STANDARDS OF PRACTICE

Adult and Pediatric Antibiotic Prophylaxis during Vascular and IR Procedures: A Society of Interventional Radiology Practice Parameter Update Endorsed by the Cardiovascular and Interventional Radiological Society of Europe and the Canadian Association for Interventional Radiology

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ABBREVIATIONS

CI = confidence interval, IV = intravenous, IVC = inferior vena cava, TIPS = transjugular intrahepatic portosystemic shunt, UAE = uterine artery embolization

PREAMBLE

In 2010, the Society of Interventional Radiology (SIR) published its first practice guidelines regarding the use of antibiotic prophylaxis in vascular and interventional radiology (IR) (1). The present update to the original guidelines aims to address the expanding breadth of IR procedures, including the increasing prevalence of pediatric IR procedures, and the increasing repertoire of antibacterial agents.

As was the case for the original guidelines (1), the availability of randomized controlled data regarding antibiotic prophylaxis is lacking in the IR literature. Much data are derived from retrospective reviews

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A.M.V. receives grants from the Radiological Society of North America (Chicago, Illinois), Toshiba America Medical Systems (Tustin, California), and the University of Texas MD Anderson Cancer Center (Houston, Texas). None of the other authors have identified a conflict of interest.

An earlier version of this article appeared in J Vasc Interv Radiol 2010; 21:1611–1630.

Appendices A–D and Table E1 can be found by accessing the online version of this article on *www.jvir.org* and clicking on the Supplemental Material tab.

J Vasc Interv Radiol 2018; ■:1–19

https://doi.org/10.1016/j.jvir.2018.06.007

or extrapolated from surgical data. The relatively rare occurrence of infectious complications in IR makes large-volume, randomized controlled trials impractical. Nonetheless, antibiotic agents are an integral part of the periprocedural management of patients, and the operator must therefore be familiar with the most current clinical recommendations.

The Executive Summary (**Appendix A** [available online on the article's Supplemental Material page at *www.jvir.org*]) summarizes the updated clinical recommendations and qualifying statements. Levels of evidence have been assigned to the current recommendations on the basis of the type, quality, quantity, and consistency of the evidence, in accordance with the current American College of Cardiology/American Heart Association Clinical Practice Guideline Recommendation Classification System enabling comparison of the strength (class) and level (quality) of each recommendation with categories used by other guideline developers (2,3). This aligns with recommendations promoted by the Institute of Medicine in 2011 (4,5).

METHODOLOGY

SIR produces its Standards of Practice documents by using the following process. Topics of relevance and timeliness are conceptualized by the Standards of Practice Committee members, Service Lines, SIR members, or the Executive Council. A recognized expert or group of experts is identified to serve as the principal author or writing group for the document. Additional authors or societies may be sought to increase the scope, depth, and quality of the document depending on the magnitude of the project.

An in-depth literature search is performed, and 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 (**Table E1** [available online on the article's Supplemental Material page at *www.jvir.org*]), which is used to write the document such that it contains evidence-based data. 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 by using a modified Delphi consensus method (**Appendix D** [available online on the article's Supplemental Material page at *www.jvir.org*]) (6,7). 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 writing group and Standards of Practice Committee members by telephone conference calling or face-to-face meeting. The finalized draft from the Committee is sent to the SIR Operations Committee for approval. Any comments by the Operations Committee are discussed by the Standards of Practice Committee, and appropriate revisions are made to create the finished standards document before its submission for peer review, acceptance, and publication.

INTRODUCTION

Unlike the incision site/wound infections incurred during surgery, the infectious complications in IR are most likely the result of bacterial inoculation into the bloodstream. Common mechanisms include (*i*) contamination of a needle, catheter, or wire by contact with a nonsterile surface or residual skin flora during vascular access (8); (*ii*) traversal of small vessels located along the trajectory of a needle creating channels of communication for bacteria to enter the bloodstream (9); (*iii*) intravasation of bacteria into the bloodstream from an obstructed viscus or abscess cavity (10); and (*iv*) proliferation of bacteria on the inside or outside of an indwelling catheter tract. Antibiotic prophylaxis for IR procedures therefore aims to clear bacterial contamination from the bloodstream to prevent a systemic inflammatory reaction (ie, sepsis) or the seeding of foreign material (eg, a stent) or necrotic tissue created during embolization or ablation.

Percutaneous access limits the size and number of breaks in the body's natural defense system but does not wholly obviate pathogen entry points into the body. As the breadth and complexity of procedures and patients continues to expand, procedural and preprocedural precautions aimed at limiting the spread of infection are critical components to the comprehensive management of IR patients. Standard precautions in the interventional suite emulate those in the operating room and include maintenance of maximal sterile precautions, including operating in a sterile environment, adherence to aseptic technique, and an emphasis on hand hygiene (8,11).

PROCEDURE CLASSIFICATION

Although the pathogenesis behind infectious complications in IR is different than in surgery, IR procedures have in the past been categorized by using definitions established by the National Academy of Sciences/National Research Council surgical wound classification originally defined in 1964 (12). More recent studies have found that the definitions used in this classification scheme to describe infectious adverse events, including sepsis and systemic inflammatory immune response, have inadequate sensitivity and specificity, leading to discrepancies in incidence and observed mortality (13). Newer definitions have been outlined in the Third International Consensus Definitions for Sepsis and Septic Shock ("Sepsis 3"), including the sepsis-related organ failure assessment score to describe organ dysfunction/failure (13,14). **Table 1** lists the surgical wound classification scheme and definitions of infectious adverse events, defining relevant terms used throughout this document.

ANTIBIOTIC TIMING AND DOSAGE

Prophylactic antibiotic agents are, by definition, those that are administered before creation of an incision or puncture wound. Recommendations from the governing body on hospital and patient safety standards (The Joint Commission) are that intravenous (IV) antibiotic agents be administered within 1 hour of an incision (15). A recent large surgical study (16) has reiterated support for the 60-minute time frame and found no evidence to narrow the window. A repeat dose of antibiotic agents should be administered if a period of 2 hours has lapsed from the initial dose (17). In contrast, the administration of antibiotic agents after a procedure has been associated with 4 times the number of infectious complications, equivalent to rates encountered when no prophylaxis is administered (18).

In the setting of renal dysfunction, a single dose of antibiotic agent used in IR, such as cefazolin, ciprofloxacin, piperacillin/tazobactam, ampicillin/sulbactam, and trimethoprim/sulfamethoxazole, can be given safely, but subsequent doses may need dose or timing adjustment (19,20). Ceftriaxone, clindamycin, and moxifloxacin do not require dose adjustment in renal dysfunction (19). Vancomycin should always be dosed according to pharmacy protocol, and aminoglycosides (eg, gentamycin) should be avoided in patients with renal dysfunction (20).

General Pediatric Antibiotic Dosing

In adult patients, drug doses are standardized. However, in children, drugs are prescribed based on the patient's age, weight, body surface area, and/or clinical condition (21). For pediatric antibiotic regimens, doses are usually weight-based, and therefore careful calculation is required to ensure correct dosage. Pediatric patients therefore are at a higher risk than adults for experiencing the effects of dosing errors; this may result in subtherapeutic antibiotic dosing causing treatment failure and the emergence of resistant organisms (22) or supratherapeutic dosing and toxicity. Many institutions performing pediatric interventional procedures have an antibiotic dosing standardization that minimizes the risk of calculation errors and reduces the time required for dose calculation by the prescriber (21). **Appendix C** (available online on the article's Supplemental Material page at *www.jvir.org*) describes pediatric prophylactic antibiotic dosing considerations.

Neonatal/Infant Antibiotic Dosing

Pharmacodynamic and pharmacokinetic data for antibiotic and antifungal agent administration in neonates and infants is limited, as this patient population has often been excluded from clinical trials (23). Special considerations are required for neonates and infants when administering and monitoring antibiotic regimens. This is because differences in gastric pH, intestinal transit time, immaturity of secretion, bile and pancreatic fluid, variable renal function, and interventions such as extracorporeal membrane

Table 1. Definition of Terms

Definitions/Terminology	Examples
Surgical wound classification (11)	
Clean: Any procedure performed without active inflammation, does not break sterile technique and does not violate GI, GU, or respiratory tract	Conventional angiography is a clean procedure as it only enters a blood vessel
Clean contaminated: Procedure performed without active inflammation, does not break sterile technique but does enter GI, GU, or respiratory tract	Nephrostomy tube placement in the absence of urinary tract infection
Contaminated: Procedure that enters an inflamed area, colonized GI, GU, or respiratory tract or if there is major break in aseptic technique	Percutaneous biliary drain placement in setting of bilioenteric anastomosis or sphincterotomy, or percutaneous cholecystostomy tube placed for acute cholecystitis
Dirty: Entering an infected, purulent collection or viscus	Abscess drainage or percutaneous nephrostomy drainage of pyonephrosis
Colonization: Normal bacterial flora, ie, organisms that reside on a host surface without inciting an inflammatory response	*Staphylococcus epidermidis* is a common inhabitant of skin and typically does not cause inflammation
Bacteremia: Presence of bacteria within the bloodstream without signs and/or symptoms of clinical infection	–
Clinical infection: Signs and symptoms of inflammation as a response to infectious organism or its toxins	–
Sepsis: Life-threatening organ dysfunction caused by dysregulated host response to infection (13)	–
SOFA score: An organ failure score that numerically quantifies number and severity of failed organs (13)	–
Baseline SOFA score can be assumed to be 0 in patients with no preexisting organ dysfunction	
Organ dysfunction can be defined as acute change in total SOFA score $\geq$ 2 points consequent to infection	
SOFA score $\geq$ 2 reflects overall mortality risk of approximately 10% in a general hospital population with suspected infection; even patients presenting with modest dysfunction can deteriorate further, emphasizing seriousness of this condition and need for prompt and appropriate intervention, if not already being instituted	
Septic shock: A subset of sepsis in which underlying circulatory and cellular/metabolic abnormalities are profound enough to substantially increase mortality	
Patients with septic shock can be identified with a clinical construct of sepsis with persisting hypotension requiring vasopressors to maintain MAP $\geq$ 65 mm Hg and having serum lactate level $>$ 2 mmol/L (18 mg/dL) despite adequate volume resuscitation; with these criteria, hospital mortality rate is in excess of 40% (13)	–

GI = gastrointestinal; GU = genitourinary; MAP = mean arterial pressure; SOFA = sepsis-related organ failure assessment.

oxygenation have been shown to affect dosing, bioavailability, metabolism, and clearance of antibiotic agents (23,24). In addition, laboratory assays may be confounded by alterations in serum protein levels, leading to inaccuracies in drug level monitoring (24). Expert consultation is therefore recommended to guide appropriate dosing, frequency, and monitoring of prophylactic antibiotic regimens in neonates.

ANTIBIOTIC RESISTANCE

In 2014, the World Health Organization warned of the rapid emergence of drug-resistant bacteria and their ability to outpace the development of new and effective antimicrobial agents (25). Causes of this increasing prevalence include increasing placement of invasive devices, antibiotic agents in animal feeds, poor hand hygiene, and overuse/misuse of broad-spectrum antibiotic agents in humans (26). Epidemiologic studies have demonstrated a direct relationship between the consumption of antibiotic agents and the dissemination of resistant bacterial strains via direct transfer of genetic material between microorganisms (27). Furthermore, antibiotic agents select out drug-sensitive bacteria, leaving behind bacteria that have spontaneously mutated into multidrug-resistant organisms as a result of natural selection (27). Appropriate use of antibiotic agents includes selection of an agent with the narrowest spectrum of activity toward the source organism and antibiotic agent administration for a sufficient duration (28,29). Not only will this provide the patient with sufficient protection, but it will also limit the development of antibiotic resistance. Although broad-spectrum antibiotic agents can be used empirically in the setting of an active infection, their indiscriminate use as prophylactic agents is strongly discouraged.

PENICILLIN ALLERGY

Penicillin allergy is a commonly encountered phenomenon, reported in as many as 22% of the general population (30). The occurrence of rash, hives, abdominal pain, or nausea are known side effects of penicillin-based agents. Although these symptoms are unsettling for patients, they are not true hypersensitivities (31). True penicillin allergy, manifesting as bronchospasm, pulmonary edema, laryngospasm, and hypotension is relatively uncommon, occurring in approximately 2% of the general population (32). Although natural penicillins such as penicillin G or VK are uncommonly used in IR, their semisynthetic derivatives such as amoxicillin, ampicillin, and piperacillin should be avoided in patients with a true penicillin allergy. In such patients, agents without the β-lactam ring, such as vancomycin, clindamycin, or carbapenems, can be used as alternatives, keeping in mind their added cost and broader spectrum (32,33).

The incidence of cross-reactivity between cephalosporins and penicillin has historically been reported to be approximately 10% (34). Although the prevalence with agents such as cefadroxil has been reported to be as high as 27%, the cross-reactivity rate for more commonly used first- and second-generation cephalosporins (including cefazolin) is approximately 1% (35). In addition, cross-reactivity with third- and fourth-generation cephalosporins (such as ceftriaxone) is reported to be negligible (36).

ENDOCARDITIS PROPHYLAXIS

Guidelines for the prevention of infective endocarditis from the American Heart Association in 2007 and European Society of Cardiology in 2015 (37–39) indicate that prophylaxis against α-hemolytic streptococci (*Streptococcus viridans*) is indicated only for patients at high risk, including those with prosthetic valves, a history of infective endocarditis, congenital heart disease repaired with foreign material, or cardiac transplant with valvulopathy. In these patients, antibiotic agents are recommended before lung or chest biopsy or abscess/empyema drainage (37). Amoxicillin or cefazolin are effective agents, with clindamycin as an alternative in penicillin-allergic patients. Endocarditis prophylaxis is not recommended for patients undergoing "clean" procedures or "clean contaminated" genitourinary or gastrointestinal procedures (37).

FLUOROQUINOLONE USE AND TENDINOPATHY

Fluoroquinolones, including ciprofloxacin, levofloxacin, and moxifloxacin, are some of the most commonly used antibiotic agents in IR. Although their use is generally well tolerated, one particular side effect has garnered enough attention to warrant a black box warning by the US Food and Drug Administration (40). The risks of tendinopathy resulting in tendinitis and tendon rupture have been reported at frequencies of 2.4 and 1.2 per 10,000, respectively (41). The Achilles tendon is the most commonly involved, and the most common symptoms are pain and swelling (42). In a review of 98 cases (43), symptoms occurred as early as 2 hours and as late as 6 months after taking the medication, with 85% of patients presenting within 1 month. Risk factors for tendon rupture include advanced age, concurrent steroid use, renal dysfunction, and excessive loading as with athletes (44). Alternative prophylactic agents such as amoxicillin or amoxicillin/clavulanate can be considered. When *Escherichia coli* coverage is needed, trimethoprim/sulfamethoxazole, nitrofurantoin, or fosfomycin are recommended (45).

PROPHYLAXIS FOR SPECIFIC IR PROCEDURES

When available, updates to the literature since 2010 are summarized in the present document for each procedure, and changes to the recommendations are highlighted. When procedures are common to adult and pediatric patients, the data on antibiotic prophylaxis are summarized together. A standalone section on pediatric-specific procedures has also been added. **Table 2** lists the procedures, class of recommendation and associated level of evidence, and suggested antibiotic regimens. For those procedures for which antibiotic prophylaxis regimens are lacking in the published literature, but for which expert opinion regimens are known (eg, radioembolization prophylaxis), these regimens are listed in **Table 2** with the appropriate levels of evidence.

VASCULAR INTERVENTIONS

Diagnostic Angiography and Angioplasty

Bacteremia caused by angiography/angioplasty is most likely the result of inoculation of bacteria during arterial access or catheterization (46). Positive growth on postintervention culture media reported has been reported in as many as 16% of cases following angiography and in 27% after angioplasty (47). And although the occurrence of bacteremia is relatively common, the phenomenon is typically transient and does not necessarily translate into clinically significant infection. For instance, a retrospective review of nearly 3,000 diagnostic cerebral arteriography procedures (48) found an infectious adverse event rate of 0.1%, occurring only at the femoral access site. Angioplasty has also not been shown to increase the incidence of infection, with an incidence of 0.6% among 4,217 coronary angioplasties (49). Given the low incidence of infectious complications with these procedures, routine use of prophylactic antibiotic agents is not indicated. There are, however, several risk factors that place patients at high risk for infectious complications during these procedures. These include long procedure duration, number of catheterizations at the same site, difficult arterial access, and postprocedure maintenance of an arterial sheath (49). Local bleeding and congestive heart failure were also identified as independent risk factors for bacteremia in a meta-analysis of more than 22,000 cardiac catheterizations (50). In such circumstances, prophylactic agents targeted to skin flora (ie, cefazolin) could be considered. (No new data or changes to recommendations.)

Bare Metal Stent Placement

Theoretically, a bare metal stent placed into an artery or vein could serve as a nidus for bacterial adherence and proliferation. With adherence to sterile technique, the occurrence is extremely uncommon, with only 48 cases of noncoronary bare metal stent infections reported since 1966 (51). Routine antibiotic prophylaxis is therefore not warranted. Certain patients at high risk in whom antibiotic agents should be considered include cases of advanced age, chronic kidney disease, diabetes, immunosuppression, long procedures with multiple guide wire exchanges, placement of indwelling catheters in place > 6 hours, and known colonization by drug-resistant organisms (51,52). (No new data or changes to recommendations.)

Arterial Endografts

Graft infection is very rare, occurring in fewer than 1% of placements (53–55). Nonetheless, an endograft infection carries high morbidity and mortality rates (as high as 27%), as the tight interstices of a covered stent can be extremely difficult to sterilize (54). As with bare metal stents, the underlying cause of stent infection is most likely contamination with skin flora (53). The incidence of endograft infection has been found to be higher when performed in an emergency setting (56). Antibiotic prophylaxis targeted to skin flora is recommended, and a single preprocedural dose of cefazolin is an effective regimen (56). As noted in 1 study (56), only 12 stent infections were identified in a total of 1,432 thoracic and abdominal aortic stent grafts placed over a 13-year period during which this regimen was used. (New data reviewed, no changes to recommendations.)

Catheter-Directed Thrombolysis

As noted for diagnostic angiography, the risk factors that predispose a patient to infectious complications include multiple catheterizations and maintenance of sheaths overnight. Although no specific recommendations regarding the use of antibiotic prophylaxis are available, catheter-directed thrombolysis may be a situation in which antibiotic agents targeted to skin flora can be used. In a series of 69 acutely thrombosed infrainguinal arterial bypass grafts, Conrad et al (57) routinely used a single prophylactic cephalosporin and reported no infectious complications. Other studies have suggested that no routine prophylaxis is necessary. A multiinstitutional retrospective review of 57 pediatric patients (64 limbs) who underwent catheter-directed thrombectomy and/or pharmacomechanical thrombolysis over a period of 10 years (58) and a prospective cohort of 95 pediatric patients who underwent catheter-directed mechanical or pharmacomechanical thrombolysis (59) reported no use of prophylactic antibiotic agents and no infectious complications. (New data reviewed, no changes to recommendations.)

Table 2. Suggested Antibiotic Regiments for Vascular and Interventional Radiology Procedures

Procedure	Class of Recommendation	Level of Evidence	Potential Organisms Encountered	Procedure Classification	Routine Prophylaxis Recommended*	First-Choice Antibiotic	Suggested Antibiotic Regimens	Other Antibiotic Regimens	Comments*
Diagnostic angiography and angioplasty	III	B-NR	*Staphylococcus aureus*, *Staphylococcus epidermis*	Clean	No	None	NA	NA	Special considerations: 1–2 g cefazolin IV in high-risk patients; vancomycin recommended in penicillin-allergic patients
Intravascular placement of bare metal stent	III	C-LD	*S. aureus*, *S. epidermis*	Clean	No	None	NA	NA	Special considerations: 1–2 g cefazolin IV in high-risk patients; vancomycin recommended in penicillin-allergic patients
Arterial endografts	IIb	B-NR	*S. aureus*, *S. epidermis*	Clean	Yes	1–2 g cefazolin IV	NA	NA	Vancomycin recommended in penicillin-allergic patients
AV fistula and graft angioplasty, stent placement, thrombectomy. and coil embolization	IIb	C-LD, C-EO	*S. aureus*, *S. epidermis*	Clean	No	None	NA	NA	Special considerations: 1–2 g cefazolin IV in high-risk patients, especially those receiving covered stent; vancomycin recommended in penicillin-allergic patients
Closure devices	III	B-NR	*S. aureus*, *S. epidermis*	Clean	No	None	NA	NA	Special considerations: 1–2 g cefazolin IV in high-risk patients; vancomycin recommended in penicillin-allergic patients
Uterine artery embolization	IIa	C-EO	*S. aureus*, *S. epidermis*, *Streptococcus* spp., *Escherichia coli*, vaginal flora	Clean, clean contaminated	Yes	No consensus	1–2 g cefazolin IV	(i) 900 mg clindamycin IV + 1.5 mg/kg gentamicin; (ii) 2 g ampicillin IV; (iii) 1.5–3 g ampicillin/sulbactam IV; (iv) 100 mg doxycycline twice daily for 7 d (in women with hydrosalpinx)	Vancomycin recommended in penicillin-allergic patients
Hepatic embolization and chemoembolization	IIb	B-NR, C-LD	*S. aureus*, *S. epidermidis*, enteric flora: anaerobes, eg, *Bacteroides* spp., *Enterococcus* spp., *Enterobacteriaceae* spp. (*E. coli*, *Klebsiella* spp., *Lactobacillus* spp.), *Candida* spp.	Clean, clean contaminated (if history of biliary colonization)	Yes	No consensus	With competent sphincter of Oddi: (i) 1.5–3 g ampicillin/sulbactam IV (hepatic chemoembolization); (ii) 1 g cefazolin + 500 mg metronidazole IV (hepatic chemoembolization); (iii) 2 g ampicillin IV + 1.5 mg/kg gentamicin (hepatic chemoembolization);	With incompetent sphincter of Oddi: oral moxifloxacin 400 mg/d beginning 3 d before and continuing for 17 d postprocedure, (ii) levofloxacin 500 mg/d + metronidazole 500 mg twice daily beginning 2 wk after chemoembolization with bowel	Vancomycin or clindamycin/gentamycin recommended in penicillin-allergic patients

continued

Table 2. Suggested Antibiotic Regiments for Vascular and Interventional Radiology Procedures *(continued)*

Procedure	Class of Recommendation	Level of Evidence	Potential Organisms Encountered	Procedure Classification	Routine Prophylaxis Recommended*	First-Choice Antibiotic	Suggested Antibiotic Regimens	Other Antibiotic Regimens	Comments*
							(iv) 1 g ceftriaxone IV (hepatic chemoembolization or renal, splenic embolization)	preparation of neomycin 1 g + erythromycin base 1 g orally at 1, 2, and 11 PM the day before chemoembolization and 1 g ceftriaxone IV preprocedure; (iii) 1.5–3 g ampicillin sulbactam IV; (iv) 1–2 g cefazolin IV with 500 mg metronidazole IV preprocedure followed by amoxicillin/clavulanic acid for 5 d postdischarge	
Radioembolization	IIb	C-LD	*S. aureus*, *S. epidermidis*, enteric flora: anaerobes, eg, *Bacteroides* spp., *Enterococcus* spp., *Enterobacteriaceae* spp. (*E. coli*, *Klebsiella* spp., *Lactobacillus* spp.), *Candida* spp.	Clean, clean contaminated (if history of biliary colonization)	No consensus	No consensus	With competent sphincter of Oddi: none	When infusing proximal to cystic artery: ciprofloxacin 500 mg twice per day for 5 d; with incompetent sphincter of Oddi, (i) oral moxifloxacin 400 mg/d beginning 2 d before radioembolization and continued for 10 d after, (ii) oral moxifloxacin 400 mg started 3 d before radioembolization and continued for 18 d after	Amoxicillin/clavulanic acid 875 mg twice daily for similar duration if allergic to moxifloxacin
Gastrointestinal embolization	IIb	C-LD, C-EO	*Streptococcus*, *Staphylococcus*; if evidence of hemobilia: enteric organisms, eg, *E. coli*, *Enterococcus* spp., anaerobes	Clean, clean contaminated (if history of biliary colonization)	Not in average-risk patients; antibiotics recommended for patients with hemobilia	No consensus	(i) 1 g ceftriaxone IV; (ii) 1.5–3g ampicillin/ sulbactam IV; (iii) 1 g cefotetan IV + 4 g mezlocillin IV; (iv) 2 g ampicillin IV + 1.5 mg/kg gentamicin IV; (v) if penicillin-allergic, can use vancomycin or clindamycin and aminoglycoside	NA	NA
Partial splenic embolization for hypersplenism	IIb	C-LD, C-EO	*Streptococcus*, *Staphylococcus*	Clean	Antibiotics recommended if > 70% of spleen is expected to be embolized	No consensus	(i) Gentamicin 10 mg/kg/ d, cefoxitin sodium 100 mg/kg/ d beginning 2 h before and continuing for ≥ 5 d after; soaking of embolic spheres with 1,000,000 U penicillin and 40 mg gentamicin also recommended; (ii) 1 g	NA	NA

continued

Table 2. Suggested Antibiotic Regiments for Vascular and Interventional Radiology Procedures *(continued)*

Procedure	Class of Recommendation	Level of Evidence	Potential Organisms Encountered	Procedure Classification	Routine Prophylaxis Recommended*	First-Choice Antibiotic	Suggested Antibiotic Regimens	Other Antibiotic Regimens	Comments*
							cefoperazone every 12 h postprocedure for ≥ 5 d following; (iii) embolic particles suspended in gentamicin (16 mg) in combination with 5-d course of IV amoxicillin/ clavulanate (3 g/d) and ofloxacin (400 mg/d)		
Totally implanted central venous access ports	IIb	B-R, C-EO	*S. aureus, S. epidermidis*	Clean	No	No consensus	1–2 g cefazolin IV	NA	Vancomycin recommended in penicillin-allergic patients
Tunneled dialysis catheters	IIb	B-R, C-EO	*S. aureus, S. epidermidis*	Clean	Yes	No consensus	1–2 g cefazolin IV	NA	Vancomycin recommended in penicillin-allergic patients
Other central venous access catheters, including nontunneled hemodialysis catheters	IIb	C-LD, C-EO	*S. aureus, S. epidermidis*	Clean	No, except in high-risk patients, including immunocompromise	No consensus	1–2 g cefazolin IV	NA	Vancomycin recommended in penicillin-allergic patients
Lower-extremity superficial venous insufficiency treatment	III	C-LD, C-EO	*S. aureus, S. epidermidis*	Clean	No	None	NA	NA	NA
IVC filter placement	III	C-LD, C-EO	*S. aureus, S. epidermidis*	Clean	No	None	NA	NA	NA
IVC filter retrieval	IIb	C-EO	*S. aureus, S. epidermidis*, possibly polymicrobial colonic flora including anaerobes	Clean, clean contaminated	No except in cases of embedded IVC filters with known bowel penetration	No consensus	NA	NA	Special considerations: (i) piperacillin/ tazobactam or (ii) ampicillin/ sulbactam may be considered for prophylaxis for retrieval of embedded IVC filters with known bowel penetration
Thrombolysis	IIa	C-EO	*S. aureus, S. epidermis*	Clean	No	None	NA	NA	Special considerations: 1–2 g cefazolin IV in high-risk patients; Vancomycin recommended in penicillin-allergic patients
Vascular malformation	IIb	C-EO	*S. aureus, S. epidermis*	Clean, contaminated	Yes	None	(i) 1–2 g cefazolin for adults, (ii) cefazolin 25 mg/kg for pediatric patients, (iii) clindamycin 10 mg/kg for oral lesions	NA	Recommendations primarily for percutaneous sclerotherapy/ ablation of slow flow venous or

continued

Table 2. Suggested Antibiotic Regiments for Vascular and Interventional Radiology Procedures *(continued)*

Procedure	Class of Recommendation	Level of Evidence	Potential Organisms Encountered	Procedure Classification	Routine Prophylaxis Recommended*	First-Choice Antibiotic	Suggested Antibiotic Regimens	Other Antibiotic Regimens	Comments*
									venolymphatic malformations.
Varicocele embolization (transcatheter)	III	C-EO	*S. aureus*, *S. epidermis*	Clean	No	None	None	NA	–
TIPS	IIb	C-LD, C-EO	*S. aureus*, *Enterococcus faecalis*, *E. coli*, *Klebsiella* spp., *Lactobacillus acidophilus*, *Gemella morbillorum*, *Acinetobacter* spp., *Streptococcus sanguinis*, *Streptococcus gallolyticus*, and *Candida albicans*	Clean, clean contaminated	Yes	No consensus	(i) 1 g ceftriaxone IV; (ii) 1.5–3 g ampicillin/ sulbactam	NA	Vancomycin or clindamycin/ gentamycin recommended for penicillin-allergic patients
Percutaneous transhepatic biliary drain and cholecystostomy	IIb	C-LD, C-EO	*Enterococcus* spp., *Candida* spp., Gram-negative aerobic bacilli, *Streptococcus viridans*, *E. coli*, and *Clostridium* spp.; *Klebsiella*, *Pseudomonas*, and *Bacteroides* spp., particularly in cases of advanced biliary disease, including hepatolithiasis	Contaminated, dirty	Yes for new placement and routine exchanges	No consensus	(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	NA	Vancomycin or clindamycin-gentamycin recommended for penicillin-allergic patients
Percutaneous nephrostomy tubes	IIb	C-LD, C-EO	*E. coli*, *Proteus*, *Klebsiella*, and *Enterococcus* spp.	Clean contaminated, contaminated, or dirty	Yes except in routine catheter exchange for low-risk patients	No consensus	(i) 1–2 g ceftriaxone IV single dose; (ii) 1.5–3 g ampicillin/ sulbactam IV every 6 h + 5 mg/kg gentamycin IV single dose	NA	Patients with indwelling ureteral catheters, ureteroileal anastomosis should be considered high-risk; vancomycin recommended in penicillin-allergic patients
Gastrostomy tube placement	IIb	B-NR, C-LD	Push type, *S. aureus*, *S. epidermis*, pull type, *S. aureus*, *S. epidermidis*, and oropharyngeal flora (eg, *S. viridans* (α-hemolytic), *Lactobacillus* spp., non-diphtheroid *Corynebacterium* spp., anaerobes *Bacteroides* spp., *Actinobacillus* spp.)	Clean contaminated	Yes for push and pull type	Push type, cefazolin single dose; pull type, cefazolin/ cefalexin for 6 d	Push type, 1–2 g cefazolin or clindamycin (if penicillin-allergic); pull type, (i) 1–2 g cefazolin preprocedure followed by 500 mg cephalexin oral/ gastrostomy-inserted twice daily for 5 d; (ii) 600 mg clindamycin IV at time of procedure followed by 600 mg oral clindamycin twice daily for 5 d	NA	Special consideration: 1–2 g cefazolin IV pre-procedure for push-type gastrostomies in patients with head and neck cancer; Vancomycin or clindamycin-gentamycin is recommended for penicillin-allergic patients

continued

Table 2. Suggested Antibiotic Regiments for Vascular and Interventional Radiology Procedures *(continued)*

Procedure	Class of Recommendation	Level of Evidence	Potential Organisms Encountered	Procedure Classification	Routine Prophylaxis Recommended*	First-Choice Antibiotic	Suggested Antibiotic Regimens	Other Antibiotic Regimens	Comments*
Liver tumor ablation	IIb	C-LD, C-EO	*S. aureus*, *S. epidermidis*, *E. coli*, *Clostridium perfringens*, *Enterococcus* spp.	Clean contaminated, contaminated if sphincter of Oddi dysfunction	Yes, especially in high-risk patients (eg history of biliary–enteric anastomosis, cirrhosis, diabetes)	No consensus	In low-risk patients, 1–2 g cefazolin IV	In high risk patients, (i) oral levofloxacin 500 mg/d + oral metronidazole 500 mg twice daily beginning 2 d before and continuing for 14 d after ablation + neomycin 1 g and erythromycin base 1 g orally at 1, 2, and 11 PM on the day before ablation; (ii) 1.5 g ampicillin/sulbactam IV; (iii) vancomycin or clindamycin can be given for Gram-positive coverage and gentamicin for Gram-negative coverage	NA
Renal tumor ablation	IIb	C-LD, C-EO	*E. coli*, *Proteus*, *Klebsiella* spp.	Clean contaminated, contaminated if urothelial colonization	No, except in patients with colonized urothelium	No consensus	1 g ceftriaxone IV		Clindamycin/ gentamycin recommended for penicillin-allergic patients
Other tumor ablation (lung, adrenal, bone)	IIb	C-EO	Skin and respiratory flora	Clean, clean contaminated (lung)	No consensus	No consensus	1–2 g cefazolin IV	NA	Special consideration: for patients with single lung, ablation/amoxicillin clavulanate 2 g or ofloxacin 400 mg/d continued for 3–7 d postablation
Percutaneous abscess drainage	IIb	C-EO	Polymicrobial	Dirty	Yes if not already on antibiotics	Location of abscess influences organisms encountered	Single-agent regimens for intraabdominal infections: meropenem, imipenem/cilastatin, doripenem, piperacillin/ tazobactam	Metronidazole in combination with ciprofloxacin, levofloxacin, ceftazidime, ampicillin, sulbactam, or cefepime	Antibiotics should cover anticipated organisms for empiric treatment and then be adjusted for final culture results
Paracentesis and thoracentesis	IIb	C-EO	*S. aureus*, *S. epidermidis*, *S. viridans*	Clean	No	NA	NA	NA	Special considerations: 1–2 g cefazolin IV can be considered for tunneled pleural or peritoneal catheters; vancomycin can be considered in patients with penicillin allergy
Percutaneous biopsy	I	B-R, B-LD	Transrectal Gram-negative bacteria *Enterococcus* spp., *E. coli*, *Bacteroides* spp., other anaerobes	Clean, transrectal biopsies, contaminated	No, except for transrectal prostate biopsy	No consensus	For transrectal prostate biopsy: (i) 500 mg ciprofloxacin + 1.5 mg/kg gentamycin	(i) 1 g ceftriaxone + 1.5 g/kg gentamycin, (ii) 160 mg trimethoprim/ 800 mg sulfamethoxazole orally as single dose 1 h before biopsy	NA
	IIb	C-EO	*S. aureus*, *S. epidermis*	Clean	Yes		NA	NA	

continued

Table 2. Suggested Antibiotic Regiments for Vascular and Interventional Radiology Procedures *(continued)*

Procedure	Class of Recommendation	Level of Evidence	Potential Organisms Encountered	Procedure Classification	Routine Prophylaxis Recommended*	First-Choice Antibiotic	Suggested Antibiotic Regimens	Other Antibiotic Regimens	Comments*
Percutaneous vertebral body augmentation						1–2 g cefazolin IV			Vancomycin recommended in penicillin-allergic patients
Salivary gland Botox injections	IIb	C-LD, C-EO	*S. aureus*, *S. epidermis*	Clean	No	NA	NA	NA	NA
Percutaneous cecostomy insertion	IIa	C-LD, C-EO	Polymicrobial-including anaerobes from colonic flora, *S. aureus*, *S. epidermidis*	Clean contaminated	Yes	No consensus	(i) Cefoxitin 30 mg/kg single prophylactic dose; addition of triple antibiotic regimen only in complicated insertions using gentamycin 2.5 mg/kg IV, metronidazole 10 mg/kg IV, and ampicillin 20 mg/kg IV administered before and for 2 d after procedure with continuation of metronidazole 10 mg/kg orally for total of 5 d; (ii) prophylactic gentamycin 2.5 mg/kg IV, metronidazole 10 mg/kg IV, and ampicillin 20 mg/kg IV administered before and for 2 d after procedure with continuation of metronidazole 10 mg/kg orally for total of 5 d; (iii) prophylactic gentamycin 2.5 mg/kg IV and metronidazole 10 mg/kg IV before and 2 d after procedure	NA	NA
Bone interventions (osteoid osteoma ablation, sclerotherapy)	IIb	C-LD, C-EO	*S. aureus*, *S. epidermis*	Clean	No	NA	NA	NA	NA

AV = arteriovenous; EO = expert opinion; IV = intravenous; IVC = inferior vena cava; LD = limited data; NA = not applicable; NR = nonrandomized; TIPS = transjugular intrahepatic portosystemic shunt.

*When routine antibiotic prophylaxis is recommend or suggested, please see Appendix C for pediatric dosing recommendations.

Arteriovenous Fistula and Graft Interventions

Salman and Asif (60) conducted a large retrospective series of infectious complications occurring within 72 hours of dialysis access. This included 2,078 arterial and venous balloon angioplasties (performed in 1,310 arteriovenous fistulae and 768 arteriovenous grafts), 110 venography procedures, 26 stent insertions, and 31 intravascular coil placements. All procedures were performed without antibiotic prophylaxis, and the infectious adverse event rate was 0.04%, with 1 patient having fever and chills following an arteriovenous fistula angioplasty (60). Although the routine use of antibiotic prophylaxis is not indicated, antibiotic agents can be considered in high-risk cases, especially when placing a covered stent. (New data reviewed, new recommendations.)

Closure Devices

The reported risk of infectious complications (ie, groin cellulitis or arteritis) with closure devices is < 1% (61). Although certain risk factors have been associated with increased risk of infection (obesity, diabetes, closure device placement in the previous 6 mo), the routine use of antibiotic prophylaxis is not recommended (62,63). A meta-analysis by Jaffan et al (64) evaluated the use of 3,606 suture-mediated closure devices employed during percutaneous endovascular aortic repair (Perclose device; Abbott Vascular, Santa Clara, California). They found groin infection rates of 0.003% (2 of 592) in patients who received antibiotic prophylaxis and 0.002% (5 of 3,014) in patients who did not (P = .3232). (New data reviewed, no changes to recommendations.)

Uterine Artery Embolization

The necrotic material created during uterine artery embolization (UAE) can be seeded by skin flora inoculated during arterial access or via direct invasion of bacteria from the bladder or vagina as a result of endocervical incompetence (65). Serious infectious complications have been reported in as many as 2% of cases (66,67). Two deaths have been described related to sepsis, one as a result of *E. coli* acquired from a urinary tract infection (68). There have also been 2 hysterectomies related to infectious endometritis, one in a patient who did receive antibiotic prophylaxis (69). Martins et al (70) suggested that leiomyoma location, especially when submucosal, may be associated with increased risk of the tumor becoming intracavitary following embolization and increasing the risk of severe complications such as sepsis.

The use of antibiotic prophylaxis continues to be debated (9). Historically, multidrug regimens have been associated with a decrease in the rate of hysterectomy-associated infections from 2% to 0.8%, but have been associated with an increase in vaginal discharge, likely from imbalances in vaginal flora (71). Such aggressive protocols have largely been abandoned. In 2013, the Royal College of Obstetricians and Gynecologists (72) acknowledged that a single dose of prophylactic antibiotic agents targeted at skin flora was reasonable for UAE prophylaxis, extrapolating from data on prophylaxis used during hysterectomy for cesarean section. Alternative regimens were also suggested, but the recommendations concluded that there are limited data and that prophylaxis is at the discretion of the treating hospital.

The presence of hydrosalpinx at the time of UAE has been described as a risk factor for the development of pyosalpinx (73). In the past, multiday regimens of doxycycline have been suggested in this setting (73). More recently, a study by Petruzzi et al (74) demonstrated no infectious complications in 16 women with hydrosalpinx when administered 1-g IV cefazolin before UAE. (New data reviewed, recommendations updated.)

Hepatic Embolization and Chemoembolization

Infectious complications following transcatheter embolization can have serious clinical implications because the necrotic material created can serve as a fertile breeding ground for bacterial proliferation. Contamination can occur via two sources: (*i*) bacteremia during arterial catheterization or (*ii*) the translocation of bacteria across the biliary tree as a result of ischemic biliary ductal injury by the embolic agent (75). This latter risk is especially serious for patients with colonization of their biliary tree in the setting of incompetence of the sphincter of Oddi as a result of biliary-enteric anastomosis, biliary stent, or sphincterotomy (76,77). Infectious complications in patients with a competent sphincter of Oddi occur at an incidence of < 1%, and a single dose of cefazolin (targeted to skin flora) is recommended (78). In patients with an incompetent sphincter (history of sphincterotomy, biliary stent placement, or bilioenteric anastomosis), the risk is substantially higher, at 5%–25%, with 9 deaths having been reported as a result of sepsis (76,79–82). In such patients, the use of prophylactic antibiotic agents against Gram-positive skin flora and Gram-negative enteric flora is recommended (76). Recently, Khan et al (83) showed that a 21-day course of moxifloxacin (Avelox; Bayer, Whippany, New Jersey) is an effective regimen in patients with previous biliary interventions, with 0 infectious complications in 10 patients who underwent 25 procedures. A more aggressive regimen described by Patel et al in 2006 (84) that included levofloxacin and metronidazole begun 2 days before the procedure and continued for 2 weeks afterward (plus cathartic bowel preparation) demonstrated a trend toward a lower incidence of abscess formation compared with studies without antibiotic prophylaxis. Other regimens such as IV ceftriaxone, ampicillin sulbactam, and cefazolin plus metronidazole have also been described, with their use continued for 3–7 days after the procedure (76,85). (New data reviewed, recommendations updated.)

Radioembolization

Infectious complications with transarterial radioembolization of liver tumors are extremely uncommon, with very few cases of hepatic abscess reported (79–81). Generally speaking, the risk of abscess formation with radioembolization is thought to be lower than that encountered with chemoembolization given the reduced ischemia created by the microspheres (82). When adhering to a 21-day course of multidrug prophylaxis plus bowel preparation, Khan et al (83) showed that the risk of hepatic abscess formation with radioembolization (0 of 16) was lower than that with chemoembolization (3 of 13) in patients with a history of sphincter of Oddi incompetence.

Currently, there are no specific guidelines for radioembolization prophylaxis, and recommendations are largely made based on expert opinion. Most practitioners do not employ antibiotic prophylaxis in routine cases. In cases of previous sphincter of Oddi/biliary intervention, with an increased incidence of bacterial colonization of bile, most experts recommend antibiotic prophylaxis, as would be used in cases of bland embolization or chemoembolization, even though consensus is lacking and not all experts advocate antibiotic prophylaxis for these patients. (New data reviewed, new recommendations.)

Other Arterial Embolization Procedures

Antibiotic prophylaxis for embolization of gastrointestinal bleeding is not necessary (17) except in cases of hemobilia in which accumulation of blood can lead to cholangitis (9). For splenic artery embolization, the risk of infection depends on the extent of ischemia created. Specifically, the risk of splenic abscess or peritonitis is reported at 16% when greater than 70% of the spleen is infarcted, as opposed to 3% when 50%–70% of the spleen is infarcted (86). In cases of partial splenic artery embolization for hypersplenism, the use of IV antibiotic agents and/or antibiotic agent–soaked embolic spheres/foam is recommended (87,88). (New data reviewed, recommendations updated.)

Totally Implanted Central Venous Access Ports

Totally implanted central venous access ports have become an integral component in the care of patients requiring long-term venous access. In a study of 512 ports placed by IR means without antibiotic prophylaxis (89), local infections occurred in 25 of 512 patients (4.9%) and systemic infections occurred in 2 of 512 patients (0.4%). Similarly, in a cohort of 1,183 patients who underwent port placement without antibiotic prophylaxis (90), a 0.6% infection rate (7 of 1,183) within 30 days was reported. A randomized controlled trial by Karanlik et al (91) found no difference in the number of infections in ports placed with versus without antibiotic prophylaxis (5 of 203 [2.5%] vs 6 of 201 [3%]; P = .75). In a recent meta-analysis, Johnson et al (92) showed that the incidence of infectious complications was similar with or without antibiotic prophylaxis (5 of 360 [1.39%] vs 22 of 1,794 [1.23%], respectively; odds ratio, 0.84; 95% confidence interval [CI], 0.29–2.35). Despite such data against the use of antibiotic prophylaxis, many operators (including more than 85% of surgeons) still administer a single dose of antibiotic agent targeted to skin flora, as ports are most commonly placed in patients with cancer who are or will become immunocompromised with the administration of chemotherapy (93). (New data reviewed, new recommendations.)

Tunneled Dialysis Catheters

Dialysis catheters offer short- and long-term means of hemodialysis. Life-threatening bacteremia is expected to occur in as many as 10% of patients, with a median time to first catheter-related bacteremic episode of 163 days (94). Although the presence of an indwelling catheter is a well-established risk factor for systemic infection (95), clinically significant bacteremia occurring at the time of catheter placement is less common. Historically, recommendations have been against antibiotic prophylaxis for tunneled central venous catheters, although such studies did not include large-bore tunneled dialysis catheters (96–99). Salman and Asif (60) found only 1 of 283 patients (0.4%) undergoing tunneled catheter placement or exchange without prophylactic antibiotic treatment who reported fever or chills. Huddam et al (100) conducted a prospective study of 60 patients with uremia randomized to undergo a single dose of IV cefazolin or IV saline solution before tunneled hemodialysis catheter placement. Over their follow-up period of 8 months, patients who received cefazolin had significantly lower occurrences of catheter loss caused by infection ($n = 3$ vs $n = 6$), tunnel site infection ($n = 2$ vs $n = 5$), exit site infection ($n = 4$ vs $n = 6$), and bacteremia ($n = 6$ vs $n = 10$; all $P < .05$). Despite conflicting evidence on the true value of antibiotic prophylaxis, many authors in IR continue to use antibiotic agents targeted to skin flora before tunneled catheter placement (101).

The use of antibiotic agent–impregnated cuffs and catheters has been evaluated (102). Although these may reduce the risk of catheter-related infections, their routine use is limited by high cost and antimicrobial resistance, and therefore they should be used only in patients with recurrent infection or at centers with high rates of catheter-related infection despite sterile precautions (103). Ethanol locking solutions have been shown to be effective at reducing catheter-related bloodstream infections (104–106), are inexpensive (107), and are compatible with silicone- and polyurethane-based catheters (108,109), but their use has been limited. (New data reviewed, new recommendations.)

Other Central Venous Access Catheters, Including Nontunneled Hemodialysis Catheters

Routine antibiotic prophylaxis for nontunneled hemodialysis catheters and other central venous catheters (for pressure monitoring, medication/fluid administration, and frequent blood draws) is not recommended (99,103), with the exception of those placed in immunocompromised patients (110). However, the Centers for Disease Control and Prevention have established guidelines to reduce the risk of catheter-related bloodstream infections (102). These include washing of the operator's hands before and after each procedure (111), maximal sterile barrier precautions, and the use of all-inclusive catheter kits that minimize handling of nonsterile equipment or surfaces (102). A recent meta-analysis (112) also found that several interventions can reduce bloodstream infections, including closed infusion systems, appropriate site selection, nursing education on proper catheter management, and early catheter removal. Other catheter care measures, including cleansing of catheter port sites with 2% chlorhexidine (rather than iodine or alcohol) while in the intensive care unit, are also recommended (103,113). (New data reviewed, new recommendation.)

Lower-Extremity Superficial Venous Insufficiency Treatment

Minimally invasive techniques with the use of lasers, sclerotherapy, and radiofrequency ablation have transformed varicose vein treatment from a highly morbid surgery into a minimally invasive outpatient procedure (114). In a large meta-analysis of 1,128 limbs treated with endovenous laser ablation (115), the infectious adverse event rate was 0.33%, notably lower than the rate of 1.91% associated with surgical ligation and stripping. Although the routine use of antibiotic prophylaxis is not indicated, adherence to sterile technique remains paramount (116). (No new data or changes to recommendations.)

Inferior Vena Cava Filter Placement

Endovascular infection with inferior vena cava (IVC) filter placement is an extremely uncommon, occurring in 3 of 406 patients (0.7%) (117), and prophylactic antibiotic therapy is not recommended (118). A "fresh stick" access site is recommended (ie, jugular or femoral vein), away from any indwelling catheters that may harbor bacteria and become dislodged by the filter device (119). In the rare instance in which a patient with septic at risk for life-threatening pulmonary embolism requires an IVC filter, the use of a retrievable filter is advisable, as it can be removed if the infection cannot be cleared (120). (No new data or changes to recommendations.)

IVC Filter Retrieval

In a study of 231 routine and advanced IVC filter retrievals in adults (121), there was a 0% incidence of infectious complication in all cases performed without antibiotic prophylaxis. Similarly, a retrospective review of 20 IVC filter retrieval procedures in children (122) reported a 0% infectious adverse event rate without the use of prophylactic antibiotic agents. A retrospective study of 9 patients (including 2 pediatric patients) (123) reviewed gastrointestinal complications following IVC filter retrievals. Without prophylactic antibiotic treatment, sepsis developed in 1 patient following retrieval of an embedded IVC filter associated with bowel penetration (123). A periprocedural antibiotic regimen was then instituted with piperacillin/tazobactam or ampicillin/sulbactam for subsequent retrievals in cases in which cross-sectional imaging demonstrated bowel penetration by the IVC filter. (New data reviewed, new recommendations.)

Vascular Malformation Treatment

Vascular malformations consist of a diverse group of conditions, often requiring multiple approaches and techniques for treatment. In general, these procedures are considered clean, and prophylactic antibiotic therapy is not routinely administered. However, if the lesion is in a "dirty" or contaminated location (ie, oropharynx/gastrointestinal tract), antibiotic prophylaxis is usually recommended, as the treatment site can be contaminated by the needle or translocation of bacteria across the mucosal surface disrupted by the sclerosing agent.

In 2 retrospective reviews of 10 and 74 pediatric patients undergoing percutaneous lymphatic malformation sclerotherapy of lesions in the head and neck region, abdomen, and retroperitoneum (124,125), a single dose of prophylactic antibiotic agents targeted to skin flora was recommended. Clindamycin can be used as an alternative to cefazolin in patients with penicillin allergies or as a first choice for intraoral malformations (126). (New data reviewed, new recommendations.)

Varicocele Embolization

Transcatheter embolization of the gonadal vein/internal spermatic vein and its associated collateral veins can be performed without antibiotic agents regardless of the embolic agent used. Retrospective reviews of 58 and 244 adult (127,128) and 30, 40, and 41 pediatric patients (129–131) performed without antibiotic prophylaxis did not report infectious complications, and therefore their routine use is not recommended. (New data reviewed, no changes to recommendations.)

Transjugular Intrahepatic Portosystemic Shunt Creation

Transient bacteremia during creation of a transjugular intrahepatic portosystemic shunt (TIPS) is common (as many as 35% of patients), as enteric bacteria within the static portal system can enter the systemic circulation through the newly created shunt (132). Approximately 10% of patients who receive a TIPS will have a mild postprocedure fever, as deployment of the stent itself has been postulated to incite a transient, self-limited inflammatory reaction (133,134). "Endotipsitis" (ie, infection of the stent lumen itself) occurs in fewer than 2% of cases (135,136). The use of prophylactic antibiotic agents is generally accepted as routine (101). Historically, the use of a second-generation cephalosporin agent, cefotiam, with limited Gram-negative coverage, did not affect the infectious adverse event rate (137). An agent with stronger Gram-negative coverage (ie, ceftriaxone) may be better suited for TIPS prophylaxis (31). Extended coverage against *Enterococcus* species with ampicillin/sulbactam is another consideration (17). Deibert et al (137) suggested the removal of central venous catheters following TIPS creation to reduce the risk of endotipsitis (137). (No new data or changes to recommendations.)

NONVASCULAR INTERVENTIONS

Percutaneous Transhepatic Biliary Drains and Cholecystostomy Tubes

In the setting of obstruction, stasis leads to bacterial proliferation, and purulent material is present in as many as 70% of obstructed systems (75). Therefore, transhepatic cholangiography or placement of drainage catheters in patients with biliary obstruction should be considered dirty (138). Minor cases of sepsis occur in 7.7% of biliary drain placements, and major septic events are seen in as many as 2.5% (139). Bacteremia is thought to be secondary to communication between the bile ducts and vasculature during passage of a needle or intravasation of bacteria across the sinusoids with even slight mechanical agitation or pressurization by wires, catheters, or contrast agent injection (140). Care should be made not to overdistend the biliary system, as increased pressure can result in bacterial and endotoxin cholangiovenous reflux (141). Ultrasound guidance for biliary access may be helpful in reducing the number of passes (65). Patients with bilioenteric anastomosis, previous biliary instrumentation, advanced age (> 70 y), obstructive jaundice, acute cholecystitis, or diabetes mellitus are at an increased risk for positive bile culture and/or sepsis (140,142,143). Antibiotic therapy is accepted as standard before percutaneous transhepatic cholangiography and should include coverage against drug-resistant organisms such as *Pseudomonas aeruginosa* and *Enterococcus faecium* (144). Agents with strong Gram-negative coverage with (at least some) biliary excretion are options, such as ceftriaxone or cefepime (145) or piperacillin/tazobactam (17). Bile cultures should always be obtained when access into the biliary system has been obtained, with antibiotic type and dose adjusted based on bile culture and sensitivities (144).

Antibiotic agents are also recommended for routine biliary tube exchanges, as the presence of an internal–external biliary drain allows for free communication of bacteria from the duodenum and the biliary tree (140). In general, this colonization is asymptomatic. However, bloodstream infections have been reported even with routine catheter exchanges (145), and antibiotic prophylaxis is recommended.

The majority of patients presenting for acute cholecystostomy tube placement will already be receiving antibiotic therapy, and the need for additional prophylaxis is not needed. In patients who are not already receiving antibiotic therapy, antibiotic prophylaxis is recommended because positive bile cultures occur at an incidence of 49% (146). The suggested prophylactic antibiotic regimens for primary percutaneous cholecystostomy tube placement or exchange are similar to those employed for biliary tube placement (140). (No new data or changes to recommendations.)

Percutaneous Nephrostomy Tubes

Percutaneous nephrostomy catheter placement for pyonephrosis or known urinary tract infection is considered a contaminated or dirty procedure and carries a 7% risk of septic shock (147). Antibiotic prophylaxis is always recommended if the patient is not already receiving IV antibiotic therapy. On the contrary, the role of antibiotic prophylaxis before nephrostomy tube placement into an uninfected system is less clear and should be based on each patient's risk factors. Advanced age, diabetes, bladder dysfunction, neurogenic bladder, previous ureteral manipulation (stents, ureterointestinal anastomosis) are considered risk factors for serious procedure-related infection and may warrant prophylactic antibiotic therapy (148). Antibiotic prophylaxis in such patients has been shown to reduce the risk of serious postprocedural complications from 50% to 9% (149). Data for patients at low risk (ie, without the aforementioned risk factors) suggest no significant difference in the occurrence of sepsis between patients who receive prophylactic antibiotic therapy (14%) and those who do not (10%; $P = .75$) (149). Despite the latter findings, some authors advocate the administration of prophylactic antibiotic agents in all patients (31). When antibiotic agents are used, the typical organisms requiring coverage include Gram-negative rods such as *E. coli*, *Klebsiella* species, *Proteus* species, as well as *Enterococcus* species. Therefore, ceftriaxone or ampicillin/sulbactam are potential agents.

Patients with indwelling percutaneous nephrostomy tubes will invariably have bacterial colonization of their urinary tract, as the catheters provide a surface for biofilm formation (150). Colonization is typically asymptomatic when there is no catheter occlusion (151). Bacteremia has been described in as many as 17% of catheter exchanges, but clinically relevant infection is less common (151). Routine tube exchanges in patients at low risk can be performed without prophylactic antibiotic therapy (1). As with nephrostomy tube placement, patients with risk factors for urothelial colonization such as ureteral stents or ureteroilieal anastomosis should be considered to be at high risk during nephrostomy or nephroureteral or antegrade ureteral stent exchange, and antibiotic prophylaxis is recommended (152). Furthermore, patients with catheter malposition or malfunction (ie, occlusion) are predisposed to the overgrowth of urinary bacteria and should receive antibiotic prophylaxis before tube replacement or exchange (9). (No new data or changes to recommendations.)

Gastrostomy Tube Placement

The use of prophylactic antibiotic agents during gastrostomy tube placement depends on the technique used. Previous data have indicated that the percutaneous, fluoroscopically guided "push method" (ie, retrograde technique) is associated with an infectious adverse event rate of approximately 3%, with no significant reduction when prophylactic antibiotic agents are used (153). As such, the routine use of prophylaxis has not been recommended in the past except in patients with a history of head and neck cancer (154). However, in a recent single-center randomized trial of 122 patients referred for image-guided gastrostomy tube placement (155), a significant difference in early peristomal infection was observed between those patients randomized to receive placebo versus those randomized to receive antibiotic therapy. On intent-to-treat analysis, the early infection rates were 11.8% (4 of 34 patients; 95% CI, 0.0%–9.4%) in the placebo arm and 0% (0 of 34 patients; 95% CI, 0.0%–8.4%) in the antibiotic arm ($P = .057$). On per-protocol analysis, early infection rates were 13.3% (4 of 30 patients; 95% CI, 4.4%–29.1%) in the placebo arm and 0% (0 of 32 patients; 95% CI, 0.0%–8.9%) in the antibiotic arm ($P = .049$). Numbers needed to treat to prevent 1 early infection were 8.5 and 7.5 from the 2 analyses, respectively (155). These data suggest a trend toward reduction in the rate of peristomal infection after percutaneous gastrostomy placement when prophylactic antibiotic agents are administered (155).

The "pull method" (ie, antegrade technique) exposes the tube to oropharyngeal flora, which can potentially seed the skin entry site. This procedure carries a peristomal infection rate of approximately 30% (156). Prophylactic antibiotic therapy is therefore recommended for all patients undergoing this procedure with antimicrobial agents targeting skin and oropharyngeal bacteria, eg, cefazolin followed by oral/enteric cephalexin (156). (New data reviewed, recommendations updated.)

Liver Tumor Ablation

In 2015, Bhatia et al (157) described a very low incidence of hepatic abscess in patients at low risk (ie, without biliary-enteric anastomosis) undergoing radiofrequency ablation of liver tumors without prophylactic antibiotic therapy (1 of 123; 0.8%). Although bacterial seeding is uncommon, the large amount of necrotic material created during ablation poses a risk for bacterial seeding during percutaneous access, and the use of a single agent targeted to skin flora (ie, cefazolin) may be reasonable (65).

As with embolization, patients undergoing liver tumor ablation with a history of biliary colonization as a result of an incompetent sphincter of Oddi are at higher risk for the development of an abscess (158). For these patients, a reduced risk of infectious complications has been associated with administration of biliary-excreted antibiotic agents at the time of the procedure and continued for 5–10 days after (158). Odisio et al (159) reported their experience in 12 patients who underwent microwave ablation and cryoablation with a previous hepaticojejunostomy. There was an abscess rate of 0% in 10 patients who received an aggressive 16-day multidrug regimen plus bowel preparation (similar to the chemoembolization regimen described by Patel et al [84]). On the contrary, abscesses developed in 2 patients who received alternative prophylactic regimens (piperacillin/tazobactam 4.5 g IV 4 times daily plus metronidazole 500 mg IV twice daily within 1 h of the procedure on the day of the procedure followed by ciprofloxacin and metronidazole 500 mg orally twice daily for 7 d and metronidazole 500 mg orally twice daily within 1 h of the procedure for 10 d) at 34 and 43 days after ablation, respectively (159). (New data reviewed, recommendations updated.)

Renal Tumor Ablation

Infectious complications with renal tumor ablation are rare, having been reported in 2 of 311 renal cryoablations (0.4%) and 2 of 254 radiofrequency ablations (0.6%) (160). For renal tumor ablation, there is a lack of consensus regarding antibiotic prophylaxis (161). One study (162) has suggested the use of an aggressive protocol consisting of amoxicillin trihydrate/potassium clavulanate during the procedure and at 12 hours after treatment, followed by a 10-day course of oral ciprofloxacin (500 mg twice daily). On the contrary, some authors employ prophylaxis only when there is urothelial colonization (eg, ileal conduit urinary diversion) or in diabetic or immunocompromised patients (163,164). As for hepatic ablation, the necrotic material created during ablation could serve as a nidus for bacterial seeding, and a one-time dose of cefazolin covering skin flora is reasonable. (New data reviewed, no changes to recommendations.)

Other Tumor Ablation

There remains no consensus as to the use of antibiotic prophylaxis for lung, adrenal, bone, or other solid-tumor ablation. Given that the thermal injury incurred during these procedures could create a hospitable environment for bacterial infection, a single dose of prophylactic antibiotic agents targeted to skin flora is recommended by some authors (165,166). For lung tumor ablation, the use of antibiotic prophylaxis has not been shown to reduce infectious adverse event rate (pneumonia, abscess), although the incidences of these occurrences are low (167,168). Risk factors predisposing to infectious complications include irradiated lung, primary tumors, and previously compromised parenchyma (168). For patients with a single lung, protocols that include amoxicillin clavulanate or ofloxacin continued for 3–7 days after ablation have been described (169). (New data reviewed, no changes to recommendations.)

Percutaneous Abscess Drainage

If a patient undergoing percutaneous abscess drainage is not already receiving antibiotic therapy, initiation of antibiotic therapy is recommended, as manipulation within the abscess with a wire or needle poses the risk of rupturing the cavity and spilling its contents into the surrounding space (170). Initiation of antibiotic agents should be considered empiric treatment rather than prophylaxis, and antibiotic agents should be continued after aspiration and drainage. Given the variation in likely organisms by anatomic site, consultation with infectious disease personnel may be prudent.

Abdominal abscesses are frequently polymicrobial, and broad-spectrum antibiotic agents that provide coverage for Gram-negative and anaerobic organisms (including *Enterobacter* and *Pseudomonas* species) are warranted (170). Single-agent regimens for intraabdominal infections include meropenem, imipenem/cilastatin, doripenem, or piperacillin/tazobactam. A combination of metronidazole with ciprofloxacin, levofloxacin, ceftazidime, ampicillin sulbactam, or cefepime can also be used (55,171).

For pleural abscesses, antibiotic regimens such as piperacillin/tazobactam or amoxicillin/clavulanic acid that cover *Streptococcus*, *Staphylococcus*, *Enterococcus*, and *Pseudomonas* species are suggested (172).

Paracentesis and Thoracentesis

Paracentesis and thoracentesis are considered clean procedures with infectious adverse event rates as low as 0.2% (173,174). Therefore, routine prophylaxis is not indicated. Tunneled pleural or peritoneal drainage catheters are typically placed for palliative fluid management. No studies have directly evaluated the role of prophylactic antibiotic agents, and some have suggested that their use is unlikely to be of benefit (65). Although the incidence of infectious complications is low (175), a single dose of prophylactic antibiotic agents targeting skin flora to prevent a potentially devastating infection (eg, bacterial peritonitis) could be considered in immunocompromised patients. (New data reviewed, new recommendations.)

Percutaneous Biopsy

Transrectal biopsy of the prostate is the only percutaneous biopsy in which the administration of prophylactic antibiotic agents has been shown to be of benefit. Specifically, Kapoor et al (176) demonstrated a lower rate of bacteriuria (6 of 227; 3%) in patients who received a single dose of ciprofloxacin than in those who did not (19 of 268; 8%). Agents targeting enteric organisms are recommended, including fluoroquinolones; first-, second-, or third-generation cephalosporins; or trimethoprim/sulfamethoxazole (177–179). Although complex, multiday regimens have been described, Aron et al (180) described the comparable effectiveness of a single dose of ciprofloxacin plus tinidazole and a similar 3-day regimen. During the past 20 years, there has been a dramatic increase in fluoroquinolone-resistant *E. coli*, which now occurs in the rectum of more than 20% of males (181). Therefore, the addition of an IV aminoglycoside such as gentamycin to minimize the risk of *E. coli* urinary tract infection is advised. The use of broad-spectrum antibiotic agents has been advocated by some authors, but their use should be avoided because of the long-term risk of bacterial resistance (178). Prebiopsy bowel preparations should not be used because they have not been shown to reduce the risk of infection (178). (New data reviewed, recommendations updated.)

Percutaneous Vertebral Body Augmentation

Although the incidence of infectious complications with vertebral body augmentation is less than 0.5% (182,183), the difficulty of treating cement contamination (ie, surgical debridement) argues for the use of prophylaxis (138). Antibiotic agents targeting skin flora are generally recommended (184). The use of antibiotic-impregnated cement has been explored but has not been show to confer advantage over IV antibiotic agents alone (9). (New data reviewed, no changes to recommendations.)

COMMON PEDIATRIC PROCEDURES

Salivary Gland Botox Injections

Percutaneous botulinum toxin A (Botox; Allergan, Dublin, Ireland) for the treatment of sialorrhea is associated with a low incidence of infectious complications (~0.9%), and prophylactic antibiotic therapy is not routinely recommended (185). A controlled trial comparing Botox versus placebo (186) and another controlled trial comparing Botox versus scopolamine (187) reported no infectious side effects in either treatment arm. (New data reviewed, new recommendations.)

Percutaneous Cecostomy Insertion

Bowel preparation regimens (including a clear liquid diet, laxatives, and prophylactic antibiotic agents) are traditionally used before percutaneous cecostomy insertion to decrease fecal burden and infection risk of the skin and peritoneal cavity. In a retrospective review of 163 pediatric percutaneous cecostomy tube insertions over a period of 7 years (188), the use of prophylactic antibiotic agents (gentamycin, metronidazole, and ampicillin) was associated with no immediate postprocedural complications. In longer-term follow-up of 124 of the original 163 patients, cecostomy tube site infections requiring antibiotic treatment developed in 8 patients (6%). A retrospective review of 290 percutaneous cecostomy insertions over a period of 15 years at the same institution (189) reported a change in clinical practice to a single prophylactic dose of cefoxitin 30 mg/kg, with use of the triple antibiotic regimen reserved only for complicated insertions. Of these patients, 1 (0.3%) had peritoneal spillage during the procedure, and peritonitis developed in 6 (2%), with 1 (0.3%) requiring abscess drainage and 1 (0.3%) dying despite antibiotic treatment. A smaller retrospective review of 21 cecostomy tube insertions with the use of prophylactic gentamycin and metronidazole administration before and 2 days following the procedure (190) reported no immediate complications. (New data reviewed, new recommendations.)

Bone Interventions

Osteoid osteoma ablation and aneurysmal bone cyst sclerotherapy are considered clean procedures with a low risk of infection, and prophylactic antibiotic agents are not routinely recommended. A retrospective study of 263 adult and pediatric patients (mean age, 19 y) undergoing radiofrequency ablation of osteoid osteomas (191) did not report the use of prophylactic antibiotic agents and found an infection rate of 0.4%, with cellulitis developing in only 1 patient 2 weeks after the procedure. In retrospective reviews of 20 (192) and 29 (193) pediatric patients undergoing aneurysmal bone cyst sclerotherapy, there were no reported infectious complications. (New data reviewed, new recommendations.)

CONCLUSIONS

These revised antibiotic prophylaxis guidelines are intended to provide the interventional radiologist with an updated summary of available literature on the topic. Although there is a lack of robust data or clear consensus for some procedures, antibiotic prophylaxis remains a critical component in preventing serious, potentially fatal complications. Furthermore, the appropriate use of antibiotic agents mitigates the likelihood of antibiotic resistance. Ideally, randomized control trials are necessary to determine the most appropriate agent and optimal duration of therapy for each procedure. Until such data become available, the interventional radiologist must be cognizant of the available practice guidelines and incorporate them according to local practice patterns and individualized patient care.

ACKNOWLEDGMENTS

The authors thank Daniel B. Brown, MD, Matthew S. Johnson, MD, Robert J. Lewandowski, MD, Riad Salem, MD, and Daniel Y. Sze, MD, PhD, for their review of the radioembolization content in this practice parameter.

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Appendix A. Executive Summary, Adult and Pediatric Antibiotic Prophylaxis During Vascular and IR Procedures: SIR Practice Parameter Update

Guideline Questions:

For adult and pediatric antibiotic prophylaxis during vascular and interventional radiology procedures, what are the current recommendations for antibiotic prophylaxis?

Target Population:

Adult and pediatric patients undergoing vascular or nonvascular interventional radiology procedures.

Target Audience:

Interventional radiologists and other clinicians who provide care for patients defined by the target population.

Methods:

A systematic review of the literature was performed and relevant evidence was evaluated for inclusion into this updated document. Evidence was rated according to the American College of Cardiology/American Heart Association Clinical Practice Guideline Recommendation Classification System (2).

New Recommendations:

Arteriovenous fistulae and graft intervention
Radioembolization
Totally implanted central venous access ports
Tunneled hemodialysis access catheters
Non tunneled hemodialysis access catheters
Vascular and lymphatic malformation sclerotherapy/ablation
Salivary gland botulinum toxin injection
Percutaneous cecostomy tube placement
Bone intervention (osteoid osteoma, aneurysmal bone cyst)

Updated Recommendations:

Uterine artery embolization
Hepatic embolization and chemoembolization
Other arterial interventions (gastrointestinal bleeding embolization, splenic artery embolization)
Gastrostomy tube placement
Liver tumor ablation
Percutaneous biopsy

Unchanged Recommendations:

Diagnostic angiography and angioplasty
Bare metal stent placement
Arterial endografts
Catheter-directed thrombolysis
Closure devices
Lower extremity venous insufficiency intervention
IVC filter
IVC filter retrieval
Varicocele embolization (gonadal vein embolization)
TIPS
Percutaneous transhepatic biliary drainage
Percutaneous nephrostomy tube
Renal and other tumor ablation
Abscess drainage
Paracentesis, thoracentesis
Vertebral body augmentation

continued

Appendix A. Executive Summary, Adult and Pediatric Antibiotic Prophylaxis During Vascular and IR Procedures: SIR Practice Parameter Update *(continued)*

Qualifying Statements:

The Society of Interventional Radiology (SIR) develops Clinical Practice Guidelines (CPGs) to provide educational resources to practicing clinicians to promote high-quality outcomes and patient safety in in vascular and interventional radiology. CPGs are not fixed rules, nor are they the sole determinant of treatment choice, and are not intended to establish a legal standard of care. Use of the CPGs is voluntary, and a deviation from the recommendations should not automatically be interpreted as the delivery of care that is substandard. CPGs are not intended to supplant professional judgment, and a physician may deviate from these guidelines as necessitated by the individual patient, practice setting, or available resources. Other sources of information may be used in conjunction with these principles to produce a process leading to high-quality medical care. The ultimate judgment regarding the conduct of any specific procedure or course of management must be made by the physician, who should consider all circumstances relevant to the individual clinical situation. These Guidelines are provided "as is," and SIR does not warrant the accuracy, reliability, completeness, or timeliness of the Guidelines. SIR is not responsible for any actions taken in reliance on these Guidelines, including but not limited to any treatment decisions made by any health care provider reading these Guidelines, and SIR assumes no responsible for any injury or damage to persons or property arising out of or related to any use of these Guidelines or for any errors or omissions.

IVC = inferior vena cava; TIPS = transjugular intrahepatic portosystemic shunt.

APPENDIX B. THE AMERICAN COLLEGE OF CARDIOLOGY/AMERICAN HEART ASSOCIATION RECOMMENDATION SYSTEM—APPLYING CLASS OF RECOMMENDATION AND LEVEL OF EVIDENCE TO CLINICAL STRATEGIES, INTERVENTIONS, TREATMENTS, OR DIAGNOSTIC TESTING IN PATIENT CARE (UPDATED AUGUST 2015)

Note–The full evidence grading table appears on p. 1213 of Jacobs AK, Anderson JL, Halperin JL. The evolution and future of ACC/AHA Clinical Practice Guidelines: a 30-year journey: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Circulation 2014; 130:1208–1217. To access this article, please visit the *Circulation* Web page: http://circ.ahajournals.org/.

Appendix C. Pediatric Prophylactic Antibiotic Dosing Considerations

Agent	Dose (mg/kg)	Maximum Dose	Age-Based Dose or Repeat Dose
Ampicillin	50	2 g	≤ 14 d or ≤ 2 kg, 6 h; > 15 d and > 2 kg, 3 h
Ampicillin/sulbactam	50	2 g	≤ 1 mo, contact pharmacy; > 1 mo, 3 h
Cefazolin	30	< 120 kg, 2 g; ≥ 120 kg, 3 g	≤ 7 d or ≤ 2 kg, 6 h; > 7 d and > 2 kg, 3 h
Cefotaxime	50	2 g	≤ 7 d or ≤ 2 kg, 8 h; > 7 d and > 2 kg, 6 h; > 1 mo, 3 h
Cefoxitin	40	2 g	≤ 1 mo, 3 h; > 1 mo, 2 h
Ceftriaxone	50	2 g	≤ 1 mo, contact pharmacy; > 1 mo, 12 h
Ciprofloxacin	10	400 mg	≤ 1 mo, contact pharmacy; > 1 mo, 8 h
Clindamycin	≤ 1 mo, 5; > 1 mo, 10	900 mg	≤ 7 d or ≤ 2 kg, 12 h; > 7 d and > 2 kg, 6 h
Gentamicin	≤ 1 mo, 4; 1 mo to 17 y, 2.5; ≥ 18 y, 5	NA	No repeat dose
Metronidazole	< 1,200 g, 7.5; ≥ 1,200 g, 15	500 mg	≤ 1 mo, no repeat dose; > 1 mo, 12 h
Vancomycin	15	1 g	≤ 7 d or ≤ 2 kg, no repeat dose > 7 d and > 2 kg, 12 h; > 1 mo, 8 h

Note–These are suggested considerations. The local pharmacy should be contacted for exact doses and timings per institutional protocol.
NA = not applicable.

APPENDIX D. CONSENSUS METHODOLOGY

Reported adverse event-specific rates in some cases reflect the aggregate of adverse events of varying severities. Thresholds are derived from critical evaluation of the literature, evaluation of empiric data from Standards of Practice Committee members, and, when available, the National Benchmarks from the National Quality Registry for Interventional Radiology. Modified Delphi technique maybe used to enhance effective decision-making (6,7).