

of other anaerobic pulmonary infections. Patients may report pleuritic chest pain and marked chest-wall tenderness.

Empyema may be masked by overlying pneumonitis and should be considered especially in cases of persistent fever despite antibiotic therapy. Diligent physical examination and the use of ultrasound to localize a loculated empyema are important diagnostic tools. The collection of a foul-smelling exudate by thoracentesis is typical. Cultures of infected pleural fluid yield an average of 3.5 anaerobic and 0.6 facultative or aerobic bacterial species. Drainage is required. Defervescence, a return to a feeling of well-being, and resolution of the process may require several months.

Extension from a subdiaphragmatic infection may also result in anaerobic empyema.

Intraabdominal Infections Intraabdominal infections—mainly peritonitis and abscesses—are usually polymicrobial and represent the normal intestinal (especially colonic) microbiota. These infections most often follow a breach in the mucosal barrier resulting from appendicitis, diverticulitis, neoplasm, inflammatory bowel disease, surgery, or trauma. On average, four to six bacterial species are isolated per specimen submitted to the microbiology laboratory, with a predominance of enteric aerobic/facultative gram-negative bacilli, anaerobes, and streptococci/enterococci. The most common isolates are *Escherichia coli* (found in $\geq 50\%$ of patients) and *B. fragilis* (30–50%). Other anaerobes commonly isolated from this type of infection include *Peptostreptococcus*, *Prevotella*, and *Fusobacterium* species. The involvement of clostridia can lead to severe infections. The dominance of four to six bacterial species out of the more than 500 colonic mucosal species is related both to the virulence factors of these species and to the inability of clinical laboratories to culture many other species residing in the colonic mucosa.

Disease originating from proximal-bowel perforation reflects the microbiota of this site, with a predominance of aerobic and anaerobic gram-positive bacteria and *Candida*.

Neutropenic enterocolitis (typhlitis) has been associated with anaerobic infection of the cecum but—in the setting of neutropenia (**Chap. 104**)—may involve the entire bowel. Patients usually present with fever; abdominal pain, tenderness, and distention; and watery diarrhea. The bowel wall is edematous with hemorrhage and necrosis. The primary pathogen is thought by some authorities to be *Clostridium septicum*, but other clostridia and mixed anaerobes have also been implicated. More than 50% of patients developing early clinical signs can benefit from antibiotic therapy and bowel rest. Surgery is sometimes required to remove gangrenous bowel. **See Chap. 159 for a complete discussion of intraabdominal infections.**

Enterotoxigenic *B. fragilis* has been associated with watery diarrhea in a few young children and adults. In case-control studies of children with undiagnosed diarrheal disease, enterotoxigenic *B. fragilis* was isolated from significantly more children with diarrhea than children in the control group.

Pelvic Infections The vagina of a healthy woman is a major reservoir of anaerobic and aerobic bacteria. In the normal microbiota of the female genital tract, anaerobes outnumber aerobes by a ratio of $\sim 10:1$ and include anaerobic gram-positive cocci and *Bacteroides* species (Table 201-1). Anaerobes are isolated from most women with genital tract infections that are not caused by a sexually transmitted pathogen. The major anaerobic pathogens are *B. fragilis*, *P. bivia*, *P. disiens*, *P. melaninogenica*, anaerobic cocci, and *Clostridium* species. Anaerobes are frequently encountered in pelvic inflammatory disease, pelvic abscess, endometritis, tubo-ovarian abscess, septic abortion, and postoperative or postpartum infections. These infections are often of mixed etiology, involving both anaerobes and coliforms; pure anaerobic infections without coliform or other facultative bacterial species occur more often in pelvic than in intraabdominal sites. Septic pelvic thrombophlebitis may complicate the infections and lead to repeated episodes of septic pulmonary emboli. **See Chap. 163 for a complete discussion of pelvic inflammatory disease.**

Anaerobic bacteria have been thought to be contributing factors in the etiology of bacterial vaginosis. This syndrome of unknown etiology is characterized by a profuse malodorous discharge and a change in

the bacterial ecology that results in replacement of the *Lactobacillus*-dominated normal microbiota with an overgrowth of bacterial species including *Gardnerella vaginalis*, *Prevotella* species, *Mobiluncus* species, peptostreptococci, and genital mycoplasmas. A study based on 16S rRNA identification found other anaerobes that were predominant in cases but not in controls: *Atopobium*, *Leptotrichia*, *Megasphaera*, and *Eggerthella*. Pelvic infections due to *Actinomyces* species have been associated with the use of intrauterine devices (**Chap. 200**).

Skin and Soft Tissue Infections Injury to skin, bone, or soft tissue by trauma, ischemia, or surgery creates a suitable environment for anaerobic infections. These infections are most frequently found in sites prone to contamination with feces or with upper airway secretions—e.g., wounds associated with intestinal surgery, decubitus ulcers, or human bites. Moreover, anaerobes have been isolated from cutaneous abscesses, rectal abscesses, and axillary sweat gland infections (*hidradenitis suppurativa*). Anaerobes also are often cultured from foot ulcers of diabetic patients. The deep soft-tissue infections associated with anaerobic bacteria are crepitant cellulitis, synergistic cellulitis, gangrene, and necrotizing fasciitis (**Chaps. 156 and 179**).

These soft tissue or skin infections are usually polymicrobial. A mean of 4.8 bacterial species are isolated, with an anaerobe-to-aerobe ratio of $\sim 3:2$. The most frequently isolated organisms include *Bacteroides*, *Peptostreptococcus*, *Clostridium*, *Enterococcus*, and *Proteus* species. The involvement of anaerobes in these types of infections is associated with a higher frequency of fever, foul-smelling lesions, gas in the tissues, and visible foot ulcer.

Anaerobic bacterial synergistic gangrene (*Meleney's gangrene*), a rare infection of the superficial fascia, is characterized by exquisite pain, redness, and swelling followed by induration. Erythema surrounds a central zone of necrosis. A granulating ulcer forms at the original center as necrosis and erythema extend outward. Symptoms are limited to pain; fever is not typical. These infections usually involve a combination of *Peptostreptococcus* species and *S. aureus*; the usual site of infection is an abdominal surgical wound or the area surrounding an ulcer on an extremity. Treatment includes surgical removal of necrotic tissue and antimicrobial administration.

Necrotizing fasciitis, a rapidly spreading destructive disease of the fascia, is usually attributed to group A streptococci (**Chap. 173**) but can also be a mixed infection involving anaerobes and aerobes, usually occurring after surgeries and in patients with diabetes or peripheral vascular disease. The most frequently isolated anaerobes in these infections are *Peptostreptococcus* and *Bacteroides* species. Gas may be found in the tissues. Similarly, myonecrosis can be associated with mixed anaerobic infection. *Fournier's gangrene* consists of cellulitis involving the scrotum, perineum, and anterior abdominal wall, with mixed anaerobic organisms spreading along deep external fascial planes and causing extensive loss of skin.

Bone and Joint Infections Although actinomycosis (**Chap. 200**) accounts on a worldwide basis for most anaerobic infections in bone, organisms including peptostreptococci or microaerophilic cocci, *Bacteroides* species, *Fusobacterium* species, and *Clostridium* species can also be involved in osteomyelitis (**Chap. 158**). These infections frequently arise adjacent to soft tissue infections. Many patients with osteomyelitis due to anaerobic bacteria have evidence of an anaerobic infection elsewhere in the body; most commonly, infected adjacent soft-tissue sites are the source of the organisms involved. Examples are diabetic foot ulcers and decubitus ulcers that may be complicated by mixed aerobic-anaerobic osteomyelitis. Hematogenous seeding of bone is uncommon. *Prevotella* and *Porphyromonas* species are detected in infections involving the maxilla and mandible, whereas *Clostridium* species have been reported as anaerobic pathogens in cases of osteomyelitis of the long bones following fracture or trauma. *Fusobacteria* have been isolated in pure culture from sites of osteomyelitis adjacent to the perinasal sinuses. Peptostreptococci and microaerophilic cocci have been reported as significant pathogens in infections involving the skull, mastoid, and prosthetic implants placed in bone. In patients with osteomyelitis, the most reliable culture specimen is a bone biopsy sample free of normal uninfected skin and subcutaneous tissue.