SURGICAL INFECTIONS

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Definition and Classification

Surgical infection is the product of entrance, growth, metabolic activities, and resultant physiologic effects of microorganisms in the tissues of a patient. There are four characteristics to all surgical infections.

1. They involve postoperative wounds.
2. The infection is unlikely to resolve spontaneously or with simple antibiotic treatment; suppuration, necrosis, gangrene, osteomyelitis, prolonged morbidity and mortality may occur if untreated.
3. Excision or incision and drainage are very often necessary.
4. Surgical infections are usually monomicrobic but may be polymicrobic. They are often invasive with rapid growth and regional or systemic spread.

Classification of surgical infections by location and pathophysiologic changes is as follows:

1. A wound infection: presents with increased inflammation and cellulitis, suppuration or liquefication of tissues, abscess formation, septic necrosis. Further involvement involves number 2.
2. Regional extension: this occurs by direct extension into adjacent tissues by lym phangitis and lymphadenitis, by septic thrombophlebitis and by spreading fasciitis or necrotizing fasciitis. Further involvement involves number 3.
3. Bacteremia and septicemia.

Characteristics of infection are as follows. Infection starts as an exaggerated inflammatory response without suppuration. The marked erythema and warmth of the skin is termed cellulitis. Pain, swelling, and edema also occur. Suppuration and liquefaction of tissues follows in 72 to 96 hours and the presence of a pus-filled abscess is soon noted. The abscess is walled off by a membrane which produces induration about the abscess, giving a rather solid feel to the tumor. Regional involvement occurs from direct extension of microorganisms along areolar, fascial, muscular, and other anatomical planes.

Bacteria release proteinases which aid the process of tissue liquefaction. Collagenase is an example of such an enzyme and aids in the spread of the infection.

Bacteria and their metabolic products may be carried from the area of primary infection into the lymph fluid and distributed to large areas through the lymphatics and larger lymph nodes. In doing so they may cause lymphangitis (red streaking) and lymphadenitis (palpable lymph nodes).

Involvement of local blood vessels may result in thrombophlebitis and further spread of the infection. Necrotizing fasciitis is usually of regional extent but can go on to involve the foot and/or lower leg.

Systemic infections occur through the dissemination of microorganisms from a distributing focus into the blood stream resulting in either bacteremia or septicemia. Bacteremia is present when the primary focus distributes bacteria once or intermittently, resulting in their transient appearance in the blood. Septicemia results when the bacterial distribution is more or less constant, causing their continued presence within the bloodstream. Therefore, the difference is in the rate of dissemination and density of release from the distributing focus with the rate constant in septicemia and intermittent in bacteremia.

Bacteremia and/or septicemia can cause distant organ involvement. Examples include those infections which develop in the liver, pancreas, biliary tract, lung, or kidneys.

The presence and complete identification of microorganisms in a surgical infection is important. Although staphylococcus aureus is most frequently found in the postoperative patient it must be remembered that surgical infections may be mixed bacterial infections produced by a variety of bacteria both gram-positive and gram-negative, aerobic and anaerobic. The incidence of gram-negative, fungal, and viral surgical infections has steadily increased with the expanding clinical use of steroids, immunosuppressive agents, and multiple antibiotic agents. This is especially prevalent in the burn patient.

The enteric gram-negative bacteria are found in almost 50% of postoperative wounds which become infected. Also staphylococcus is found in over 60% of cases where postoperative wounds become infected. Because of this prevalence patients are usually given prophylactic first generation cephalosporin in increased risk and contaminated cases. It is effective on not only staphylococcus, but also on many of the enteric gram-negative organisms.

Certain criteria are established in order to provide objective definitions and understanding of surgical infections that will permit consistent evaluation. Microbial reports alone are unreliable because of limitation of some bacteriology labs, inadequate sampling and testing, or positive results secondary to outside contaminants. Therefore, universal or uniform clinical criteria are used to promote understanding and agreement among physicians. These are as follows:

1. Wounds are definitely not infected when there is a healing ridge by five to eight days and/or primary intention healing is noted.
2. Wounds are definitely infected when there is purulent drainage noted even if no organisms are found under the microscope.
3. Wounds are possibly infected when there is marked inflammation without discharge or when there isculture positive serous drainage from the wound. Other helpers in identifying infected wounds include the vital signs, the CBC with differential.

Wound classification is based on clinical estimation of bacterial density, contamination, and risk of subsequent infection. Clean wounds are elective wounds which are primarily closed and do not drain. They are non-traumatic, uninfected wounds. There is very minimal inflammation encountered, and there is no break in the aseptic technique. lean wounds have an infection rate of 1% to 2%.

Clean contaminated wounds constitute a minor break in aseptic technique. There is some mechanical drainage noted and the infection rate in these is approximately 8%.

Contaminated wounds are open wounds which are flushed and are usually traumatic in nature. There are major breaks in aseptic technique and infection is prevalent in 15% to 23% of these cases.

Finally, dirty or infected wounds include traumatic wounds with devitalized tissue and there is acute bacterially induced inflammation and pus encountered during the operation.

Laboratory Support in Surgical Infections

The microbiology lab is of particular importance in the prevention and control of surgical infections. Clinicians using the lab should become familiar with its work since specimens are selected and taken more intelligently when it is known what the lab can do, how it is done, and how the results are interpreted.

Effective management of patients with surgical infections necessitates constant surveillance of hospital practices and regular assessment of sensitivity of causative organisms in order to employ proper therapy. The laboratory support begins with the culture techniques employed. It is the responsibility of the physician to recognize the need for culture and to use proper method and timing for collection of culture material. The following rules should be followed to ensure proper microbiological diagnosis.

1. Obtain an appropriate specimen for the type of disease and organism anticipated. Example is to culture the walls of an abscess rather than the center only. Also bone tissue is needed for culture material in suspected osteomyelitis. Culturing sinus tracks in osteomyelitis and other infections is worthless.
2. Collect specimens prior to the initiation of antimicrobial therapy by means of aseptic technique. Transport the specimen in a sterile container using transport media appropriate for the specimen concerned.
3. Swab cultures of open, draining wounds or tracks should first be cleaned with betadine, milked, and then cultured.
4. Provide the microbiologist with a presumptive diagnosis based on clinical presentation. Also describe antibiotic therapy if it is being used.
5. Ensure appropriate transport and timely delivery to the laboratory of each specimen. This is especially important in cases of suspected anaerobic infections.
6. At the time of the culture, submitting additional specimen material for direct gram strain smears may permit presumptive diagnosis, thus enabling the initiation of appropriate antibiotic therapy.

Mycology

The increased occurrence of nonbacterial infections in surgical patients has accentuated the need for accurate diagnosis of yeasts and fungii removed from surgical patients. Examination of a Wright stain of a peripheral blood smear may reveal a systemic fungal infection or the presence of fungii in the blood. In general, swabs and surface culture techniques are ineffective in the isolation of fungii and yeast, and tissue biopsies are necessary.

Fungal organisms causing infections of clinical importance in surgery include Candida albicans, aspergillus, fusarium, histoplasma coccidioides, and blastomyces.

Antibiotic Therapy

Certain criteria must be met if antimicrobial agents are to be effective in the treatment of established infection or prevention of potential infection. They are:

1. The pathogen must be sensitive to the antimicrobial agent
2. The agent must make contact with the pathogen.
3. There should be nothing at the site of microbial activity that interferes with the action of the antimicrobial agent.
4. Untoward consequences of drug therapy should be anticipated, recognized and treated.
5. Unsatisfactory response during treatment must be evaluated.

Pathogen Sensitivity

A pathogen is considered sensitive to an antibiotic agent if its growth *in vitro* is inhibited with a concentration usually obtained in tissue fluid or blood following the customary dose. Selection of an antimicrobial agent should involve identification of the microbe and determination of the agents to which it is susceptible. This is done by the collection and culturing of pathological material and *in vitro* testing for sensitivity to commonly used drugs. Specimens should be obtained before starting the administration of an antimicrobial agent. Susceptibility testing of these specimens is done with disc diffusion tests or the so called Kirby Bauer sensitivity test.

In disc diffusion tests, once the pathogen is grown on a culture plate, antibiotic discs are placed on that culture plate, and the effectiveness of the antibiotic is measured as the zone of inhibition or the zone of bacterial death around that disc.

The terms "susceptible" or "resistant" are based on the zones of inhibition produced by the concentrations of antimicrobial agents usually obtainable in blood levels with usual doses of that drug.

Many labs now report microbe sensitivity to antibiotics as MIC (minimal inhibitory concentration) levels. This measures the amount of antibiotic needed to inhibit the growth of the microbe cultured, or the inhibitory concentration. The MIC level differs for every organism cultured and the different antibiotics used on them. Therapeutic dose is equal to four times the MIC. This test is preferred. It gives the physician a dose as well as sensitivity or resistance of the organism.

Antimicrobial agents only help the usual defense mechanisms of the host against infection. Some drugs are bactericidal (that is, they destroy bacteria) while others are bacteriostatic (they inhibit the multiplication of the bacteria without destroying it). When bacteriostatic agents are used the final resolution of the infection depends on the natural defenses of the body. Therefore, these agents should be reserved for use in those patients whose usual host mechanisms are intact. When dealing with infections in patients in whom the natural microbial defense mechanisms are impaired, bacteriocidal agents are preferred.

Antibiotic Pathogen Contact Of critical importance to effective antibiotic therapy is contact between microorganism and an adequate amount of the drug. To start with, the route of administration is important. In surgical patients, particularly in the perioperative period, oral administration is an inadequate method of delivery. Intravenous administration provides more rapid tissue perfusion and usually higher tissue concentrations without adverse reaction. In many infections, intermittent administration of intravenous bolus antibiotics resulting in intermittent yet very high tissue levels of the drug is preferred to continuous infusion.

Another important consideration is that when antibiotics are used systemically, blood flow to the area of infection must be adequate to permit delivery of an effective concentration to that site of the pathogens. In acute and localized infection such as cellulitis or lymphangitis, blood flow is usually abundant and tissue perfusion by the drug most adequate. On the other hand, areas of fluid accumulation or tissue death, such as abscesses or necrotizing fasciitis may be penetrated very poorly and inadequate tissue levels of antibiotic will result.

Another consideration is interference with the antimicrobial action. This should be avoided for adequate antibiotic therapy to be effective. The penicillins are most susceptible to interference by the enzyme penicillinase. This enzyme is produced by certain staphylococci and coliform bacilli (E. Coli). The cephalosporins are inhibited by cephalosporinase (believed to be very similar to penicillinase), and the sulfanomides are inhibited by paraaminobenzoic acid.

Infections caused by penicillinase producing staph aureus are very common in the postoperative patient. In these patients, penicillinase resistant antibiotics are used. If the result of culture and sensitivity show staph to be resistant to methocillin (the prototype of all penicillinase resistant penicillins), Vancomycin is the drug of choice.

Still another consideration is that one should always anticipate, recognize, and promptly treat untoward consequences of drug therapy. No antibiotic is free of potentially adverse effects, therefore, one must always be alert when prescribing antibiotics, especially in higher doses where the margin between therapeutic and toxic doses is narrowed. Adverse reactions include hypersensitivity of the patient, changes in microbial flora resulting in superinfection, and patient idiosyncracy. A final consideration is that if a patient does not improve during drug therapy, diagnostic reevaluation is essential. The evaluation should include a physical examination, laboratory tests, including blood culture and diagnostic x-rays, isotopic studies, and search for new sites of infection.

Causes of failure include the wrong initial diagnosis, resistance of the pathogen, new pathogen introduction. For most acute surgical infections, it is not necessary to prescribe antibiotic therapy for more than ten days. However, chronic infections such as osteomyelitis and tuberculosis usually require prolonged antimicrobial therapy.

Antibiotic Dosing

For an antibiotic to be effective its concentration at the site of infection must exceed the minimal concentration of antibiotic required to kill or inhibit bacteria involved. Factors determining the concentration of antibiotic within the body include absorption, protein binding, distribution, and excretion.

Rapid and accurate measurement of antibiotic concentrations in blood have made it possible to apply pharmacokinetics to antibiotic dosing. This is especially important in managing the dosage of aminoglycosides considering their narrow toxic-therapeutic ratio and the wide variation in elimination and dose requirements among different patients. Patients with a moderate to marked infection requiring aminoglycosides are often in a hyperdynamic state with increased intravascular volume, increased cardiac output, and increased glomerular filtration rate. In these patients, aminoglycosides are rapidly excreted by the kidney, and the patient may need to be dosed every four to six hours to maintain proper antibiotic levels. Conversely, elderly individuals with decreased glomerular filtration rate and decreased kidney function may not excrete the drug as rapidly and effectively as normal and may require a longer interval between doses. Therefore, for agents that pose a serious medical threat to patients because of their low therapeutic-toxic dose ratio, serum drug levels are determined throughout therapy.

Agents where this is routinely done include aminoglycosides and Vancomycin. The level of the antibiotic is measured from a sample of the patient's blood after 72 hours of therapy. The peak level of the drug is measured 30 minutes after the infusion of the drug, and the trough is measured 30 minutes before the infusion of the drug. If the peak level fails to reach true minimal inhibitory concentrations, the dose of the drug should be increased to allow therapeutic levels of the drug in the tissues. If the trough level of the drug does not fall below a certain safe level, the dose of the drug is lowered to prevent toxic reactions to the drug from occurring.

Surgical Intervention and Its Relationship to Antibiotic Therapy

The relationship between surgical intervention and antimicrobial therapy in the management of infection depends upon the characteristic of the clinical lesion. In many cases of postoperative infection a surgical operation is the primary therapeutic modality, and antibiotics are of secondary importance. These include all cases of pyogenic abscess formation, infected gangrene, and infected tissue necrosis.

In unlocalized infection the use of an antibiotic without operative intervention is often recommended provided the tissues at the site of bacterial activity are intact, well vascularized, and not threatened by pressure (edema). Lymphangitis and cellulitis meet these requirements.

When the inflammatory process localizes and presents as a pyogenic abscess, tissue necrosis or confinement within a closed space, surgical intervention is of primary importance. Antimicrobial therapy alone is minimally or not at all effective. The antibiotics are used to deal with the residual elements of the infection and prevent extension to uninvolved tissues.

Surgical intervention in the management of localized infection includes the following:

1. Incision and drainage of purulent material.
2. Excision of devitalized tissue including sinus tracks.
3. Decompression of tension in closed space.
4. Removal of foreign bodies.

The prophylactic use of antibiotics employs the drugs during the period of primary lodgement prior to colonization and before the contamination is localized.

Osteomyelitis

Osteomyelitis is an inflammation of bone secondary to pyogenic infection of the bone. Although numerous microbes have been implicated in the disease process only a handful are seen with regularity, especially in the postoperative patient. Effective treatment of osteomyelitis depends on early and accurate diagnosis, appropriate antibiotic selection, and oftentimes surgical resection of infected necrotic bone.

Osteomyelitis presents as an acute, subacute, or chronic infection of bone. It is also classified according to endogenous or exogenous sources of bacterial origin. Endogenous infection represents blood-borne infection which seeps into the osseous architecture and is commonly referred to as hematogenous osteomyelitis. Branches of the nutrient arteries to the long bones and metaphyseal arterioles which take very acute turns back on themselves in the metaphyseal epiphyseal junction of the bone appear especially vulnerable. These arterioles end in larger sinusoidal veins, making circulation in this area very sluggish. It is in these areas of sluggish circulation that bacteria are able to proliferate and cause infection.

Exogenous osteomyelitis results from direct extension or contiguous foci and direct implantation such as puncture wounds or intraoperative contamination.

Clinical Presentation. Acute osteomyelitis is most often found in the pediatric patient with a male predominance. It is most commonly noted in the femur, tibia, and humerus, although the foot is involved in 10% to 13% of the cases. Endogenous or hematogenous seeding of bacteria from a distant site accounts for the etiology in the majority of cases. A previous history of trauma to the involved area is reported in 30% to 50% of the cases. Primary foci include abscesses, furuncles, impetigo, eczema, upper respiratory tract infections, acute otitis media, tonsillitis, urinary tract infections, and paronychia. Bacteria from these foci allow microbes to enter the bone and start the septic process.

These patients usually present with a history of sudden onset of chills, high fever, nausea, anorexia, tachycardia, and general malaise. Progressive bone pain will also be noted that is aggravated with movement. Fluctuant swelling of subperiosteal abscesses may be palpable.

Subacute osteomyelitis may result from the presence of infection by an organism with reduced virulence in an individual with a high level of resistance or in a patient treated for osteomyelitis with less than optimal levels of antibiotics. The majority of these cases involve staph aureus, salmonella, and tuberculosis. Four types of bone lesions are identified: 1) Brodie's abscess, 2) Garre's sclerosing osteomyelitis, 3) osteolytic lesions, 4) diaphyseal lesions.

Brodie's abscess is the most common form of subacute osteomyelitis. It is a lytic area of bone in which the infection is walled off and effectively contained by reactive formation of a surrounding layer of granulation tissues. This lesion presents primarily in metaphyseal bone.

Chronic osteomyelitis is a sequel to untreated or inadequately treated acute osteomyelitis. The patient has a history of recurrent attacks of fever, swelling, and pain in the involved area over a period of months or years. There may be a persistent draining sinus over the area with drainage from the sinuses increased during acute episodes of osteomyelitis.

Patients are generally over 20 years of age. The presenting symptom is commonly that of pain which is worse at night, aggravated by activity, and relieved by rest. The presence of persistent or intermittent drainage of purulent material from the sinus is the usual presentation.

Laboratory studies which are used in cases of osteomyelitis include:

1) CBC with differential, looking for leukocytosis, and a shift to the left in acute stages,

2) erythrocyte sedimentation rate and C-reactive protein, both are accelerated by the body in response to infection and other inflammatory stimuli. These are both nonspecific but give the clinician an idea of response to therapy.

3) Teichoic acid antibodies. Teichoic acid is a component of the cell structure in staphylococcus bacteria. The body produces antibodies against this protein which are measured. Large levels indicate a staph infection.

4) ASO anti-DNAse D, and anti-hyaluoronidase. These are three antibodies produced in response to Group A streptococci. Antistreptolysin O is usually available and easily reproducible.

Radiographic Studies. Localization of bacteria within bone causes an inflammatory reaction and lowering pH due to increased metabolism locally. With this, there is a removal of bone matrix (collagen) and calcium. Therefore, the earliest x-ray change seen in osteomyelitis is a loss of bone density in the involved areas. As the infective process continues there is a spread of it to adjacent bone through the Haversian and Volkmann's canals. This destroys the normal vascular network and causes further bone death. As the bone dies, it appears sclerotic and radiodense on x-ray. Large islands of devitalized bone form and are referred to as sequestra (isolation of dead bone from living bone).

Simultaneously, spreading edema and fluid causes compression of soft tissue structures such as vessels, lymphatics, and nerves which lie between the bone lamellae. The ischemia produced by the compressive action of edema, together with the tendency toward embolic infarction, increases the extent of bone necrosis. Fluid passes the outer limits of the cortex and the elasticity of the periosteum replaces the rigid structures of the bone. Edema collects here and is soon replaced by pus. When infection reaches the outer cortex, it may cause the invasion of the slow periosteal blood flow and thus gain access to the subperiosteal space resulting in subperiosteal abscess. These abscesses are evidenced by reactive subperiosteal calcification. This induces exuberant growth of periosteal bone termed involucrum formation.

Osseous changes on x-ray is not evident for 10 to 14 days postinfection. However, early soft tissue changes are recognized and aid in the early accurate diagnosis. The first radiographic finding consistent with osteomyelitis is an increase in density and swelling in the anatomical configuration of involved muscles. Other early changes include subperiosteal calcification which corresponds with subperiosteal abscess formation. After 14 days the radiolucency described above appears and the involved bone takes on a mottled look due to bone lysis. The formation of cloaca or a lytic tract through the cortex may be noted this early. By the end of the second week opaque areas of new bone formation are noted. The formation of so called sequestra are noted by the third week of infection. This characterizes the beginning of the chronic osteomyelitis.

Treatment of Osteomyelitis

When osteomyelitis is highly suspected accurate and reliable cultures are mandatory. Soft tissue cultures are inadequate, especially cultures of open ulcers and sinus tracts. Bone cultures are necessary to make proper diagnosis of the causative organism. Bone cultures must be made through uncontaminated skin which often necessitates a separate incision. All antibiotics should be discontinued 48 hours before the culturing is done.

Antibiotic therapy alone is usually insufficient for resolution of osteomyelitis. This is due to the build up of fluid within the bone and subsequent increased pressure on the vessels to the bone. Once the circulation is impeded, antibiotics are not able to reach the infection to be effective. Also necrotic bone harbors bacteria which are able to produce a protective film around themselves and wall themselves off from white blood cells and antibiotics. Therefore, when osteomyelitis is diagnosed it should be surgically resected and antibiotic therapy utilized.

Identification of the pathogen is done in the microbiology laboratory. However, the majority of postoperative osteomyelitis cases are caused by staphylococcus aureus. The other common pathogens include gram-negative bacilli such as e. coli, proteus, pseudomonas, and salmonella in those patients with sickle cell disease. Hematogenous osteomyelitis caused by gram-negative bacilli is associated with gastrointestinal and genitourinary infections while acute respiratory infections cause pneumococcal and bacteroides osteomyelitis. Mycobacterium tuberculosis and fungal osteomyelitis are usually traced to chronic pulmonary processes.

Appropriate antibiotic therapy is initiated once the culture and sensitivity results are known. Intravenous antibiotic therapy is mandatory for a four to six week period. Recurrence of the infection can be expected with treatment for a shorter period of time, or with oral antibiotics.

Surgery is performed as soon as possible after the extent of involvement is defined. Only in cases of acute osteomyelitis prior to bone necrosis, in cases of chronic hematogenous osteomyelitis, and in patients with vascular disease, is antibiotic therapy alone attempted. Surgically, all soft tissue and bone which appears necrotic is resected, including a small portion of apparently good bone. If the infection continues to a joint, disarticulation is felt to be the best surgical approach, in that it maintains the cartilage at the head of the adjacent bone, and the cartilage provides a protective barrier to pathogens entering the osseous structure. If transcortical bone is cut and removed, the pathogens have easy access to the Haversian and Volkmann's canals and continued spread of infection occurs.