 28.6% to 7.4% in the setting of endoscopically placed (ie, pull-type) gastrostomy tubes. Of interest, an increasing incidence of antibiotic-resistant peristomal infections has been described, most commonly methicillin-resistant *S aureus*, attributed to nasopharyngeal colonization, which travels along the pull-type percutaneous endoscopic gastrostomy to the peristomal wound during gastrostomy placement (91–94). In principle, the percutaneous push technique avoids tube passage through the oropharynx and thereby prevents the deposition of microorganisms at the peristomal site. However, there are some data to suggest that, in head and neck cancer, there is an increased risk of peristomal infection and susceptibility to gastrostomy site infections irrespective of whether bacteria are introduced through the transoral or transesophageal route (14,95). Cantwell et al (14) described a 15% rate of peristomal infection in a series of 57 patients with head and neck cancer undergoing percutaneous gastrostomy ($n = 53$) or gastrojejunostomy ($n = 4$) tube placement (via the push or introducer technique). All instances of peristomal infection occurred in patients who had not received antibiotic prophylaxis ($n = 20$). Patients receiving prophylaxis ($n = 37$) were administered 1 g cefazolin IV and twice-daily cephalexin 500 mg for 5 days orally or via gastrostomy ($n = 35$), or clindamycin 600 mg IV and 600 mg twice daily orally or via gastrostomy for 5 days ($n = 2$) (14). Despite these findings, there remains controversy with regard to prophylaxis for push (ie, introducer) gastrostomy placement, as additional published data suggest no added benefit to antibiotic prophylaxis in this setting (95). Shastri et al (96) performed a prospective randomized double-blind placebo controlled trial in which 97 patients undergoing introducer percutaneous endoscopic gastrostomy placement for malignant oropharyngeal cancers were randomized to receive placebo or prophylaxis (2 g ceftriaxone IV). Infection rates were low in both groups, with clinically significant wound infection observed in one patient in each group during the immediate 7-day postprocedure follow-up (96).

Procedure classification: clean-contaminated.
Organisms encountered: skin flora (*S epidermidis*, *S aureus*), *Corynebacterium* species
Routine prophylaxis recommended: for pull technique, yes; for push technique, no consensus
First-choice antibiotic agent: pull technique, 1 g cefazolin IV
Special considerations: (i) second-generation cephalosporin (head/neck cancer); (ii) second-generation cephalosporin followed by an oral course of a first-generation cephalosporin (head/neck cancer); (iii) if penicillin-allergic, can use vancomycin or clindamycin
Level of evidence: 2, 3, 5

LIVER AND BILIARY INTERVENTIONS

Biliary Drainage

The normal unobstructed biliary tree typically contains no bacteria (13). However, in the setting of biliary disease, the biliary tract should be viewed as contaminated (13,97). The incidence of infectious complication after biliary drainage procedures has been reported to vary between 24% and 46%, with most interventional radiologists routinely using antibiotic prophylaxis for biliary drainage (13). In the survey of IR prophylaxis regimens by Dravid et al (8), 89% of respondents indicated that they always used prophylaxis for biliary drainage, with 53% of nonusers reporting infective complications after biliary drainage. Preprocedural biliary cultures have been reported to be useful in planning the antibiotic strategy, although few interventionalists routinely perform them (13). When obtained, the most common isolates include *Enterococcus* species, as well as yeast, Gram-negative aerobic bacilli, and *Streptococcus viridans* (9,98). Selected strains associated with mortality include *E coli* and *Clostridium* species, which have been isolated in as many as 75% of cases of fatal biliary sepsis (9,99). Risk factors for bacterial colonization in patients with biliary obstruction undergoing percutaneous biliary drainage include periprocedural fever, previous biliary instrumentation, and bilioenteric anastomosis (9,98).

Although a majority of interventionalists report antibiotic prophylaxis before biliary drainage, there is variation regarding the regimen advocated. Clark

et al (100) performed a prospective study of 480 biliary procedures, ranging from simple tube injection to primary biliary drainage tube placement, in which all patients received 1 g cefotetan IV for prophylaxis. Forty-two patients developed an increased white blood cell count or fever, with seven (2%) developing overt sepsis; greater infection risk was observed in patients who had undergone biliary intervention previously (9,100). As a result, these authors have advocated the addition of 4 g IV mezlocillin to cefotetan in patients with a history of biliary intervention (100). Other investigators advocate prophylaxis with third-generation cephalosporins, given these antibiotic agents' enhanced biliary excretion compared with second-generation agents (9). Ryan et al (9) advocate the use of 1 g ceftriaxone IV, citing its long duration of activity and its favorable dosing schedule. Ampicillin/sulbactam is considered by many the optimal antibiotic agent for prophylaxis in the setting of biliary intervention, given its activity against *Enterococcus* species (9).

As noted by Ryan et al (9), patients with advanced biliary disease, including those with hepatolithiasis, are at significant risk of liver abscess formation, secondary biliary cirrhosis, portal hypertension, and death from sepsis or hepatic failure. In these patients, the boundary between prophylaxis and therapy is becomes blurred. Effective antimicrobial therapy is as crucial a component of therapy as relief of bile stasis by IR manipulation or clearance of biliary stone burden (9). Sheen-Chen et al (101) demonstrated the presence of bacteria in the bile of all patients with hepatolithiasis, most commonly Gram-negative bacteria such as *Klebsiella* species, *E coli*, and *Pseudomonas, Enterococcus*, and *Bacteroides* species, the latter being the most frequently found anaerobes (9,101). As is the case for other IR interventions, antibiotic treatments should be adjusted according to the results of bacteriologic cultures, with antibiotic therapy continued in the setting of obstruction, until relief of the obstruction has been achieved (9,13,101).

Procedure classification: clean-contaminated; contaminated
Organisms encountered: *Enterococcus* species, *Candida* species, Gram-negative aerobic bacilli, *S viridans, E coli*, and *Clostridium* species; *Klebsiella, Pseudomonas*, and *Bacteroides* species, particularly in cases of advanced biliary disease, including hepatolithiasis
Routine prophylaxis recommended: yes
First-choice antibiotic agent: no consensus
Common antibiotic choices: (i) 1 g ceftriaxone IV; (ii)1.5–3 g ampicillin/sulbactam IV; (iii) 1 g cefotetan IV plus 4 g mezlocillin IV; (iv) 2 g ampicillin IV plus 1.5 mg/kg gentamicin IV; (v) if penicillin-allergic, can use vancomycin or clindamycin and aminoglycoside
Level of evidence: 5

GU PROCEDURES

Percutaneous Nephrostomy Tube Placement, Tube Exchange, Ureteral Stents

Percutaneous nephrostomy and ureteric stent implantation are common IR procedures (13,102). In general, procedures performed in the GU tract are regarded as clean-contaminated when they are performed on an unobstructed system, with no previous infection and no history of intervention (7). Factors predisposing to infection include advanced age, diabetes, bladder dysfunction, indwelling catheter, earlier manipulation, ureterointestinal anastomosis, bacteriuria, and stones (7,9,13,103,104). In these patients, the GU tract should be managed as contaminated (7). The GU tract is regarded as dirty if clinical infection is present; in these instances, antibiotic therapy rather than prophylaxis is the appropriate aim (7). The most common organisms to infect the GU tract are Gram-negative rods (*E coli, Proteus* species, and *Klebsiella* species) and *Enterococcus* species (7). If culture results are not available, ampicillin combined with gentamicin or sulbactam is appropriate, as is ceftriaxone (7,13). Cronan et al (102) described an incidence of bacteremia of 17% in patients undergoing nephrostomy tube exchange, with no difference in incidence between patients receiving preprocedural antibiotic agents compared with those who did not (102). Serious infectious complications are encountered in patients undergoing treatment for urinary obstruction, with septic shock reported in as many as 7% of patients undergoing nephrostomy drainage for pyonephrosis (7,103–106). Cochran et al (104) stratified patients into a high-risk group (aforementioned risk factors) and a low-risk group (none of the aforementioned risk factors) (104). In the low-risk group, 14% developed evidence of sepsis when prophylactic antibiotic drugs were not given; 10% developed evidence of sepsis when prophylactic antibiotic drugs were given (no statistical difference). In the high-risk group, these figures were 50% and 9%, respectively (104). Despite these results, many authors recommend the use of a prophylactic antibiotic agent for all patients, irrespective of risk, with a majority of interventionalists reporting routine antibiotic prophylaxis for GU procedures, and nonusers reporting a 40% incidence of infective complications (8,13). An exception to this practice includes the routine tube change in uninfected and unobstructed immunocompetent cases, in which routine prophylaxis has not been described in the literature, and is not warranted (7). Patients who have signs of infection, or who are classified into a high risk group as mentioned earlier, should be treated with an appropriate antibiotic agent before intervention (9). As in biliary interventions, antibiotic treatment should be continued to treat obstructed systems until relief of obstruction is achieved. The results of urine cultures should be used to tailor ongoing therapy (9).

Procedure classification: clean-contaminated; contaminated
Organisms encountered: *E coli* and *Proteus, Klebsiella*, and *Enterococcus* species
Routine prophylaxis recommended: yes (except for routine tube change in uninfected patients)
First-choice antibiotic: no consensus
Common antibiotic choices: (i) 1 g cefazolin IV; (ii) 1 g ceftriaxone IV; (ii) 1.5–3 g ampicillin/sulbactam IV; (iv) 2 g ampicillin IV and 1.5 mg/kg gentamicin IV; (v) If penicillin-allergic, can use vancomycin or clindamycin and aminoglycoside
Level of evidence: 4, 5

TUMOR ABLATION

Percutaneous tumor ablation, including radiofrequency (RF) ablation, has effectively treated small (< 3 cm) liver lesions, and has shown promise in the treatment of lung, renal, and adrenal tumors (13,107–110). The issue of prophylactic antibiotic agents for tumor ablation is controversial, with some operators administering them universally and others only in selected cases (13). There have been no randomized controlled trials on antibiotic agent use in patients undergoing RF ablation; at present, most of the published data pertaining to this topic relate to the personal experience of various groups (13). Infections after tumor ablation have been mostly described in the setting of hepatic RF ablation, with complications including cholangitis and liver abscess being rare (reported in < 1.5% of cases) but potentially severe (13,111,112). Instances in which patients are at an increased risk of hepatic abscess warrant careful evaluation, and include histories of bilioenteric anastomosis, biliary stent placement, and sphincterotomy, all of which lead to retrograde enteric bacterial communication with the biliary tract (13). As noted by Choi et al (111), the mechanism of abscess formation is thought to result from bacterial colonization and growth in the zone of ablation (111). Before RF ablation of hepatic lesions in routine cases, investigators have recommended 1.5 g IV ampicillin/sulbactam (13). There remains no consensus on the effectiveness of prophylactic antibiotic agents for patients undergoing RF ablation of liver, lung, adrenal, renal, or other solid lesions (13). Indeed, the occurrence of delayed abscess formation weeks after tumor ablation despite prophylactic antibiotic coverage makes superinfection of the thermal lesion a possibility, given that thermally damaged tissue may provide an especially favorable environment for bacterial growth (109). This phenomenon highlights the importance of postprocedural follow-up and surveillance to ensure timely and appropriate antibiotic therapy, in addition to up-front prophylaxis in patients at risk. In the absence of definitive scientific evidence, many practitioners continue to empirically use prophylaxis (13,64,112).

Procedure classification (site-dependent): clean; clean-contaminated (eg, bilioenteric anastomosis/bypass)
Organisms encountered (organ-dependent): generally *S aureus, S epidermidis, Streptococcus* species with or without *E coli*; in cases of previous bilioenteric anastomosis, consider organisms similar to those for liver/biliary intervention, eg, *E coli, Proteus* species, *Klebsiella* species, and *Enterococcus* species
Routine prophylaxis recommended: no consensus
First-choice antibiotic agent: no consensus
Common antibiotic choices: (i) 1.5 g ampicillin/sulbactam IV (liver); (ii) 1 g ceftriaxone IV (renal); (iii) 1 g cefazolin IV (bone); alternate choices (site-dependent), (iv) if penicillin-allergic, can substitute vancomycin or clindamycin for Gram-positive coverage; aminoglycoside for Gram-negative coverage
Level of evidence: 8

PERCUTANEOUS ABSCESS DRAINAGE

Patients referred for percutaneous abscess drainage are typically already being treated with antibiotic drugs (7). When patients are referred for percutaneous abscess drainage and are not already being treated with antibiotic drugs, the IR physician should evaluate the appropriateness of empiric antibiotic therapy before obtaining culture data via catheter drainage. In the absence of published data on this subject, it is the opinion of the authors that empiric antibiotic coverage before abscess drainage should be reserved for patients who present with clinical signs and symptoms of infection (eg, fever, leukocytosis) at the time of the drainage procedure. Admittedly, antibiotic agent use in this setting spans the boundary between prophylaxis and treatment. As abscesses are typically polymicrobial, broad-spectrum antibiotic agents are warranted in the absence of existing culture data. In the otherwise asymptomatic patient, there is potential benefit to avoiding unnecessary wide-spectrum antibiotic coverage by awaiting the results of culture and sensitivity of drainage specimens when available. The most common bacteria found in intraabdominal abscesses are Gram-negative rods and anaerobes, particularly *E coli, Bacteroides fragilis*, and *Enterococcus* species (7,8,113). Pyogenic liver abscesses are most often caused by *Enterobacter* species and anaerobes (7,114). Older antibiotic regimens used in this setting have included ampicillin, gentamicin, and metronidazole, but more common current regimes include second- or third-generation cephalosporins, such as cefoxitin 1 g IV every 6 hours, ceftriaxone 1 g IV every 24 hours, or ampicillin/sulbactam 3 g IV every 6 hours. A combination of clindamycin and gentamicin may be used if the patient has a severe penicillin allergy (8).

Procedure classification: dirty
Organisms encountered: skin flora, *S epidermidis, S aureus, Corynebacterium* species; intracavitary pathogens, Gram-negative bacteria, *Enterococcus* species, *E coli, B fragilis*, other anaerobes
Routine prophylaxis recommended: yes
First-choice antibiotic agent: no consensus
Common antibiotic choices: (i) 1–2 g cefoxitin IV every 6 hours; (ii) 1–2 g cefotetan IV every 12 h; (iii) 1 g ceftriaxone IV every 24 h; (iv) 3 g ampicillin/sulbactam IV every 6 h; (v) if penicillin-allergic, can use vancomycin or clindamycin for Gram-positive coverage; aminoglycoside for Gram-negative coverage
Level of evidence: 8

PERCUTANEOUS BIOPSY

As noted by McDermott et al (7), image-guided biopsies do not require antibiotic prophylaxis unless performed via the transrectal route. The most common indication for the transrectal approach is prostate biopsy (7). Suggested prophylaxis for this procedure includes preprocedural gentamicin 80 mg intramuscularly (IM) 30

minutes before the procedure, followed by a 5-day course of oral ciprofloxacin 250 mg twice daily (7). Sieber et al (113) advocate the use of oral ciprofloxacin 500 mg twice daily for 4 days, commencing the day before biopsy. In their retrospective review of 4,439 biopsies performed with the use of this antibiotic regimen (113), infective complications (ie, urinary tract infection) occurred in a minority of patients ($n = 5$).

Procedure classification: nontransrectal, clean; transrectal, contaminated
Organisms encountered: transrectal, Gram-negative bacteria, *Enterococcus* species, *E coli, B fragilis*, other anaerobes
Routine prophylaxis recommended: yes (transrectal route); no (nontransrectal route)
First-choice antibiotic agent: transrectal, no consensus
Common antibiotic choices: transrectal, (i) 80 mg gentamicin IM plus 250 mg ciprofloxacin twice daily orally for 5 days; (ii) 500 mg ciprofloxacin twice daily orally for 4 days, commencing the day before biopsy
Level of evidence: 4

PERCUTANEOUS VERTEBROPLASTY

Vertebroplasty is employed to treat the pain associated with osteoporotic compression fractures and pathologic vertebral compression (13). Postprocedure infection is rare in this setting, and clinical data from randomized trials are currently lacking. However, when infection does occur in this setting, surgical debridement of the infected vertebral body can be technically very difficult (13,115,116). The common pathogens are from skin flora. Prophylactic antibiotics are therefore commonly administered to these patients, with some investigators adding antibiotics to the polymethyl methacrylate before intraosseous injection, although the efficacy of the latter has not been proven (13,117). An appropriate prophylactic regimen against the involved pathogens involves 1 g cefazolin IV 30 minutes before the procedure (13). If the patient is allergic to penicillin or cephalosporins, vancomycin may be administered (13).

Procedure classification: clean
Organisms encountered: skin flora (*S epidermidis, S aureus, Corynebacterium* species)
Routine prophylaxis recommended: yes
First-choice antibiotic agent: (i) 1 g cefazolin IV
Alternate choices: (ii) if penicillin-allergic, can use vancomycin or clindamycin
Level of evidence: 8

MANAGEMENT OF ANTIBIOTIC HYPERSENSITIVITY

Patients frequently state that they have a penicillin allergy (9). However, penicillin allergies are only uncommonly manifested as an anaphylactic reaction. Macpherson et al (118) studied 1,260 patients attending a preadmission clinic before routine surgery, among whom 22% described an antibiotic allergic reaction. After review of the patient medical charts and on further follow-up questioning, the majority of "allergies" were known side effects of the drugs (118). In all patients who had been administered an alternative agent as a result of a history of previous "penicillin allergy," none were found to have had a previous allergic reaction (13,118). Patients who have a questionable penicillin allergy, or have had only fever or rash, may be safely given β-lactam antibiotic agents without fear of anaphylaxis (9,13). If a patient has a penicillin allergy, the clinician should determine whether it is of an anaphylactic or nonanaphylactic variety (9). Two percent of the population has some degree of penicillin hypersensitivity, but most reactions to β-lactam agents are nonanaphylactic and usually manifest clinically as a mild maculopapular rash or fever (9). Such considerations are not insignificant, as the cost of prescribing alternative agents to a patient with a documented penicillin allergy can be more than double the cost of an appropriate penicillin and generally results in the use of more broad-spectrum agents, which are more likely to confer antibiotic resistance (13,119). Penicillin allergies are only uncommonly caused by an anaphylactic reaction (eg, bronchospasm, laryngospasm, hypotension, or hives) (13). However, if a patient has had an anaphylactic reaction to penicillins, they should never receive penicillin. In addition, use of cephalosporins in these patients should be approached with caution because of the 15% cross-hypersensitivity with these agents (9). However, it is advisable in this setting to query hospital records to determine if the patient has ever received a cephalosporin in the past without allergic reaction. If so, a cephalosporin can be used in the future. Although monobactams (eg, aztreonam) are structurally related to β-lactam agents, they are unrelated in terms of allergic potential (9). There is no cross-reactivity between monobactam and β-lactam agents, and these drugs may be used safely in patients with anaphylactic reactions to β-lactam agents (9,120). However, it should be noted that there is cross-reactivity between carbapenem (eg, imipenem, meropenem) and β-lactam agents.

MANAGEMENT OF VALVULAR HEART DISEASE

Current AHA recommendations for antibiotic prophylaxis against infective endocarditis (IE) are for those cardiac conditions associated with the highest risk of adverse outcomes from endocarditis (121). These include cases of prosthetic cardiac valve or prosthetic material used for cardiac valve repair; previous IE; unrepaired cyanotic congenital heart disease, 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 congenital heart disease with residual defects at the site or adjacent to the site of a prosthetic patch or prosthetic device (which inhibit endothelialization); and cardiac transplantation recipients who develop cardiac valvulopathy (121). Notably, except for these conditions, IE prophylaxis is not recommended for any other form of congenital heart disease, including mitral valve prolapse (121).

For patients at high risk who undergo an invasive respiratory tract procedure to treat an established infection, such as drainage of an ab

scess or empyema, the antibiotic regimen administered to these patients should contain an agent active against *S viridans* (121). Suggested regimens include 2 g amoxicillin orally, 2 g ampicillin IM or IV, or 1 g cefazolin IM or IV or 1 g ceftriaxone IM or IV (121). In patients allergic to penicillin or ampicillin and able to take oral medications, 2 g cephalexin orally or 600 mg clindamycin orally or 500 mg azithromycin orally or 500 mg clarithromycin orally may be administered (121). In patients allergic to penicillins or ampicillin and unable to take oral medication, 1g cefazolin IM or IV or 1 g ceftriaxone IM or IV or 600 mg clindamycin IM or IV may be administered (121). If the infection is known or suspected to be caused by *S 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 agent (121). Vancomycin should be administered if the infection is known or suspected to be caused by a methicillin resistant strain of *S aureus* (121).

In a departure from previous recommendations, the AHA indicated in their 2007 guidelines (121) that administration of prophylactic antibiotic agents solely to prevent endocarditis should not be recommended for patients who undergo GU or GI tract procedures. Reasons cited for this departure include the lack of studies showing a possible association between GI or GU tract procedures and IE (122,123). As indicated by Wilson et al (121), the cases of IE temporally associated with a GI or GU tract procedure have been largely anecdotal, with a single or very small number of cases reported. No published data demonstrate a conclusive link between procedures of the GI or GU tract and the development of IE (121). Also cited is the increase in *Enterococcus* species resistant to penicillins, vancomycin, and aminoglycosides (122–124). These were antibiotics recommended for IE prophylaxis in previous AHA guidelines (125). Therefore, only in patients at high risk 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 is antienterococcal coverage considered reasonable, such as with penicillin, ampicillin, piperacillin, or vancomycin (121). However, as noted by the current AHA guideline authors (121), no published studies demonstrate that such therapy would prevent enterococcal IE. For patients at high risk scheduled for an elective ureteral stent placement or other urinary tract manipulation who have an enterococcal urinary tract infection or colonization, antibiotic therapy to eradicate *Enterococcus* species from the urine before the procedure is considered reasonable (121). Amoxicillin or ampicillin is the preferred agent for enterococcal coverage for these patients. Vancomycin may be administered to patients unable to tolerate ampicillin (121).

For patients at high risk who undergo an invasive procedure that involves infected skin, skin structure, or musculoskeletal tissue, the therapeutic regimen administered for treatment of the infection should contain an agent active against *Staphylococcus* species and β-hemolytic *Streptococcus* species, such as an antistaphylococcal penicillin or a cephalosporin (121). Vancomycin or clindamycin may be administered to patients unable to tolerate a β-lactam agent or who are known or suspected to have an infection caused by a methicillin-resistant strain of *Staphylococcus* (121).

CONCLUSIONS

Effective antibiotic prophylaxis for vascular and IR requires a thorough knowledge of likely pathogens, procedure-specific infection risks, and appropriate antibiotic coverage (7). Choice of medication should also take into account patient-specific factors, including renal and hepatic function and antibiotic allergy history. There continues to be few randomized controlled data to help formulate the prophylactic regimens for interventional procedures. Clinical practice is largely informed, at present, via existing surgical data and interventional radiology cohort studies and clinical series. Given the ability of antibiotic resistance to obviate historically effective regimens, an ongoing review of current primary surgical and IR literature on this topic by interventional radiologists remains crucial. It is equally important to remain abreast of current hospital and/or area practice. These measures underscore a timely and evidence-based approach to antibiotic prophylaxis for interventional procedures.

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APPENDIX A: CONSENSUS METHODOLOGY

Reported complication-specific rates in some cases reflect the aggregate of major and minor complications. Thresholds are derived from critical evaluation of the literature, evaluation of empirical data from Standards of Practice Committee members' practices, and, when available, the SIR HI-IQ System national database.

Consensus on statements in this document was obtained with a modified Delphi technique (1–3).

APPENDIX B

Levels of Evidence and Classes of Recommendation to Adhere to Definitions Established by the American College of Cardiology/American Heart Association Guidelines Task Force (4,5)

Level of Evidence	Definition
1	Randomized clinical trials or metaanalyses of multiple clinical trials with substantial treatment effects
2	Randomized clinical trials with smaller or less significant treatment effects
3	Prospective, controlled, nonrandomized, cohort studies
4	Historic, nonrandomized, cohort, or case-control studies
5	Case series: patients compiled in serial fashion, lacking a control group
6	Animal studies or mechanical model studies
7	Extrapolations from existing data collected for other purposes, theoretical analyses
8	Rational conjecture (common sense); common practices accepted before evidence-based guidelines

APPENDIX C: SIR STANDARDS OF PRACTICE COMMITTEE CLASSIFICATION OF COMPLICATIONS BY OUTCOME

Minor Complications

A. No therapy, no consequence

B. Nominal therapy, no consequence; includes overnight admission (up to 23 hours) for observation only.

Major Complications

C. Require therapy, minor hospitalization (> or = to 24 hrs, but < 48 hours)

D. Require major therapy, unplanned increase in level of care, prolonged hospitalization (> 48 hours).

E. Permanent adverse sequelae

F. Death

Practice Guidelines for Antibiotic Prophylaxis During Vascular and Interventional Radiology Procedures

Procedure	Potential Organisms Encountered	Routine Prophylaxis Recommended	First-choice Antibiotic
Angiography, angioplasty, thrombolysis, arterial closure device placement, stent placement	*S aureus, S epidermidis*	No	None
Endograft placement	*S aureus, S epidermidis*	Yes	Cefazolin 1 g IV
Superficial venous insufficiency treatment	*S aureus, S epidermidis*	No	None
IVC filter placement	*S aureus, S epidermidis*	No	None
Tunneled central venous access	*S aureus, S epidermidis*	No consensus	None
Embolization and chemoembolization (if intent to create infarction or high likelihood of infarction)	*S aureus, S epidermidis, Streptococcus* spp, *Corynebacterium* spp, and/or enteric flora (if prior sphincter of Oddi manipulation or bilioenteric surgery)	Yes	No consensus
UAE	*S aureus, S epidermidis, Streptococcus* spp, and/or *E coli*	Yes	No consensus
TIPS creation	*S aureus, S epidermidis, Corynebacterium* spp, biliary pathogens, enteric Gram-negative rods, anaerobes, *Enterococcus* spp	Yes	No consensus
Fluoroscopically guided gastrostomy and gastrojejunostomy tube placement	*S aureus, S epidermidis, Corynebacterium* spp	No consensus (if introducer "push" technique); Yes (if pull gastrostomy)	1g cefazolin IV (pull gastrostomy)
Liver and biliary interventions	*Enterococcus* spp, *Streptococcus* spp, aerobic Gram-negative organisms (*E coli, Klebsiella* spp, etc) *Clostridium* spp, *Candida* spp, and anaerobes	Yes	No consensus
GU procedures	*E coli, Proteus, Klebsiella, Enterococcus*	Yes	No consensus
Tumor ablation	*S aureus, S epidermidis, Streptococcus* spp, and/or *E coli*	No consensus	No consensus
Percutaneous abscess drainage	*S aureus, S epidermidis, Corynebacterium* spp; aerobic Gram-negative bacteria and anaerobes	Yes	No consensus
Percutaneous biopsy	Transrectal: bowel flora, mostly anaerobes and aerobic Gram-negative, *Streptococcus* spp	No (nontransrectal); yes (transrectal)	Nontransrectal, none; transrectal, 80 mg gentamicin IV/IM plus 250 mg ciprofloxacin twice daily orally for 5 d
Percutaneous vertebroplasty	*S aureus, S epidermidis, Corynebacterium* spp	Yes	1 g cefazolin IV

Practice Guidelines for Antibiotic Prophylaxis During Vascular and Interventional Radiology Procedures

Common Antibiotic Choices	Comments	Level of Evidence
1 g cefazolin IV (if high risk stent infection); if penicillin-allergic, can use vancomycin or clindamycin	Procedure classification: clean	5, 8
If penicillin-allergic, can use vancomycin or clindamycin	Procedure classification: clean	5, 8
None	Procedure classification: clean	8
None	Procedure classification: clean	5, 6
1g cefazolin IV (eg, immunocompromised patients before chemotherapy; history of catheter infection); if penicillin-allergic, can use vancomycin or clindamycin	Procedure classification: clean (nontunneled catheter: no prophylaxis)	8
1.5–3 g ampicillin/sulbactam IV (hepatic chemoembolization); 1 g cefazolin and 500 mg metronidazole IV (hepatic chemoembolization); 2 g ampicillin IV and 1.5 mg/kg gentamicin (hepatic chemoembolization); 1 g ceftriaxone IV (hepatic chemoembolization or renal, splenic embolization); if penicillin-allergic, use vancomycin or clindamycin and aminoglycoside	Special considerations: if patient without intact sphincter of Oddi, consider tazobactam/piperacillin and bowel preparation; procedure classification: clean-contaminated; contaminated (bilioenteric surgery)	4, 7, 8
(i) 1 g cefazolin IV; (ii) 900 mg clindamycin IV plus 1.5 mg/kg gentamicin IV; (iii) 2 g ampicillin IV; (iv) 1.5–3 g ampicillin/sulbactam IV; if penicillin-allergic, can use vancomycin or clindamycin	If history of hydrosalpinx, doxycycline 100 mg twice daily for 7 d; procedure classification, clean; clean-contaminated	4, 5, 8
(i) 1 g ceftriaxone IV; (ii) 1.5-3 g ampicillin/sulbactam IV; if penicillin-allergic, can use vancomycin and aminoglycoside	Procedure classification: clean; clean-contaminated	2, 4, 5
—	Procedure classification: clean-contaminated; special considerations: if head and neck cancer, consider (i) a second-generation cephalosporin; (ii) second-generation cephalosporin followed by oral course of first-generation cephalosporin, or (iii) clindamycin or vancomycin in penicillin-allergic patients	3, 5
(i) 1 g ceftriaxone IV; (ii) 1.5–3 g ampicillin/sulbactam IV; (iii) 1 g cefotetan IV and 4 g mezlocillin IV; (iv) 2 g ampicillin IV and 1.5 mg/kg gentamicin IV; (v) if penicillin-allergic, can use vancomycin or clindamycin and aminoglycoside	Procedure classification: clean-contaminated, contaminated	5
(i) 1 g cefazolin IV; (ii) 1 g ceftriaxone IV; (iii) 1.5–3 g ampicillin/sulbactam IV; (iv) 2 g ampicillin IV and 1.5 mg/kg gentamicin IV; (v) if penicillin-allergic, can use vancomycin or clindamycin and an aminoglycoside	Procedure classification: clean-contaminated; contaminated; cover any organisms already found in urine	4, 5
(i) 1.5–3 g ampicillin/sulbactam IV (liver); (ii) 1 g ceftriaxone IV (renal); (iii) 1 g ceftriaxone IV (bone); (iv) if penicillin-allergic, can use vancomycin or clindamycin for Gram-positive coverage and aminoglycoside for Gram-negative coverage	Procedure classification: (site-dependent) clean; clean-contaminated (eg, bilioenteric anastomosis/bypass)	8
(i) 1–2 g cefoxitin IV every 6 h (ii) 1–2 g cefotetan IV every 12 h; (iii) 3 g ampicillin/sulbactam IV every 6 h; (iv) 3.375 g piperacillin/tazobactam IV; if penicillin-allergic, can use vancomycin or clindamycin for Gram-positive coverage; aminoglycoside for Gram-negative coverage with or without metronidazole for anaerobic coverage	Procedure classification: dirty; antibiotics should cover anticipated organisms for empiric treatment and then adjusted for final culture results	8
500 mg ciprofloxacin twice daily for 4 d commencing the day before biopsy	Procedure classification: nontransrectal, clean; transrectal, contaminated	4
If penicillin-allergic, can use clindamycin or vancomycin	Procedure classification: clean	8

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