TREATMENT OF WOUNDS

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There can be no standard treatment for wounds. The treatment of each wound must be individualized, taking into account such factors as destruction of tissue, amount of contamination, and lapse of time since the wound was received. The final decision as to the treatment of a wound must be based on sound knowledge of the physiology and pathology of the healing process.

The chief factors that promote sound and rapid wound healing are as follows:

1. Absence of infection
2. Absence of foreign material
3. Good blood supply
4. Complete immobilization
5. Pressure dressing
6. Normal serum proteins
7. Normal supply of vitamin C
8. Absence of nerve injuries, debilitating disease, and unrecognized factors that may retard healing

BACTERIOLOGY

The staphylococcus is one of the most common contaminants of wounds. This organism is widely distributed in the skin, in the nose and throat, and often even in the air.

Staphylococcic infections are characterized by suppuration. Thick creamy pus forms early, and in the average case the infection remains more or less localized. When the organisms are of high virulence (usually hemolytic Staphylococcus aureus) or when the patient's resistance is low, the staphylococcus may become more invasive and is likely to cause spreading cellulitis, lymphangitis, or septicemia. But most staphylococcic infections of wounds are low grade and often cause protracted suppuration and drainage.

Before the advent of the sulfonamides, hemolytic streptococcus was the most dreaded cause of fulminating infection. Infections from this organism have been known to produce septicemia and death within a day or two of onset. A rapidly spreading cellulitis, lymphangitis, or septicemia, often accompanied by chills and fever, is characteristic of virulent infection with hemolytic streptococcus. The pus is likely to be

thin, brownish or reddish in color due to hemolysis of blood cells, and relatively scanty in comparison with the amount of cellulitis. In its less virulent forms, or when the resistance of the patient is high, the hemolytic streptococcus may cause persistent suppuration.

Nonhemolytic streptococci and Bacillus coli predominate in the gastrointestinal tract and are the most common contaminants of penetrating wounds of the abdomen. These organisms are of relatively low virulence, do not invade the tissues extensively, and cause relatively little cellulitis or lymphangitis. They rarely cause septicemia. The most common infection by these organisms is localized suppuration. The pus may vary in consistency and color from thin and brown to thick and white; if B. coli is present, the pus has a characteristic foul odor.

B. pyocyaneous causes superficial, usually nonpathogenic infections characterized by the production of green pus. Except for delaying wound healing and interfering with skin grafting, this type of infection is of little clinical significance.

Mixed infections, in which several or all of these organisms may be present, may occur and are unpredictable in their course.

SOURCES OF CONTAMINATION

Most wounds are contaminated not so much by the instruments which inflict them as by subsequent exposure to virulent bacteria. An instrument which inflicts a wound, although far from sterile, is not likely to be contaminated with virulent organisms unless it has been in contact with infected material, such as a knife blade used in operating in a case of infection. Pocket knives, kitchen utensils, tools, and so forth, even if dirty, are not too dangerous a source of infection provided that the wounds they inflict are protected from further contamination. The resistance of the tissues is high when a wound is inflicted by a sharp instrument that does not traumatize and devitalize tissues.

The reaction to nonmetallic foreign bodies is more severe than is that to most metals, and infection is likely to occur. Infection introduced by these missiles is not likely to be virulent unless the wound is further contaminated by ill guided attempts at treatment.

The most virulent organisms that commonly infect wounds come from the nose and throat of the patient or his attendants. These organisms, hemolytic streptococcus, staphylococcus, and various other pathogens, are easily transferred to the wound from the nose and throat or from the hands of the attendants. For this reason the wound should

be protected as early as possible with a sterile or at least a clean covering to prevent contamination with virulent organisms. Definitive treatment should be deferred until sterile gloves, masks, and instruments are available.

A serious and common error made by the layman is to wrap a fresh wound in a handkerchief or to suck it. There is no single way to infect a wound more seriously than to expose it to the contamination of the mouth or of a used handkerchief. A piece of shirt tail or any piece of clothing which is not grossly dirty makes a suitable emergency covering for a wound until sterile dressings are available. The most important thing is to cover the wound so that it will not become contaminated by organisms from the nose, throat, or hands of the patient or his attendants.

The air contains organisms which, although generally of low virulence, will contaminate a wound and cause infection. This is particularly true in crowded places and when upper respiratory tract infections are prevalent. It is important that a wound be protected as soon as possible from contamination by organisms in the air.

Penetrating wounds of the abdomen or wounds around the rectum may be contaminated by B. coli or other organisms from the gastrointestinal tract. Little can be done to prevent such contamination, but adequate drainage should be provided for the infection which ensues.

PREVENTION OF INFECTION

Second in importance only to protecting a wound from contamination is prompt and adequate chemotherapy. Sulfonamides and penicillin effectively control infections due to hemolytic streptococcus and staphylococcus, which constitute the most common and severe pyogenic infections. If a chemotherapeutic drug is not introduced directly into the wound, systemic chemotherapy should be instituted at once.

If the wound is severe or possibly contaminated, the dissemination of the infection can be best prevented by immobilizing the affected part by application of a splint or a plaster cast. The spread of infection though the lymphatics is thereby controlled, and infection, should it occur, tends to remain localized.

Pressure dressings are of value in combating infection: They not only obliterate the dead space, which would otherwise fill up with serum or air, but also approximate the tissues and allow normal healing to take place. Cavities filled with blood or serum have an increased tendency to become infected, and if accumulation of serum can be prevented, the incidence of infection will be lowered.

TREATMENT OF ESTABLISHED INFECTION

Chemotherapy. The new chemotherapy, the sulfonamides and penicillin, has largely replaced the antiseptic therapy of the last decade. It has long been realized that older types of antiseptic when introduced into wounds in concentrations sufficiently high to destroy bacteria also destroy tissue cells. This destruction of tissue does more harm than the antiseptic action of the drugs does good.

Sulfonamides. The sulfonamides, and more recently penicillin, do not have the disadvantage of destroying sensitive tissue cells. At the same time their bacteriostatic and bactericidal properties render them effective in the prevention and control of infection from many common pyogenic organisms. Whether the efficacy of these products will prove to be higher when introduced directly into the wound than when given systemically is still debatable. Most well controlled experiments on animals indicate that the protective and therapeutic value of these products is no higher when used locally than when used systemically. The occurrence of this phenomenon in sulfonamide therapy is explained by the fact that the action of sulfonamides is inhibited by pus, necrotic tissue, or products of proteolysis. It is established beyond a doubt, however, that sulfonamides, whether given locally or systemically, do prevent the invasion of tissue by organisms sensitive to their activity.

Hemolytic streptococcus is specifically controlled by sulfonamide therapy. To a lesser degree staphylococcus is controlled by sulfathiazole and sulfadiazine as well as by high concentrations of sulfanilamide. Even nonhemolytic streptococcus and B. coli appear to be somewhat inhibited by high concentrations of these drugs.

Sulfathiazole, and to a lesser degree sulfadiazine, is irritating to tissues. Sulfanilamide causes little irritation and is absorbed rapidly and completely. Probably the rate of absorption as well as the amount of tissue reaction caused by these drugs is an expression of their solubility. Sulfanilamide, which is more soluble, is absorbed so rapidly that extremely high concentrations of the drug are obtained in the tissues. When the concentration of sulfanilamide rises, the staphylococcus, which is not susceptible to sulfanilamide levels obtained by systemic administration, is also amenable to control. In view of this fact, and since the more soluble sulfanilamide does not tend to cake in tissues or cause excessive foreign body reaction, sulfanilamide would seem to be preferable for local application. Those who favor sulfathiazole state that foreign body reaction and tendency to cake are minimal when sulfathiazole

is prepared in microcrystalline form[1] and are enthusiastic about the results. In all probability there is little difference between the efficacy of the two drugs used locally, or between results obtained by the local use of these drugs and those obtained by systemic administration of full doses of either sulfathiazole or sulfadiazine.

When sulfanilamide is introduced into the peritoneal cavity, absorption is extremely rapid, and high blood levels may be expected; the same results are obtained to a lesser extent when the drug is introduced into the pleural cavity. The level of sulfanilamide in the blood rises approximately 1 mg. per 100 cc. for every gram of powder introduced into the peritoneal cavity. Thus, if 10 Gm. is used, a blood level of approximately 10 mg. per 100 cc. may be expected.

When sulfonamides are applied to freshly burned surfaces, similar rapid absorption into the blood takes place, but when sulfonamides are introduced into a wound or are applied to granulating surfaces, the process is much slower, and there need be no fear of overabsorption.

Since the effects of the sulfonamides are neutralized by peptones and products of proteolysis, sulfonamide therapy is obviously no substitute for prompt and adequate drainage of abscesses or pockets of pus. Azochloramid, however, has a specific effect in neutralizing products of proteolysis and thereby facilitates the activity of sulfonamides. The effect of azochloramid and sulfanilamide used together is better than that of either of the drugs used independently.

One objection to the local use of sulfonamides is the tendency for the drugs, when applied locally, to sensitize the patient to their subsequent use. Oral administration of sulfonamides rarely induces sensitivity, but evidence is accumulating to indicate that topical application often induces both local and systemic sensitivity. The routine use of sulfonamides in the local treatment of minor cuts and burns must be evaluated in the light of this possibility.

Penicillin. The clinical action of penicillin is identical with that of the sulfonamides and is more effective. Organisms that are susceptible to sulfonamide therapy respond even better to treatment with penicillin. Again hemolytic streptococcus is the most sensitive, staphylococcus is somewhat less sensitive, and nonhemolytic streptococcus and B. coli are only slightly susceptible to control. Penicillin should promptly and completely control cellulitis or lymphangitis due to the hemolytic streptococcus or staphylococcus but will have little effect on mixed flora in peritonitis resulting from a ruptured appendix. Penicillin is not a sub-

stitute for surgical drainage of pus, and although occasionally it will sterilize cavities filled with pus or clear up infection when drainage is inadequate, it cannot be counted on to do so.

Like the sulfonamides, penicillin will control cellulitis around an abscess and will diminish the systemic reaction to infection. Even in such mixed infections as ulcerative colitis and pulmonary suppuration the systemic reaction is often partially controlled when penicillin is given. But the underlying disease condition, whether it be an undrained abscess, empyema, or an ulcerative lesion of the bowel, is rarely affected by the administration of the drug.

The advent of penicillin has not widened the field of chemotherapy but has merely rendered it more fertile. Penicillin does just what sulfadiazine does, but it does it better.

Penicillin is ineffective when given by mouth and must be given either intramuscularly or intravenously. The drug is excreted rapidly by the kidneys and hence should be given in small divided doses rather than in single large ones. If the drug is given intramuscularly, the absorption is slower, and satisfactory levels are maintained in the blood for a longer time than when the same dose is given intravenously. An alternative method is the continuous intravenous drip.

The average daily dose of penicillin for controlling infections of moderate severity due to the hemolytic streptococcus or staphylococcus is 90,000 units given intramuscularly, 15,000 units every four hours day and night. If the infection is susceptible to control with penicillin, it will show definite evidence of improvement within twelve to forty-eight hours. If no improvement is noted in three days, improvement probably will not occur, no matter how long the drug is given. The average course of penicillin therapy lasts four days. Relapses may occur, just as they do with sulfonamide therapy, if treatment is discontinued too soon. In severe infections it is often well to continue to give small amounts (30,000 units daily) for several days to prevent such relapses.

In fulminating infections or in infections caused by organisms not susceptible to penicillin therapy, larger doses, up to 300,000 units daily, may be given by continuous intravenous drip. Lyons[2] believes it is better to begin with a relatively large dose lest the organisms become penicillin-fast and render subsequent treatment less satisfactory. In most cases doses in excess of 100,000 units daily are no more effective than smaller doses.

Penicillin may be used locally as well as systemically. A solution containing 25,000 units of penicillin in 100 cc. of water may be used to instil in cavities or to saturate packs applied to infected surfaces. The results of local application of penicillin are often dramatic, but the test of time has not as yet determined whether it is actually more effective when applied topically than when given systemically. The dry powder not only is irritating but also is expensive and has not been widely used for local application.

Penicillin is practically nontoxic. Occasionally mild febrile reactions and urticaria result from its administration, but these are thought not to be caused by the drug itself.[3] It has no untoward effect on the blood, kidneys, or liver, and no serious complications have been reported from its use.

Infection with the B. pyocyaneus does not respond favorably to treatment with sulfonamides, and it is doubtful whether penicillin therapy will prove more effective. Although this infection is often difficult to eradicate, saturation of the dressings with ½ per cent or 1 per cent acetic acid every four hours for a day or two will usually bring it under control.

Drainage. The provision of adequate drainage is the most important feature of the treatment of infection. If drainage is not provided, the infection will spread, systemic reaction will increase, healthy tissue will be destroyed, anaerobic organisms may gain a foothold, and chemotherapy will be ineffective.

Continuous soaks or wet dressings afford the best means of maintaining drainage. The constant moisture not only dilutes and washes away the pus but also prevents secretions from agglutinating the edges of the wound and from coagulating on the dressings to block drainage. Vaseline gauze packed loosely into a cavity is another effective means of maintaining drainage, but the surfaces when treated with vaseline are never so clean and healthy as when treated with continuous saline dressings.

When inadequately drained cavities are present or when a deep penetrating wound is infected, drainage may be provided by inserting a catheter into the depths of the wound and irrigating it every hour or two. Sometimes, if the wound is favorably located, a continuous drip system of irrigation may be set up.

The type of fluid used for irrigation is not so important as the frequency and regularity of the irrigations. Sulfanilamide powder suspended in a 1:500 aqueous azochloramid solution produces good results,

but plain saline will often clean up a bad infection in short order. Penicillin may be used when the cavity will hold the solution or when packing can be saturated with the solution.

If the infection does not respond to this type of therapy within three or four days, surgical revision of the wound should be considered. Often a minor procedure involving establishment of dependent drainage, removal of a piece of skin under which secretions are accumulating, or widening of a sinus draining a deep pocket will produce dramatic results. These revisions are less radical than those which were thought necessary before the advent of modern chemotherapy.

Immobilization. When wounded limbs are immobilized in plaster, healing takes place with remarkable freedom from spreading infection. If the casts are removed too early, and especially if the parts are not again immobilized, a flare-up of the infection may occur. For this reason it is well to immobilize a wounded extremity by splinting or encasing in plaster the joints both distal and proximal to the wound. The wound should be dressed infrequently, if at all, in the first two weeks. If no systemic reaction occurs and if the dressings do not become too foul, there is no indication for changing the dressings for two weeks or more. Wounds do better when left alone than when subjected to frequent dressings, provided, of course, that drainage is adequate.

Moist heat is of value in localizing infections, especially superficial infections which are pointing through the skin. Care must be taken to immobilize the part while heat is applied. If the infection is open and draining, heat is of less importance than moisture.

FOREIGN MATERIAL

Certain types of foreign material in a wound may interfere seriously with its healing, whereas others cause no untoward reaction. Some metals such as tantalum and to a lesser degree stainless steel lie inert in the tissues and cause no reaction even in the presence of infection. Tantalum plates have been reported to have remained securely in place and to have caused no foreign body reaction or drainage even when severe infection was present at the time they were introduced.[4]

Steel, brass, and lead cause relatively little tissue reaction. Aluminum, glass, and bits of wood and clothing, on the other hand, are irritating and cause a pronounced foreign body reaction. If fragments of nonirritating foreign bodies are small, they become encapsulated by fibrous tissue and may remain encysted in the body for years without causing any difficulty. One must think of these foreign bodies, encased

as they are in fibrous tissue, as little fibromas, not as jagged bits of metal. The reaction that they produce may be no more pronounced than that of a fibroma of comparable size.

Irritating foreign bodies never become encapsulated in fibrous tissue, because the reaction about them is so great that infection occurs, and abscesses or draining sinuses are formed. These foreign bodies must be removed.

Another kind of foreign body that is commonly seen in wounds is introduced by the surgeon in the form of suture material, drains, and strangulated tissue. Catgut is the most irritating of all suture materials, and plain catgut is more irritating than chromic. The very fact that plain catgut is absorbed more rapidly than chromic catgut indicates that it causes a greater reaction in the tissues, calls forth a greater number of phagocytes, and is therefore destroyed more rapidly than is the chromic. The incidence of infection will always be higher in wounds closed with catgut than in those closed with nonabsorbable and relatively nonirritative sutures. Silk is probably more irritating than cotton and certainly has a greater tendency to cause draining sinuses. The spaces between the fibers form pockets in which bacteria multiply and thrive. Fine cotton, no. 40 or finer, is less apt to cause persistent sinuses than is fine silk. In the presence of infection nothing larger than no. 60 cotton in single short-cut sutures should be used if the formation of sinuses is to be avoided.

Stainless steel wire, no. 32 or smaller, or fine tantalum wire is the best suture material for use in the presence of contamination. The nonirritating properties of these metals promote primary healing without infection, and if infection does occur, draining sinuses rarely follow.

Drains, whether they be of rubber, vaseline gauze, or plain gauze, act as foreign bodies and favor development of infection. Drainage with plain gauze is never indicated, because as soon as secretions from the wound coagulate upon it, dry gauze acts as a dam to obstruct further discharge of secretions. The only indication for plain gauze is as a pack to control hemorrhage.

Vaseline gauze and rubber drains keep the wound edges apart and allow secretions to escape. But they open the wound to contamination from the outside and lower its resistance to infection from within. One hopes that the pus in a wound will be attracted by some mysterious magnetism to the drain and escape to the surface. Too often the reverse is true, and contamination from the surface follows the drain to the depth

of the wound; then, when the tissue resistance is lowered by reaction around the drain, infection develops and spreads to involve the entire wound.

When wounds are clean enough to close, they do better when closed without drainage. When wounds are contaminated so badly that one hesitates to close them without a drain, it is better to pack them wide open. Exceptions to this rule occur when a hollow viscus or the liver has been injured, and when leakage of bile or gastrointestinal contents is anticipated. When rigid walled abscesses are opened, drains should be used. Drains are of value when bleeding is not completely controlled, but meticulous hemostasis produces better results.

Fat and fascia do not appear to cause much reaction in the tissues when they are strangulated by tight sutures, but necrotic muscle or glandular tissue acts as a foreign body and impairs healing. Sutures and ligatures should be placed so as to minimize strangulation of tissue, and all blood clots should be removed before a wound is closed.

Blood supply. Interference with the blood supply of a wound invariably results in poor healing. Every effort must be made to maintain an adequate blood supply lest infection become established and anaerobic organisms multiply in necrotic tissue.

When the blood supply of the bowel is interfered with or when circulation of an extremity is questionable, it is important to maintain blood pressure, hemoglobin level, and oxygenation of the blood so that whatever circulation remains in the affected part will function as efficiently as possible. Blood transfusion and oxygen therapy, when indicated, may make the difference between survival and gangrene of the affected part.

Application of tight bandages may impair circulation to such an extent that healing will be poor. In the lower leg or forearm the blood supply passes between the bones and is thereby protected from pressure, but tight bandages around a finger may hinder circulation. Pressure necrosis may occur in the skull and tibia where the bandage presses against the bone.

When a wound heals slowly over a long time, dense scar tissue is deposited at its base. As the scar contracts, the blood supply to the surface of the wound is impaired, and healing progresses very slowly. Epithelium may fail to grow on such a surface or may be extremely thin and susceptible to destruction by the slightest trauma. When wounds heal too slowly, it is often advisable to excise the scar tissue and to either close the wound or apply a skin graft.

REST

Immobilization of the wound is one of the most important features of treatment. It is hard to overemphasize the importance of rest in preventing the development and dissemination of infection. In addition, when the part is not placed at rest, mechanical factors prevent healing, as in the case of wounds over joints. We have all noticed the slowness with which wounds on the knuckles tend to heal and that these wounds break open repeatedly when the finger is moved. The healing process is mechanically disrupted by motion and may be retarded if rest is not provided.

PRESSURE DRESSINGS

When wound surfaces can be brought snugly together with a pressure dressing to eliminate dead space in which air, serum, or blood can accumulate, prompt healing is the rule. If pressure dressings are not applied, infection tends to occur in the dead space, and healing may be retarded. An efficient pressure dressing may be made of cotton waste secured with a woven elastic bandage or elastic adhesive tape.[5]

Pressure dressings not only obliterate dead space but also reduce edema around the wound. Tissues which are not edematous maintain a higher resistance to infection. Elevation of the part may help to reduce edema. Raw surfaces treated with pressure dressing are epithelized faster and with less infection than when pressure dressings are not applied.

VITAMIN C

Many studies on wound healing in the presence of vitamin deficiency have been made, but only a deficiency of vitamin C has been proved to retard wound healing.[6] Vitamin C deficiencies of sufficient severity to interfere with wound healing are rarely encountered. A deficiency of this vitamin should be considered when there is no other explanation for the failure of a wound to heal.

OTHER FACTORS INFLUENCING HEALING OF WOUNDS

It is likely that other vitamins as yet undiscovered play a part in wound healing. Certainly a deficiency in the serum proteins will produce edematous tissues, which heal poorly.[7] When serum proteins are low, every effort should be made to raise their level to normal.

The age of the patient does not appear to influence wound healing but debilitating disease does. Poor healing of wounds is often noted in jaundice, in advanced carcinoma, and when malaria complicates convalescence.

SUMMARY

The treatment of wounds must be based on sound knowledge of the physiology and pathology of the healing process. Wounds must be treated individually; no standard treatment can be defined.

Knowledge of the bacteriology of infections enables the physician to recognize types of wound infections, to judge their virulence, and to treat them. Sources of contamination include the instrument which inflicted the wound, ill guided attempts at emergency treatment, organisms from the nose and throat of the patient or his attendants and from the air. Established infections may be treated with the sulfonamides or penicillin, by immobilization, and by pressure dressings, which obliterate dead spaces, approximate the tissues, and allow normal healing to take place. Continuous soaks or wet dressings afford the best means of maintaining drainage, which is the most important feature of treatment of infection.

Nonirritating foreign bodies, if the fragments are small, may remain encysted within the body without causing difficulty: Irritating foreign bodies must be removed. It must be remembered that a foreign body is introduced into the wound by the surgeon in the form of suture material, drains, and strangulated tissue.

Interference with good blood supply invariably results in poor healing. Although only a deficiency of vitamin C has been proved to retard wound healing, it is likely that a deficiency in the serum proteins or in other vitamins as yet undiscovered or the presence of a debilitating disease also plays an important part.

Immobilization of the wound is of prime importance in preventing the development and dissemination of infection and in eliminating mechanical factors which prevent healing.

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