Chapter 49: Surgical Prophylaxis

INTRODUCTION

- Antibiotics administered prior to the contamination of previously sterile tissues or fluids are considered prophylactic. The goal of prophylactic antibiotics is to prevent an infection from developing.
- Presumptive antibiotic therapy is administered when an infection is suspected but not yet proven. Therapeutic antibiotics are required for established infection.
- *Surgical-site infections* (SSIs) are classified as either incisional (eg, cellulitis of the incision site) or involving an organ or space (eg, with meningitis). Incisional SSIs may be superficial (skin or subcutaneous tissue) or deep (fascial and muscle layers). Both types, by definition, occur by postoperative day 30. This period extends to 1 year from the date of surgery in the case of prosthesis implantation involvement with a deep incisional or organ/space infection

RISK FACTORS FOR SURGICAL WOUND INFECTION

- The traditional classification system developed by the National Research Council (NRC) stratifying surgical procedures by infection risk is reproduced in **Table 49-1**. The NRC wound classification for a specific procedure is determined intraoperatively and is the primary determinant of whether antibiotic prophylaxis is warranted.
- The Study on the Efficacy of Nosocomial Infection Control (SENIC) analyzed more than 100,000 surgery cases and identified abdominal operations, operations lasting more than 2 hours, contaminated or dirty procedures, and more than three underlying medical diagnoses as factors associated with an increased incidence of SSI. When the NRC classification described in **Table 49-1** was stratified by the number of SENIC risk factors present, the infection rates varied by as much as a factor of 15 within the same operative category.
- The SENIC risk assessment technique has been modified to include the American Society of Anesthesiologists preoperative assessment score (**Table 49-2**). An American Society of Anesthesiologists score greater than or equal to three was a strong predictor for the development of an SSI.

TABLE 49-1

National Research Council Wound Classification, Risk of Surgical Site Infection, and Indication for Antibiotics

Classification	SSI Rate (%)		Criteria	Antibiotics
	Preoperative Antibiotics	No Preoperative Antibiotics		
Clean	0.8	5.1	No acute inflammation or transection of GI, oropharyngeal, genitourinary, biliary, or respiratory tracts; elective case, no technique break	Not indicated unless high-risk procedure[a]
Clean–contaminated	1.3	10.1	Controlled opening of aforementioned tracts with minimal spillage/minor technique break; clean procedures performed emergently or with major technique breaks	Prophylactic antibiotics indicated
Contaminated	10.2	21.9	Acute, nonpurulent inflammation present; major spillage/technique break during clean–contaminated procedure	Prophylactic antibiotics indicated
Dirty	N/A	N/A	Obvious preexisting infection present (abscess, pus, or necrotic tissue present)	Therapeutic antibiotics required

[a]High-risk procedures include implantation of prosthetic materials and other procedures where surgical site infection is associated with high morbidity (see the text).

N/A, not applicable; SSI, surgical site infection.

TABLE 49-2

Surgical Site Infection Incidence (%) Stratified by NRC Wound Classification and SENIC Risk Factors[a]

Number of SENIC Risk Factors	Clean	Clean–Contaminated	Contaminated	Dirty
0	1.1	0.6	N/A	N/A
1	3.9	2.8	4.5	6.7
2	8.4	8.4	8.3	10.9
3	15.8	17.7	11.0	18.8
4	N/A	N/A	23.9	27.4

[a]Study on the Efficacy of Nosocomial Infection Control (SENIC) risk factors include abdominal operation, operations lasting >2 hours, contaminated or dirty procedures by National Research Council (NRC) classification, and more than three underlying medical diagnoses.

N/A, not applicable; NRC, National Research Council; SENIC, Study on the Efficacy of Nosocomial Infection Control.

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BACTERIOLOGY

- Bacteria involved in SSI are acquired either from the patient's normal flora (endogenous) or from contamination during the surgical procedure (exogenous).
- The loss of normal flora through the use of broad-spectrum antibiotics can destabilize homeostasis, allowing pathogenic bacteria to proliferate and infection to occur.
- Normal flora can become pathogenic when translocated to a normally sterile tissue site or fluid during surgical procedures.
- The five most common pathogens encountered in surgical wounds are *Staphylococcus aureus*, coagulase-negative staphylococci, Enterococci, *Escherichia coli*, and *Pseudomonas aeruginosa*.
- Impaired host defenses, vascular occlusive states, traumatized tissues, and the presence of a foreign body greatly decrease the number of bacteria required to cause an SSI.

ANTIBIOTIC ISSUES

Scheduling Antibiotic Administration

- The following principles must be considered when providing antimicrobial surgical prophylaxis:

  ✔ Antimicrobials should be delivered to the surgical site prior to the initial incision. They should be administered within 60 minutes prior to the initial incision, preferably at the time of anesthetic induction. Antibiotics should not be prescribed to be given "on-call to the OR (operating room)."

  ✔ Bactericidal antibiotic tissue concentrations should be maintained throughout the surgical procedure.

- Strategies to ensure appropriate antimicrobial prophylaxis use are described in **Table 49-3**.

TABLE 49-3

Strategies for Implementing an Institutional Program to Ensure Appropriate Use of Antimicrobial Prophylaxis in Surgery

1. **Educate:** Develop an educational program that enforces the importance and rationale of timely antimicrobial prophylaxis. Make this educational program available to all healthcare practitioners involved in the patient's care.
2. **Standardize the ordering process**: Establish a protocol (eg, a preprinted order sheet) that standardizes antibiotic choice according to current published evidence, formulary availability, institutional resistance patterns, and cost.
3. **Standardize the delivery and administration process**: Use system that ensures antibiotics are prepared and delivered to the holding area in a timely fashion. Standardize the administration time to <1 hour preoperatively. Designate responsibility and accountability for antibiotic administration. Provide visible reminders to prescribe/administer prophylactic antibiotics (eg, checklists). Develop a system to remind surgeons/nurses to readminister antibiotics intraoperatively during long procedures.
4. **Provide feedback**: Follow up with regular reports of compliance and infection rates.

Antimicrobial Selection

- The choice of the prophylactic antimicrobial depends on the type of surgical procedure, most likely pathogenic organisms, safety and efficacy of the antimicrobial, current literature evidence supporting its use, and cost.
- Typically, gram-positive coverage is included in the choice of surgical prophylaxis because organisms such as *S. aureus* and *S. epidermidis* are common skin flora.
- Parenteral antibiotic administration is favored because of its reliability in achieving suitable tissue concentrations.
- First-generation cephalosporins (particularly **cefazolin**) are the preferred choice, particularly for clean surgical procedures. Antianaerobic cephalosporins (eg, **cefoxitin** or **cefotetan**) are appropriate choices when broad-spectrum anaerobic and gram-negative coverage are desired.
- Although third-generation cephalosporins (eg, **ceftriaxone**) have been advocated for prophylaxis because of their increased gram-negative coverage and prolonged half-lives, their inferior gram-positive and anaerobic activity and high cost have discouraged the widespread use of these agents.
- **Vancomycin** may be considered for prophylactic therapy in surgical procedures involving implantation of a prosthetic device in which the rate of methicillin-resistant *S. aureus* (MRSA) is high. If the risk of MRSA is low and a β-lactam hypersensitivity exists, **clindamycin** can be used instead of cefazolin in order to limit vancomycin use.

RECOMMENDATIONS FOR SPECIFIC TYPES OF SURGERIES

- Specific recommendations are summarized in **Table 49-4**.

TABLE 49-4

Most Likely Pathogens and Specific Recommendations for Surgical Prophylaxis

Type of Operation	Likely Pathogens	Recommended Prophylaxis Regimen[a]	Comments	Grade of Recommendation[b]
GI surgery				

Gastroduodenal	Enteric gram-negative bacilli, gram-positive cocci, oral anaerobes	Cefazolin 1 g × 1	High-risk patients only (obstruction, hemorrhage, malignancy, acid suppression therapy, morbid obesity)	IA
Bariatric Surgery	Enteric gram-negative bacilli, gram-positive cocci, oral anaerobes	Cefazolin 2 g × 1	Intraoperative redosing required for procedures longer than 4 hours	IB
Cholecystectomy	Enteric gram-negative bacilli, anaerobes	Cefazolin 1 g × 1 for high-risk patients; laparoscopic: controversial	High-risk patients only (open biliary tract procedures, acute cholecystitis, common duct stones, previous biliary surgery, jaundice, age >60 years, obesity, diabetes mellitus)	IA
Transjugular intrahepatic portosystemic shunt (TIPS)	Enteric gram-negative bacilli, anaerobes	Ceftriaxone 1 g × 1	Longer-acting cephalosporins preferred	IA
Appendectomy	Enteric gram-negative bacilli, anaerobes	Cefoxitin or cefotetan 1 g × 1 or cefazolin 1 g plus metronidazole 1 g × 1	Second intraoperative dose of cefoxitin may be required if procedure lasts longer than 3 hours	IA
Colorectal	Enteric gram-negative bacilli, anaerobes	Orally: neomycin 1 g + erythromycin base 1 g at 1, 2, and 11 pm 1 day preoperatively plus mechanical bowel preparation IV: cefoxitin or cefotetan 1 g × 1	Role of mechanical bowel preparation is controversial. It is widely used despite evidence suggesting it may have no effect on SSI or other clinical outcomes	IA
GI endoscopy	Variable, depending on procedure, but typically enteric gram-negative bacilli, gram-positive cocci, oral anaerobes	Orally: amoxicillin 2 g × 1 IV: ampicillin 2 g × 1 or cefazolin 1 g × 1	Recommended only for high-risk patients undergoing high-risk procedures (see the text)	IA
Urologic surgery				
Prostate resection, shock-wave lithotripsy, ureteroscopy	*E. coli*	Ciprofloxacin 500 mg orally *or* Trimethoprim–sulfamethoxazole 1 DS tablet	All patients with positive preoperative urine cultures should receive a course of antibiotic treatment	IA–IB
Removal of external urinary catheters, cystography, urodynamic studies,	*E. coli*	Ciprofloxacin 500 mg orally *or* Trimethoprim–sulfamethoxazole 1 DS	Should be considered only in patients with risk factors (see the text)	IB

simple cystourethroscopy		tablet		
Gynecological surgery				
Cesarean section	Enteric gram-negative bacilli, anaerobes, group B streptococci, enterococci	Cefazolin 2 g × 1 and azithromycin 500 mg IV × 1	Antimicrobial administration should be prior to the initial incision as opposed to after umbilical cord clamping	IA
Hysterectomy	Enteric gram-negative bacilli, anaerobes, group B streptococci, enterococci	Vaginal: cefazolin 1 g × 1 Abdominal: cefotetan 1 g × 1 or cefazolin 1 g × 1	Metronidazole 1 g IV × 1 is recommended alternative for penicillin allergy	IA
Head and neck surgery				
Maxillofacial surgery	*Staphylococcus aureus*, streptococci spp., oral anerobes	Cefazolin 2 g or clindamycin 600 mg	Repeat intraoperative dose for operations longer than 4 hours	IA
Head and neck cancer resection	*S. aureus*, streptococci spp., oral anerobes	Clindamycin 600 mg at induction and every 8 hours × 2 more doses	Add gentamicin for clean–contaminated procedures	IA
Cardiothoracic surgery				
Cardiac surgery	*S. aureus*, *S. epidermidis*, *Corynebacterium*	Cefazolin 1 g every 8 hours × 48 hours Intranasal mupirocin twice daily for 5 days preoperatively for patients colonized with *S. aureus*	Patients >80 kg (>176 lb) should receive 2 g of cefazolin instead; in areas with high prevalence of *S. aureus* resistance, vancomycin should be considered	IA
Thoracic surgery	*S. aureus*, *S. epidermidis*, *Corynebacterium*, enteric gram-negative bacilli	Cefuroxime 750 mg IV every 8 hours × 48 hours	First-generation cephalosporins are deemed inadequate, and shorter durations of prophylaxis have not been adequately studied	IA
Vascular surgery				
Abdominal aorta and lower extremity vascular surgery	*S. aureus*, *S. epidermidis*, enteric gram-negative bacilli	Cefazolin 1 g at induction and every 8 hours × 2 more doses	Although complications from infections may be infrequent, graft infections are associated with significant morbidity	IB
Orthopedic surgery				
Joint replacement	*S. aureus*, *S. epidermidis*	Cefazolin 1 g × 1 preoperatively, then every 8 hours × 2 more doses Intranasal mupirocin twice daily for 5 days	Vancomycin reserved for penicillin-allergic patients or where institutional prevalence of methicillin-resistant *S. aureus* warrants use	IA

		preoperatively for patients colonized with *S. aureus*		
Hip fracture repair	*S. aureus*, *S. epidermidis*	Cefazolin 1 g × 1 preoperatively, then every 8 hours for 48 hours	Compound fractures are treated as if infection is presumed	IA
Open/Compound fractures	*S. aureus*, *S. epidermidis*, gram-negative bacilli, polymicrobial	Cefazolin 1 g × 1 preoperatively, then every 8 hours for a course of presumed infection	Gram-negative coverage (ie, gentamicin) often indicated for severe open fractures	IA
Neurosurgery				
CSF shunt procedures	*S. aureus*, *S. epidermidis*	Cefazolin 1 g every 8 hours × 3 doses or ceftriaxone 2 g × 1	No agents have been shown to be better than cefazolin in randomized comparative trials	IA
Spinal surgery	*S. aureus*, *S. epidermidis*	Cefazolin 1 g × 1	Limited number of clinical trials comparing different treatment regimens	IB
CSF shunt procedures	*S. aureus*, *S. epidermidis*	Cefazolin 1 g every 8 hours × 3 doses or ceftriaxone 2 g × 1	No agents have been shown to be better than cefazolin in randomized comparative trials	IA
Craniotomy	*S. aureus*, *S. epidermidis*	Cefazolin 1 g × 1 or cefotaxime 1 g × 1	Vancomycin 1 g IV × 1 can be substituted for patients with penicillin allergy	IA

[a]One-time doses are optimally infused at induction of anesthesia except as noted. Repeat doses may be required for long procedures. See the text for references.

[b]Strength of recommendations: Category IA: Strongly recommended and supported by well-designed experimental, clinical, or epidemiologic studies. Category IB: Strongly recommended and supported by some experimental, clinical, or epidemiologic studies and strong theoretical rationale. Category II: Suggested and supported by suggestive clinical or epidemiologic studies or theoretical rationale.

CSF, cerebrospinal fluid; DS, double strength.

Gastroduodenal Surgery

- The risk of infection rises with conditions that increase gastric pH and subsequent bacterial overgrowth, such as obstruction, hemorrhage, malignancy, and acid-suppression therapy (clean-contaminated).
- A single dose of intravenous (IV) **cefazolin** will provide adequate prophylaxis for most cases. Oral **ciprofloxacin** may be used for patients with β-lactam hypersensitivity.
- Postoperative therapeutic antibiotics may be indicated if perforation is detected during surgery, depending on whether an established infection is present.

Hepatobiliary Surgery

- Antibiotic prophylaxis has been proven beneficial for surgery involving the biliary tract.
- Most frequently encountered organisms include *E. coli, Klebsiella*, and Enterococci. Single-dose prophylaxis with **cefazolin** is currently recommended. **Ciprofloxacin** and **levofloxacin** are alternatives for patients with β-lactam hypersensitivity.
- For patients undergoing elective laparoscopic cholecystectomy, antibiotic prophylaxis has traditionally not been recommended but newer trials and systematic reviews are conflicting and assessments of current practice are reflective of this.
- Ciprofloxacin and levofloxacin are effective alternatives for β-lactam-allergic patients undergoing open cholecystectomy.
- Detection of an active infection during surgery (gangrenous gallbladder or suppurative cholangitis) is an indication for therapeutic postoperative antibiotics.

Colorectal Surgery

- Anaerobes and gram-negative aerobes predominate in SSIs (see **Table 49-4**), although gram-positive aerobes are also important. Therefore, the risk of an SSI in the absence of an adequate prophylactic regimen is substantial.
- Risk factors for SSIs include age over 60 years, hypoalbuminemia, poor preoperative bowel preparation, corticosteroid therapy, malignancy, and operations lasting longer than 3.5 hours.
- Reducing bacteria load with a thorough bowel preparation regimen (4 L of polyethylene glycol solution or 90 mL of sodium phosphate solution administered orally the day before surgery) is controversial, even though it is used by most surgeons.
- While oral or parenteral antimicrobials have been used, combination therapy (oral and IV) was superior to oral regimens alone and IV regimens alone. The combination of 1 g of **neomycin** and 1 g of **erythromycin base** given orally 19, 18, and 9 hours preoperatively is the most commonly used oral regimen in the United States. **Cefoxitin** and **cefotetan** are the IV agents used most commonly, but other second- and some third-generation cephalosporins also are effective.
- Postoperative antibiotics are unnecessary in the absence of any untoward events or findings during surgery.

Appendectomy

- Preoperative antimicrobials are effective at reducing the risk of infection after appendectomy and should be administered in all cases.
- A cephalosporin with antianaerobic activity, such as **cefoxitin** or **cefotetan**, is recommended as first-line therapy; however, cefotetan may be superior for longer operations because of its longer duration of action.
- Single-dose therapy with cefotetan is adequate. Intraoperative dosing of cefoxitin may be required if the procedure extends beyond 3 hours.

Urologic Procedures

- As long as the urine is sterile preoperatively, the risk of SSI after urologic procedures is low, and the benefit of prophylactic antibiotics in this setting is controversial. *E. coli* is the most frequently encountered organism.
- Antibiotic prophylaxis is warranted for all patients undergoing transurethral resection of the prostate or bladder tumors, shock wave lithotripsy, percutaneous renal surgery, or ureteroscopy.
- Specific recommendations are listed in **Table 49-4**.
- Urologic procedures requiring an abdominal approach such as a nephrectomy or cystectomy require prophylaxis appropriate for a clean-contaminated abdominal procedure.

Cesarean Section

- Antibiotics are efficacious to prevent SSIs for all women undergoing cesarean section regardless of underlying risk factors.
- **Cefazolin**, 2 g IV, remains the drug of choice. For patients with a β-lactam allergy, preoperative **metronidazole** is an acceptable alternative.
- Antimicrobial administration should occur at the time of the initial incision instead of at the time of umbilical cord clamping.

Hysterectomy

- Vaginal hysterectomies are associated with a high rate of postoperative infection when performed without the benefit of prophylactic antibiotics.
- A single preoperative dose of **cefazolin** or **cefoxitin** is recommended for vaginal hysterectomy. For patients with β-lactam hypersensitivity, a single preoperative dose of **metronidazole** or **doxycycline** is effective.
- Abdominal hysterectomy SSI rates are correspondingly lower than vaginal hysterectomy rates. However, prophylactic antibiotics are still recommended regardless of underlying risk factors.
- First-, second-, or third-generation cephalosporins can be used for prophylaxis.

Head and Neck Surgery

- Use of prophylactic antibiotics during head and neck surgery depends on the procedure type. Clean procedures, such as thyroidectomy or a simple tooth extraction, are associated with low rates of SSI and antimicrobial prophylaxis is not recommended. Head and neck procedures involving an incision through a mucosal layer carry a high risk of SSI.
- Specific recommendations for prophylaxis are listed in **Table 49-4**.
- Although typical doses of **cefazolin** are ineffective for anaerobic infections, the recommended 2 g dose produces concentrations high enough to be inhibitory to these organisms. A 24-hour duration has been used in most studies, but single-dose therapy may also be effective.
- A single dose of **clindamycin** is adequate for prophylaxis in maxillofacial surgery unless the procedure lasts longer than 4 hours, when a second dose should be administered intraoperatively. For most head and neck cancer resection surgeries, including free-flap reconstruction, 24 hours of clindamycin is appropriate,

Cardiac Surgery

- Although most cardiac surgeries are technically clean procedures, prophylactic antibiotics have been shown to lower rates of SSI.
- The usual pathogens are skin flora (see **Table 49-4**) and, rarely, gram-negative enteric organisms.
- Risk factors for developing an SSI after cardiac surgery include obesity, renal insufficiency, connective tissue disease, reexploration for bleeding, and poorly timed administration of antibiotics.
- **Cefazolin** has been extensively studied and is currently considered the drug of choice. Patients weighing more than 80 kg should receive 2 g cefazolin rather than 1 g. Doses should be administered no earlier than 60 minutes before the first incision and no later than the beginning of induction of anesthesia.
- Extending antibiotic administration beyond 48 hours does not lower SSI rates.
- **Vancomycin** use may be justified in hospitals with a high incidence of SSI with MRSA or when sternal wounds are to be explored for possible mediastinitis.

Noncardiac Vascular Surgery

- Prophylactic antibiotics are beneficial, especially in procedures involving the abdominal aorta and the lower extremities.
- Twenty-four hours of prophylaxis with IV **cefazolin** is adequate. For patients with β-lactam allergy, 24 hours of oral **ciprofloxacin** is effective.

Orthopedic Surgery

- Prophylactic antibiotics are beneficial in cases involving implantation of prosthetic material (pins, plates, and artificial joints).
- The most likely pathogens mirror those of other clean procedures and include staphylococci and, infrequently, gram-negative aerobes.
- **Cefazolin** is the drug of choice. For hip fracture repairs and joint replacements, it should be administered for 24 hours. **Vancomycin** is not recommended unless a patient has a history of β-lactam hypersensitivity or the propensity for MRSA infection at the institution necessitates its use.

Neurosurgery

- The use of prophylactic antibiotics in neurosurgery is controversial.
- Single doses of **cefazolin** appear to lower SSI risk after craniotomy.

See Chapter 141, Antimicrobial Prophylaxis in Surgery, authored by Salmaan Kanji, for a more detailed discussion of this topic.