PROPHYLACTIC ANTIBIOTICS IN SURGERY

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ABSTRACT

Prophylactic antibiotics can decrease the incidence of postoperative wound infections in indicated procedures. The accepted indications for administering prophylactic antibiotics have been clean-contaminated procedures and prosthesis insertion, but new indications are evolving that consider wound contamination together with anesthetic risk and relative duration of the operation. A prophylactic antibiotic is chosen on the basis of its activity against endogenous flora likely to be encountered, its toxicity, and its cost, in that order. Potent antibiotics used for serious infections are generally not used for prophylaxis. A maximum dose of a prophylactic antibiotic is given preoperatively so that effective tissue concentration is present at and after the time of incision. In the absence of infection, antibiotics should not be continued beyond the operative day. Regimens for specific procedures are discussed.

INTRODUCTION

Antibiotic prophylaxis in surgery refers to the administration of antimicrobial agents to surgical patients who do not have an established infection. The goal is a reduction in postoperative wound infection and other infectious complications. Well-designed trials have demonstrated that the appropriate administration of prophylactic antibiotics in selected procedures can reduce postoperative infections to about one half of the
incidence in untreated patients. The infection rates associated with procedures done without antibiotic prophylaxis are listed in Table 1.

**PRINCIPLES OF EFFECTIVE PROPHYLAXIS**

*Timing, Dosing, and Duration*

Parenteral antibiotics should be administered 30 minutes before the skin incision is made so that an effective tissue concentration will be present if intraoperative contamination occurs (1). Antibiotics administered postoperatively in the recovery room are not effective because the combination of vasoconstriction, thrombosis, and the normal inflammatory response in the tissues around the incision isolates the wound from the vascular system and prevents antibiotic delivery. A maximal dose of antibiotic should be given; a lesser dose will not produce effective tissue levels. Most of the antibiotics used for prophylaxis have a half-life of less than two hours (2); dosing should be repeated every two to four hours intraoperatively or whenever the blood loss exceeds 1000 ml. Continuing an antibiotic for prophylaxis beyond the day of the operation is controversial, and may be

<table>
<thead>
<tr>
<th>Site of operation</th>
<th>Patients (No.)</th>
<th>Infected wounds (No.)</th>
<th>Wound infection rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorectal</td>
<td>1449</td>
<td>580</td>
<td>40</td>
</tr>
<tr>
<td>Appendix</td>
<td></td>
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<tr>
<td>normal</td>
<td>176</td>
<td>24</td>
<td>14</td>
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<tr>
<td>inflamed</td>
<td>379</td>
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<td>16</td>
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<td>gangrenous</td>
<td>149</td>
<td>83</td>
<td>56</td>
</tr>
<tr>
<td>Gastroduodenal, not specified</td>
<td>252</td>
<td>69</td>
<td>27</td>
</tr>
<tr>
<td>Duodenal ulcer</td>
<td></td>
<td></td>
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<tr>
<td>elective</td>
<td>165</td>
<td>8</td>
<td>5</td>
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<tr>
<td>obstructed</td>
<td>50</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>perforated</td>
<td>45</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>Gastric ulcer</td>
<td>66</td>
<td>15</td>
<td>23</td>
</tr>
<tr>
<td>Gastric tumor</td>
<td>61</td>
<td>19</td>
<td>31</td>
</tr>
<tr>
<td>Upper gastrointestinal hemorrhage</td>
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<td>20</td>
<td>49</td>
</tr>
<tr>
<td>Cholecystectomy, risk factors</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>15</td>
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<tr>
<td>present</td>
<td>97</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
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<td>81</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
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<td>66</td>
<td>13</td>
</tr>
<tr>
<td>Head and neck</td>
<td>176</td>
<td>80</td>
<td>45</td>
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</table>
detrimental (we do not recommend dosing beyond the operative day). However, if both a prosthesis and a drain are present, continuing the antibiotic until the drain is removed is justified.

**Choice of Antibiotic**

Postoperative infections are usually caused by the endogenous microflora present at the operative site (3). The choice of an antibiotic should be based on a knowledge of these organisms (Table 2). The goal of prophylaxis is to reduce the bacterial concentration in the tissues of the operative incision and site to below the level necessary to cause infection (usually $10^3$–$10^6$ organisms per gram tissue). Additional antibiotics should not be added to a regimen proven by controlled clinical trials; this action usually increases risk more than benefit. Between drugs of equal efficacy, choose the least toxic first and then the least expensive. Antibiotics that are useful for the treatment of serious infections should not be used for prophylaxis since such use could lead to the emergence of bacteria resistant to a needed therapeutic antibiotic.

**Indications for Prophylactic Antibiotics**

The decision to use antibiotic prophylaxis is based on the relative risks (toxic or allergic reactions, emergence of resistant bacterial strains, and superinfection) and benefit (decreased infection rate). Currently available drugs administered as a single dose pose a sufficiently small risk such that, when appropriate, antibiotic prophylaxis is clearly justified. The classic indications for antibiotic prophylaxis are clean-contaminated operations (see below) or those involving insertion of a prosthesis. Less-established

<table>
<thead>
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<th>Location</th>
<th>Pathogens</th>
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<tbody>
<tr>
<td>Nose</td>
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<td>Upper respiratory</td>
<td><em>Pneumococcus</em>, <em>H. influenzae</em></td>
</tr>
<tr>
<td>Mouth/pharynx</td>
<td><em>Pneumococcus</em>, <em>Streptococci</em> (α, β), <em>E. coli</em>, <em>Bacteroides</em> <em>oralis</em>,</td>
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<td><em>melaminogenicus</em>, <em>Fusobacterium</em>, <em>Peptostreptococci</em>, <em>Actinomyces</em></td>
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<td>Colon</td>
<td><em>E. coli</em>, <em>Klebsiella</em>, <em>Enterobacter</em>, <em>B. fragilis</em>, <em>Bacteroides</em> sp.,<em>Peptostreptococci</em>, <em>Clostridia</em></td>
</tr>
<tr>
<td>Biliary tract</td>
<td><em>E. coli</em>, <em>Klebsiella</em>, <em>Proteus</em>, <em>Clostridia</em></td>
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<tr>
<td>Urinary tract</td>
<td><em>E. coli</em>, <em>Klebsiella</em>, <em>Proteus</em>, <em>Enterobacter</em></td>
</tr>
<tr>
<td>Skin</td>
<td><em>Staph. aureus</em>, <em>Staph. epidermidis</em>, <em>Propionibacterium acnes</em>, diphtheroids</td>
</tr>
<tr>
<td>Vagina</td>
<td><em>Peptostreptococci</em>, <em>Staphylococci</em>, <em>E. coli</em>, <em>Gonococcus</em>, <em>Peptostreptococci</em>, <em>Bacteroides</em> sp.</td>
</tr>
</tbody>
</table>
indications include clean operations in patients with impaired host defenses, or operations in patients for whom postoperative infection would be catastrophic as is often the case in cardiac, neurological, or ophthalmologic surgery.

The National Research Council (NRC) classification system describes wounds as clean (no infection present or organ lumen entered), clean-contaminated (controlled entry into organ lumen), contaminated (major break in sterile technique or presence of acute but nonpurulent inflammation), and dirty (infected or traumatic wound). The expected infection rates for each class are <2%, 5–15%, 15–30%, and >30%, respectively. The NRC classification scheme considers only the density of bacteria likely to be in a wound. However, weight loss, protein depletion, evidence of physiologic dysfunction of two or more organ systems, immunocompromised or poor overall health status also have been associated with an increased incidence of postoperative infection (5). Recently, The National Nosocomial Infection Surveillance (NNIS) Program retrospectively evaluated the role of these and other factors in postoperative infection and devised a surgical wound risk index (6). The risk index takes into account the American Society of Anesthesiologists’ preoperative assessment score, the classification of an operation by the NRC classification system, and the relative duration of the operation. The NNIS index appears to be a better indicator of the overall risk of postoperative infection than the traditional NRC wound classification system. Patients considered to have a medium or high risk by the NNIS index probably should receive prophylactic antibiotics even if the operation is considered clean.

PROPHYLAXIS IN GASTROINTESTINAL SURGERY

Esophagus and Gastroduodenum

The esophagus lacks a resident flora. But, when obstructed, it is rapidly colonized by aerobic and anaerobic organisms. Its relatively poor blood supply and lack of a serosa make the esophagus prone to anastomotic leakage. For these reasons, prophylaxis with cefazolin (2 g) is recommended.

In the stomach, the "acid barrier" functions to kill swallowed bacteria, but it is disabled in most patients who need a gastroduodenal operation. In the absence of gastric acid, or with bleeding or gastric outlet obstruction, the stomach develops a flora composed of β-lactam-sensitive anaerobes, salivary streptococci, staphylococci, coliforms, and yeast. Agents that block or neutralize acid secretion should not be administered for one or
two days preoperatively; cefazolin (2 g) is administered prophylactically (1).

Small Bowel and Biliary

The proximal small bowel has no resident flora; the distal 60 cm of ileum is inhabited by fecal organisms. For operations on normal small bowel, prophylaxis is not necessary. With obstruction, the small bowel rapidly accumulates fluid in the lumen that is essentially liquid feces. Intraoperative bowel decompression via an enterotomy is associated with a six-fold increase in septic complications. Whenever small bowel is not in a normal state, administer cefoxitin (2 g).

The normal biliary tract rarely harbors bacteria, but in older patients and in those with biliary tract disease the risk of bactibilia is increased. E. coli is responsible for nearly all cholecystectomy wound infection. E. coli, Klebsiella, Enterococcus, Proteus, and Clostridia are the pathogens associated with common duct obstruction. In operations for acute or chronic cholecystitis without cholangitis, cefazolin (2 g) is recommended. In the presence of cholangitis, ampicillin-sulbactam (3 g) is preferred (1).

Colorectal and Appendix

The 40% infection risk in patients undergoing colorectal operations without antibiotic cover can be lowered to 7% or less by cleansing the colon of gross feces and administering poorly absorbed oral antibiotics effective against the aerobic and anaerobic components of the fecal flora (7). Our current method of preoperative bowel preparation is outlined in Table 3. The addition of parenteral antibiotics to oral bowel preparation may add a marginally positive effect (8–10). Except in circumstances that do not allow for oral bowel preparation, we do not recommend the sole use of parenteral antibiotics.

The best results in appendectomy prophylaxis are obtained with agents effective against fecal aerobic and anaerobic organisms (11). In all cases of suspected appendicitis we recommend a preoperative dose of cefoxitin (2 g intravenously). If perforated appendicitis is found, administration of antibiotics should be viewed as therapeutic and continued as indicated by the clinical circumstances.

PROPHYLAXIS IN OTHER PROCEDURES

Head and Neck Surgery

The infection rate for head and neck operations in which the aerodigestive tract is not entered is less than 2%, and antibiotic prophylaxis is not indicated in these cases (3).
Preoperative day:
1. Oral polyethylene glycol-electrolyte solution (Colyte®, Golytely®), 4 liters taken over 2 hours, beginning at 10 a.m.
2. If chronic constipation or extensive diverticulosis exists, double the purgation volume and start 2-3 hours earlier.
3. If the patient cannot swallow the required volume in the required time frame, pass a nasogastric tube and administer purgation by gavage, removing the nasogastric tube when complete.
4. Clear liquid diet only on this day.
5. Neomycin, 1 g, and erythromycin base, 1 g, together orally at 1 p.m.; repeat at 2 p.m. and 10 p.m.

Operation day:
1. Evacuate the rectum completely into a commode before transport to the operating suite.
2. Administer ampicillin-sulbactam, 2 g intravenously, with induction of anesthesia.
3. Commence operation at 8 a.m.
4. If the operation is scheduled later in the day, appropriately adjust the oral neomycin-erythromycin dosing schedule so that the operation starts 19-20 hours after the first dose of the oral antibiotics.

Clean-contaminated operations (see Table 1) require prophylaxis for *Streptococcus* and *Bacteroides* species. Clindamycin (600 mg intravenously every six hours for one day) may decrease the infection rate to 3-15% (3, 12, 13).

**Cardiac Surgery**

Cardiac operations are considered clean surgery. With extracorporeal circulation, however, the infection rate is higher than would normally be expected. The most common pathogens in postoperative sternal infection are *Staphylococcus aureus* and *S. epidermidis*, although 20% or more of infections may be due to gram-negative bacilli (14). Based on the information in available literature, we recommend that patients undergoing either coronary artery bypass grafting or valve replacement receive cefazolin (2 g). Single doses appear to be as effective as multiple doses, provided that high concentrations are maintained in the blood throughout the operative procedure. In most instances, antibiotic prophylaxis is not needed for pacemaker implantation.

**Thoracic Surgery**

The organisms that cause infection following noncardiac thoracic surgery are those found on the skin or in the tracheobronchial tree. Controlled
trials of antibiotic prophylaxis in pulmonary resection provide conflicting results. Some have demonstrated a decrease in wound infection but not in postoperative pneumonia or empyema. If antibiotic prophylaxis is used, a short course of cefazolin is recommended (14, 15).

Neurosurgery

Recently there have been some controlled trials supporting the use of antibiotic prophylaxis in clean neurosurgical procedures (13, 16). The predominant pathogens in both clean and clean-contaminated operations are *S. aureus* and *S. epidermidis*. Depending on the sensitivity of bacteria isolated in the hospital, either cefazolin or vancomycin is recommended. While prophylaxis for cerebral shunt procedures is controversial, it would be reasonable to administer an antistaphylococcal antibiotic since shunt infection has catastrophic consequences.

Vascular Surgery

In “clean” vascular operations, reported wound infection rates vary from 6-25% in patients not receiving antibiotics to 0-3% in those who are given prophylaxis (15). *S. aureus* and gram-negative rods cause early postoperative infections, while *S. epidermidis* is the predominant cause of late graft infections. Recommended prophylaxis is cefazolin (2 g), as long as two thirds or more of *S. epidermidis* isolates are sensitive (1). If resistance is a problem, ampicillin-sulbactam or SMX-TMP are alternatives. If methicillin-resistant staphylococci are present, vancomycin (for the staphylococci) plus aztreonam (for coliforms) should be effective.

Orthopedic Surgery

The most important organisms recovered in orthopedic surgical infections are *S. aureus* and *S. epidermidis*. Because of the widespread use of antistaphylococcal prophylaxis, however, gram-negative rods now account for 10-30% of infections in prosthetic hip surgery (14). Cefazolin (2 g) can lower the risk of infection following orthopedic open fracture surgery from 4-5% to 1-2.5%, and it also may be used for prophylaxis during the insertion of plates, pins, and other hardware. Whether or not antibiotic-containing cement can replace parenteral prophylaxis in operations performed for total joint replacement is an unsettled issue (17). Open fractures warrant early use of antibiotics with activity against both *S. aureus* and aerobic gram-negative rods; prophylaxis administered for 24 hours or five days has been shown to be equally efficacious (18).

Urologic Surgery

In patients with sterile urine, bacteremia occurs in about 10% of patients undergoing prostate procedures and is usually caused by organisms in the
prostate tissue (14). Following prostatectomy, the organisms responsible for urinary tract infection are, in order of relative frequency, *E. coli*, *Proteus*, *Klebsiella*, *Enterobacter*, *Pseudomonas*, *Staphylococcus*, and *Streptococcus* species. Patients with bactiuria (>10⁵ CFU/ml) or having preoperative Foley catheter drainage should receive cefazolin (2 g). Single doses of a broad-spectrum penicillin or a third-generation cephalosporin are also effective (19).

**Obstetric and Gynecologic Surgery**

Patients at high risk during caesarean procedures include women of low socioeconomic status, those experiencing active labor prior to undergoing the caesarean section, those whose chorioamniotic membranes are ruptured, and women who had frequent preoperative vaginal examinations (20). A single dose of cefazolin (2 g) or ampicillin (2 g), administered immediately after cord clamping (21), results in a 50% reduction in the incidence of endometritis, the most common complication following caesarean section. Low-risk patients may not need prophylaxis. Patients undergoing vaginal or abdominal hysterectomy should be given a single dose of cefazolin (2 g) preoperatively (21). Broad-spectrum penicillins or second- or third-generation cephalosporins have not been shown to be more effective than ampicillin or cefazolin in hysterectomy.

**Clean Operations**

Antibiotics have not been recommended in the past for clean operations unless a prosthesis is to be inserted or the patient is immunocompromised. A recent report, however, documented a somewhat higher infection rate for inguinal hernia and breast surgery than was previously recognized (22). In addition, there has been a trend (but not a statistically significant difference) toward fewer wound infections in patients receiving antibiotic prophylaxis compared to the placebo group in many clinical trials. Some patients having clean operations are in fact at an increased risk of developing an infection, as reflected in an elevated NNIS risk index, and such patients probably would benefit from prophylactic antibiotics. More data are needed, though, before firm conclusions can be drawn about extending the indications for antibiotic prophylaxis in clean operations.

**Literature Cited**


