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Editorial

FUNDAMENTALS OF WOUND HEALING

“IF you cut well and sew well your patient will get well.” This is an ancient aphorism and, like most of the other aphorisms with which medical literature is so replete, it contains a great truth in a few words. Such a remark carries with it certain self-evident demands. It requires that anyone who contemplates performing an operation must be skilled in the art of surgery. He must know how to cut, when to cut and where to cut. In discussing the healing of wounds we are particularly concerned with how and where to cut. When to cut also plays a role in the healing process only slightly subordinate to the other two.

Let us first consider “how to cut.” If you were trying to injure an enemy, would you select a sharp instrument or a dull instrument? Would you shoot him with a steel bullet or a lead nose bullet? Naturally, in the first instance, you would use a dull weapon which would cause a lacerated wound and, in the second instance, a lead nose bullet because it would flatten out and tear large areas of flesh. Lacerated wounds are associated with destruction and injury of large areas of tissue and are more prone to become infected than incised wounds. Therefore, an incised wound with its symmetric edges is the ideal wound. Wounds made by a surgeon should at all times be incised wounds. There is no condition in surgery which calls for the production of a lacerated wound or a contused one. It is sometimes necessary to perform a punctured wound such as when doing a paracentesis or a biopsy, or to make an abraded wound when removing skin

for a skin graft, but a lacerated wound is never indicated. Frequently, a surgeon with a simple performance of a débridement will transform a lacerated wound into an incised one. All surgeons should constantly be on guard against creating a lacerated wound from an incised one. This is done by rough handling of tissue, i.e., the use of dull instruments; the use of big clamps; the unnecessary clamping of all blood vessels; the use of rough dry sponges; the constant sponging of the wound when suction would remove all blood clots; the cutting of tissue with scissors when a scalpel could be used.

To cut with a scissors requires crushing, and this causes unnecessary destruction of cells. Scissors can sometimes be used to cut fascia, pleura, peritoneum, or other membranes, but even here they should be used by approximating the blades and pushing them along a plane rather than closing the blades. Scissors should never be used to cut skin. Under all circumstances sharp dissection is better than blunt dissection, except in a few rare instances in which it is impossible or not feasible such as the dissection of subcutaneous or areolar tissue. It is almost impossible to make an incised wound with a pair of scissors. Errors in technic are often performed when it is found necessary to enlarge a wound, for it is here that the surgeon in his haste will use the scissors instead of the scalpel.

The use of large clamps with wide edges and cross striations, and worst of all, big teeth, is to be frowned upon. In many hospitals they

are no longer placed on the operative tray. Sometimes when grasping the cervix or a similar structure, it may be necessary to use such a clamp but, fortunately, its use is rapidly passing. The large curved Kelly clamp is still widely used but this also causes unnecessary destruction of tissue. Clamps can sometimes be too small and will pull off with tearing and have to be reapplied, causing additional trauma to the wound. The ideal clamp is the small hemostat commonly used in all hospitals. This is sturdy enough to hold firmly to the tissues and causes a minimum amount of crushing of tissue. The ideal way to suture a wound is not to grasp it with clamps at all; or when this is not mechanically possible, the best procedure is to use the smallest clamp available. Even in the clamping of large blood vessels the larger clamps are not necessary. These vessels should be elevated, ligated at two points, and then severed between the two ligatures. The small hemostats are large enough to grasp all smaller vessels.

The great inhibitions to perfect wound healing are dead and devitalized tissue and foreign bodies in the form of blood clots and excessive ligatures and suture material. When the mouth of the small vessels is grasped, a small bite should be taken and the ligature applied as close to the end as possible so that only a small cuff of strangulated tissue is left. If for any reason a long cuff is left, this should be cut off as near to the ligature as is safe. Under no circumstances should a ligature bind tissue other than a blood vessel. The ligatures should be just tight enough to approximate the mouth of the blood vessel and just loose enough not to strangulate it. The fallacy of mass ligation of tissue has long been known. This is frequently followed by bleeding or necrosis of a large number of cells followed by sloughing and often infection. The ideal method of controlling bleeding is by gentle pressure, and practically all capillary bleeding can be controlled by this procedure. Mont Reed, in one of his excellent articles on wound healing, made the following statement: "There can be no question that a blood clot in a wound interferes by tension with blood supply, prolongs wound healing, injects the presence of a large foreign body, and immeasurably encourages the development of infection and suppuration. Yet the excessive devitalization of living tissue by unnecessary ligatures of small blood vessels and too many tight sutures also interferes with blood supply,

prolongs wound healing and invites infection." The ideal wound is one in which there is no foreign body, a minimum of dead cells and devitalized tissue, and just enough blood clot to hold the severed edges firmly together. This ideal should be sought by every surgeon, but I am sorry to say that not all surgeons keep it constantly in mind, and even men of some surgical repute violate this principle time and time again.

Suture Material. Some surgeons apply the principles of sewing a baseball cover to the sewing of living tissues. They use the largest suture available and pull it as tight as possible. These are the surgeons who have the largest number of wound disruptions, according to hospital statistics. Fortunately, their number is becoming less and less, for the principles of gentle handling of tissue, first advocated by Paré, and many years later by Halstead and his pupil, Mont Reed, have at long last taken deep root and are now bearing a rich harvest. The larger the suture or ligature, the more inflammatory reaction it will cause and the more apt it is to be pulled too tightly and thus cut off the blood supply to the wound edges. However, regardless of the character or caliber all suture material is a foreign body and as small amount as possible should be used in any wound. Nowadays the most common sutures used are catgut, silk, cotton and steel wire. Those made from kangaroo tendons and fascia lata strips are seldom used.

Catgut is almost a universal favorite in the United States, and the manufacturers of this product are constantly experimenting to improve it. Every two years these companies issue a brochure which explains their latest findings regarding their product, and they have been in the forefront in advocating the use of the smaller sizes of their material for both ligatures and sutures. They have standardized the sizes and tensile strength of the various strands and pack their product in glass tubes under the most aseptic conditions. We cannot recall any wound disruptions we have handled that could be directly attributed to faulty catgut. This complication can be caused not only by the size of the suture or ligature, but often is also due to the excessive amounts placed in a wound; that is, by ligating too many bleeding points which could be controlled by gentle pressure, tying too many knots, using double

strands of suture and leaving excessively long ends.

Cotton is less apt to cause trouble than silk because it is a vegetable fiber and is twisted instead of spun, thus reducing its capillary attraction. It has the great advantage of being readily available at all times and is much cheaper than catgut. Like silk it cannot be used as a running stitch except in the skin for it has little elasticity and is apt to break. Its use is improved if it is oiled or greased with bone wax, as this causes the fibers to lay down and allows it to be easily drawn through the tissues. Waxing also seals the fibers and reduces their capillary attraction, thus lessening the chance of infection. Its one disadvantage when placed in the skin is that of becoming stained and being difficult to find. This disadvantage has been overcome by some surgical houses by dyeing it; however, they have also increased the price of this colored product.

Some men who like silk are fanatic advocates of it, and quick to defend its use with the statement that if it is used properly in a non-contaminated wound, the formation of abscesses will not occur. However, like most things in medicine, the nearer a technic is to being "fool proof" the better it is for general use. Silk, in particular, causes an excessive pooling of serum about it by capillary attraction with subsequent infection. This suture is now braided to reduce its capillary attraction and this has lessened the chance of a stitch abscess. Under most circumstances small size catgut is to be preferred to either silk or cotton because it is rapidly absorbed and after a short period of time is completely removed from the vicinity of the wound. Silk or cotton placed deep in a wound are not absorbed and are frequently extruded through the skin by the formation of abscesses and sinuses.

Stainless steel wire or braided tantalum is advocated by some competent surgeons as a buried suture. Its only advantage as a buried suture is that steel is practically inert to tissue juices and can remain in place indefinitely. However, it has many disadvantages which militate against its use as a buried suture. It is stiff and hard to handle. It must be used as an interrupted suture. The knots must be carefully tied and twisted, and the ends cut very short. Patients sometimes complain that they feel the sharp edge of something under the skin. This requires a careful explanation of what has been

done but many patients are still skeptical. After its use in a herniorrhaphy I have known of cases in which the wire migrated along the fascial planes from the inguinal region to the thigh. In contradistinction to its shortcomings as a buried suture wire is close to the ideal suture material for skin closure. It can be used as either a running or interrupted stitch, and in contaminated wounds it will not cause a stitch abscess even when left in place for an indefinite period. It has only two disadvantages as a skin stitch: (1) it is a little hard to handle and is apt to kink; (2) it has a tendency to bury itself and, therefore, may be difficult to remove.

In selecting any suture material it is always well to remember that its tensile strength need never be any greater than the tensile strength of the tissue in which it is placed. If it is greater, it will soon cut through the tissue which it binds.

Infection in Wounds. How many of us stop to think why it is that an open wound almost invariably remains free from infection, even when it is grossly contaminated? The reason is that the body fluids, blood and serum, flush the wound of dead and necrotic material, and at the same time make the environment undesirable for bacteria. It is only during this initial or exudative stage of wound healing that infection occurs. Sutures placed in a wound at this time prevent the flushing action of these tissue juices and encourages the production of bacteria. During the last war the Medical Advisors to the Armed Forces, who undoubtedly were men of vast surgical experience, issued a general order that all wounds should be left open until they could be properly repaired. Thousands of young lives were saved because of this order.

Sutures are man's invention, and in placing them he is merely trying to enhance and hasten the reparative stage before the wound is actually ready. He can safely and successfully do this if he first frees the wound of all harmful foreign material in the form of dead cells and bacteria which thrive on them. No single bacterium is capable of destroying a living vital cell and I am sure that a pure culture of staphylococcus could be poured into an open wound without infecting it, provided no dead or devitalized cells were present and the wound was not immediately approximated with a suture. I am not advocating the disuse of sutures, but I am trying to show that man in

using them often interferes with the natural inherent forces of resistance to infection that the body possesses.

Prevention of Infection. Any physician would be aghast if he walked into an operating room today and saw a patient's abdomen opened without first having been thoroughly prepared and a mild antiseptic applied. The use of strong antiseptics on the skin for the purpose of sterilizing it is a great error, for any antiseptic that is capable of killing bacteria is also capable of killing living cells along the wound edges. The use of strong antiseptics is particularly harmful in traumatic wounds, because they may devitalize cells which might have remained viable if the wound had been gently washed with soap and water and flushed with normal saline solution, and then approximated. The use of detergents has been a great step forward in asepsis of wounds.

It would be far better for all wounds if the principles of antiseptics were placed in the realm of discarded things, and the principles of asepsis were adhered to strictly. By this I mean that in preparing a wound, either elective or traumatic, the removal of bacteria should be aimed at rather than attempting to kill them with some antiseptic solution. The principle of asepsis in modern surgery far outweighs that of antiseptics, for the organisms carried into a wound by the hands and instruments of a surgeon are apt to be more harmful and virulent than those occurring there by accident. So modern surgery aims at removing all bacteria from the vicinity of a wound by strict sterility of all instruments and material entering it, and washing the wound thoroughly to remove all foreign material to which bacteria might cling.

Even with the best asepsis possible all wounds, elective or traumatic, have numerous organisms present, and it is in overcoming these that the sulfones and antibiotics play one of their greatest roles. All of us who were trained and practiced surgery before the advent of these drugs have been frequently amazed and constantly edified by their action. The mortality in some diseases, such as appendicitis, has dropped almost to nothing, and many other diseases are no longer the fearful plagues they once were. Contrary to what the layman might think, these drugs are not alone the cause of the lowered mortality in surgery during the past ten years. The seeds of gentleness in handling of tissues planted by Paré, cultured by Lister,

watered by Halstead and many other great surgeons have grown into full flower and mankind is now benefiting by the years of accumulated knowledge of wound healing.

We do not advocate the use of the sulfones and antibiotics following all operative procedures, for they are not necessary after the ordinary elective operation of short duration, such as a herniorrhaphy or uncomplicated hysterectomy. Their administration may bring about a sensitivity to their use later on when the individual may need them. However, when any of the systems of the body are entered, such as the gastrointestinal, respiratory or urinary tracts, these drugs should always be administered preoperatively and postoperatively. The lone exception to this rule might be following an interval appendectomy. Many surgeons, even in these instances, do not think them necessary but it is probably safer to give them for a day or two.

In preparing the gastrointestinal tract for surgery none of the sulfones or antibiotics can replace cleanliness. Any part of the alimentary canal can be opened with impunity, if the mucous membrane is completely free of foreign material or excessive secretions, and the operation is done with gentleness and minimal cell destruction. As we have repeatedly stated nothing can replace or substitute for these factors. The antibiotics are also indicated after prolonged and massive surgical procedures of all types, and their use can be supplemented by the sulfones. The combination of these two drugs give a better antibacterial spectrum than when one is used alone and is a practice of proven worth.

All traumatic wounds, no matter how well they are cleaned or débrided, are highly contaminated with bacteria, and any physician who would not administer one of the sulfones or antibiotics to a patient suffering from such a wound would be remiss. If a severe infection develops the physician could properly be criticized and possibly held legally responsible for not adhering to the ordinary mode of treatment of his community.

Physiologic Rest. One of the important fundamentals of wound healing is physiologic rest. The immediate pain and stiffness to a part following injury is nature's attempt to put the part at rest. We are all familiar with what happens to an extremity following the fracture of a bone. The part becomes painful, swollen and

the muscles go into spasm in an attempt to hold the part at rest. The swelling will gradually subside and so will the acute pain, but the stiffness will not disappear until the bone is completely healed. In the application of a cast to such an injury we aid the natural forces in resting the part. As years go by we are understanding this function of rest better, and we no longer prolong it beyond the time required by nature to heal a part. I can remember the time when a Colles' fracture was held in a cast for six to eight weeks and when the forearm was removed, the wrist and fingers were so stiff that it took weeks to overcome it. Now we know that a short initial period of complete immobilization only is needed, and after this the part will heal better if it is quickly rehabilitated. The circulation to the part will improve with motion, the muscular tone will return and the healing will be hastened. These principles hold true not only for an extremity, but also for the entire mechanism. Early ambulation and feeding of patients following massive surgery is paying large dividends in rapid recovery with lowered mortality and physiologic, psychologic and financial benefits to the sick and injured.

Systemic Factors. In addition to those local factors which are important in wound healing there are certain general or systemic factors which merit consideration. Attention to the patient as a whole is necessary, in addition to care in the management of wounds.

The normal individual who incurs trauma or undergoes surgery experiences a reaction to such injury which involves the cardiovascular, nervous, renal and other systems to a varying degree. The healing of the wound is perhaps a more obvious manifestation of this reaction but may be of relative unimportance. It should be appreciated, however, that proper atraumatic, aseptic care of the wound plays a major role in the ultimate pattern of the reaction to injury.

Frequently, patients who are subjected to surgery are not normal as regards cardiac and renal function, or are nutritionally inadequate as a result of their disease. Too, endocrine imbalances may exist and alter their response to injury. Some of these abnormalities cannot be satisfactorily adjusted, and such patients are necessarily considered "poor operative risks." However, such conditions as anemia, hypoproteinemia, undernutrition and dehydration can often be corrected prior to surgery, with

improvement in the patient's response to surgery.

It has been well demonstrated that patients with anemia and/or depleted body protein heal poorly. The physiologic process of wound healing requires healthy tissues. The preoperative use of blood transfusion and high caloric, high protein diet are indicated in patients who have significant anemia or whose nutrition is substandard. Elective surgery should be delayed in order to attend to these deficiencies. If surgery is urgent, postoperative transfusion and early restoration of diet may obviate difficulty.

The state of hydration, which implies not only body water but also the electrolyte composition of body fluids, is an important consideration in wound healing and response to surgery. Abnormal losses of water and/or electrolyte occur in a variety of conditions, both preoperatively and postoperatively. The body continually attempts to maintain an isotonic equilibrium of its fluid constituents. Recognition of fluid and electrolyte deficits and their correction preoperatively should be done whenever possible. The obtaining of a good history and careful examination of the patient usually enable fairly accurate estimate of these deficiencies. Laboratory data are adjunct to clinical appraisal, and should not, in most instances, be considered the sole guide to therapy.

Postoperatively, prevention of fluid and electrolyte deficiencies is the best treatment. Except for the more complicated cases, provision of sufficient water intake and of calories to allay ketosis are all that are required for two to four days. If the patient is unable to take nourishment orally, parenteral administration of glucose in water is used. It is an example of bodily economy that some electrolytes, notably sodium, are conserved during this period and need not be given. Other electrolytes, e.g., potassium, are not conserved but in a short period of time deficiency is unlikely. To avoid dehydration and electrolyte imbalance all patients should be examined frequently after operation and therapy begun when early signs of a deficiency are present. Subclinical vitamin deficiency, particularly vitamins A, B and C, is common and may affect the surgical patient unfavorably. Supplementary oral or parenteral administration of these vitamins may be advisable as an adjunct measure.

One must, therefore, keep in mind the important role that preoperative correction of

existing deficiencies and the prevention of development of such deficiencies after operation, play in wound healing. Proper attention to the care of the wound and to the physiologic mechanisms which are so closely related is rewarded by successful restoration of the patient to normal.

Because of modern refinements in technique and anesthesia, and because men are taken at an early age and trained in the art of surgery, each succeeding generation of surgeons are bet-

ter in all phases of surgery. These surgeons know the role the antibiotics play in prevention of infection, but they also know that the living cell is still the greatest barrier to infection. They have the same respect for the single living cell as they have for the entire mechanism, be it asleep or awake. They know that unnecessary injury to one cell might be followed by death of the entire part.

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