SURGERY, *Gynecology and Obstetrics*, 72: 318–327, February, 1941.
Fractures Oration, 1940.

TREATMENT OF TRAUMAS OF SKIN AND SUBCUTANEOUS TISSUES

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IT has been said that beauty is only skin deep. This statement may be true in individuals who have not suffered trauma, but when trauma has occurred beauty or loss of beauty of the skin depends largely on the repair of the subcutaneous soft parts and occasionally of the underlying osseous structures. The loss of beauty in old age is in part due to the atrophy of the fat and connective tissues.

I have become convinced that many of our failures in the treatment of acute traumas of the skin and soft parts are due to lack of appreciation of the pathology occurring in the subcutaneous fat and connective tissues. I desire, therefore, to present certain types of failures and to suggest methods of treatment that will improve the end-results. To facilitate the discussion the following types of traumas will be presented: (1) severe contusions of the skin and soft parts; (2) lacerated wounds of the skin, presenting a consideration of primary and delayed primary closure; (3) avulsion wounds of the skin and subcutaneous tissue; (4) lacerated tendons, presenting the criteria for immediate and late suture.

The following examples are illustrative of the types of failure due to the initial treatment in injuries of the skin and subcutaneous tissues. It is relative to these failures that I desire to present some of the later advances in surgical therapy.

We have all treated lacerated wounds after what seemed to us satisfactory débridement and suture and have been alarmed at the onset of rapid infection with loss of tissue beneath, the delay in healing, or, occasionally, a more tragic end.

Another type of case which we have all seen, for example, is illustrated by a patient admitted to the City Hospital of New York with an avulsion injury of the thigh immediately above the knee. The skin and soft tissues had been rolled downward, as a stocking. Despite careful cleansing, débridement, and loose suture, infection and gangrene of the skin resulted.

All of us have seen avulsion injuries of the dorsum of the hand and foot, in which gangrene of the skin has resulted despite careful toilet and suture.

Tendons united with extreme care often apparently heal and the patient is discharged from the hospital, but we learn on follow-up that in the meantime the wounds have opened and that pieces of necrotic tendon have been extruded.

As the common failures have been listed, it is in order to approach each type of injury from our knowledge of the pathology involved, and to present improved methods of therapy.

CONTUSED WOUNDS

The success or failure of the general treatment of contused wounds of the skin depends largely on tissue tension. If an artery, even of relatively small size, is ruptured during the injury, the extravasation of blood into the tissues increases the tissue tension, producing thrombosis of the veins, thus leaving the tissues susceptible to infection.

Severe contused wounds which produce hemorrhage beneath the surface should be carefully watched. In severe contusions, Babcock advises releasing incisions down through fascia on each side of the injury, in order to relieve tension and allow the extravasation of the collected serum. In cases in which the trauma is not as severe as he has described, the aspiration of the hematoma beneath the skin may be sufficient. Such wounds demand surgical judgment and excellent operative technique. If one hesitates when necrosis is beginning, one may lose large areas of tissue. If the patient is seen early and is in a satisfactory condition, small and deeply contused

Presented before the Clinical Congress of the American College of Surgeons, Chicago, October 21–25, 1940.

wounds may be treated by excision of the traumatized area and primary suture.

LACERATED WOUNDS

The treatment of lacerated wounds of the skin and subcutaneous tissues is dependent on: first, the age and general condition of the patient; second, the condition of the skin at the time of injury; third, the type and cleanliness of the instrument producing the injury; and, fourth, the length of time elapsing from injury to operation. While these conditions are elementary and generally known, they are not always given the attention they deserve.

1. *The age and condition of the patient.* It is advisable in obtaining the history to get the patient's reaction to previous traumas. There are some patients who, despite severe injuries in the past, have been resistant to infection, and it is logical to assume that they may be resistant in the present emergency. Others have shown susceptibility to infection and must be treated in a much more conservative manner.

2. *The condition of the skin.* Whether the skin is clean or dirty at the time of injury and also the location of the injury are important factors in our consideration of treatment of soft parts. Braine, in his discussion of primary suture, states that buttock wounds and wounds of the leg should not be treated by primary suture, as they are more susceptible to infection, due to location and blood supply. The wounds over the tibia are obviously slow of healing and need careful watching.

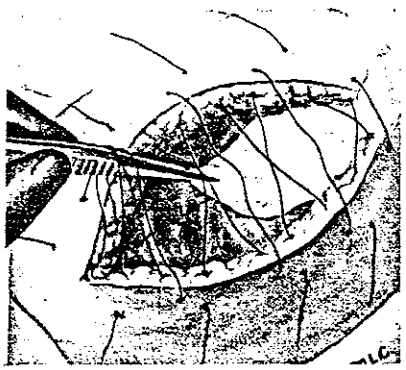
3. *The instrument.* The type of instrument producing the injury is important, as a sharp instrument causes less surrounding tissue trauma than a blunt one, which creates necrosis and hemorrhage of the deeper connective tissue structures, as well as lacerations of the skin.

4. *The lapse of time.* The length of time elapsing from injury to operation is of significance. Bruning quotes the well known experiment of Friedrich showing that there is a lag period in bacterial growth for about 6 hours. During this period the wound may be excised with little fear of bacterial spread. After this time the bacterial growth is so increased that it is difficult to obtain by débridement a relatively clean field.

The present trend in surgery in preparing a contused or lacerated wound for treatment is to avoid, in so far as possible, the active antiseptic, as it is felt that an antiseptic strong enough to kill bacteria is also apt to destroy the resistance of the living cells of the host. Many writers advise the careful washing of the wound, followed by the use of antiseptics on the neighboring skin. There are others, however, who believe that simple washing, with white soap and water for many minutes is sufficient. The author favors the method of copious gentle washing of the wound with soap and water. The wound is then protected by gauze dressing, after which the skin is prepared by cleansing with soap, water, ether, and alcohol, and the wound is again lavaged.

The foreign literature, and particularly the French literature, of the present war concerns itself especially with a discussion of primary versus delayed primary suture in lacerated wounds. While this problem has not arisen so much in civil surgery, nevertheless it is of vital import and it might be well to review some of the opinions that are expressed today. Braine, in an article on primary suture of war wounds, summarizes the situation as follows. He states that "primary closure is contraindicated when the circumstances are not ideal, when the wound is not recent, when the surgical equipment is imperfect, when the operator is not experienced, and when the injured cannot be closely followed for at least 2 weeks." He presents the following general instructions:

> "All primary sutures entail a certain risk and should never be lightly performed. They should not be done as a routine measure—each case should be considered on its merits. Suture should not be performed unless all conditions are favorable as regards the wounds, patient, surgeon's experience, and the military situation. Primary suture following excision is always a delicate operation upon which the patient's life may depend. Suture is not indispensable to save the patient's life; on the contrary, it may result in fatal accidents. Every unsuccessful suture aggravates the original condition. Meticulous excision of the wounded area, and not the suture itself, is the essential feature. The suture may be performed later at leisure with a greater margin of



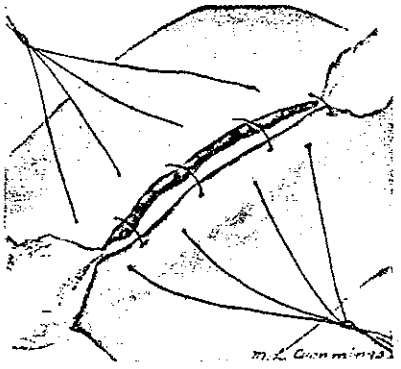


Fig. 1, left. Acriflavine pack being placed in wound. (Courtesy of Coller and Valk, *Ann. Surg.*, 1940, 112: 260.)

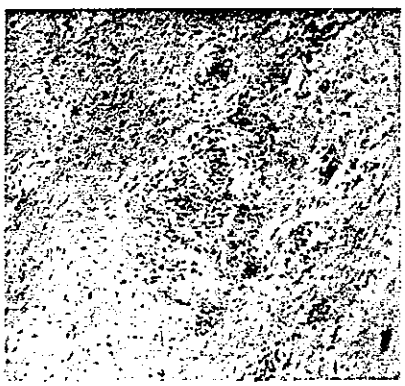
Fig. 2. Acriflavine pack in place. (Courtesy of Coller and Valk, *Ann. Surg.*, 1940, 112: 260.)

safety. Excision followed by suture is a procedure of patience, care, and thoroughness. The wound should be scrupulously examined before the tissues are approximated. In doubtful cases it is better to apply dressings and drains. Primary sutures require careful watching up to complete cicatrization, and the surgeon must be prepared at any moment to remove the sutures. The small extent of the surface injury may not be an indication of the amount of deeper injury, which should always be determined. Primary suture without drainage is exceptional in wounds of the buttocks, thigh, and calf. Primary delayed or secondary suture is worthy of increased attention; although the results are less brilliant the method is safer."

Bruning states that the most important feature in after-treatment is immobilization, which should be carried out as in the case of a fracture, in order to prevent any displacement of the tissues in relationship to one another.

Gregoire, Chevassu, Lenormant, Gosset, and Roux-Berger all warn of the damages of primary suture in war wounds. While they admit that the few spectacular cases make one attempt to utilize the procedure, the failures more than militate against these successes.

In this country, Coller has recently presented a very interesting series of cases of potentially contaminated wounds which he has treated by delayed primary suture. His discussion is largely one relative to the possible infection of abdominal wounds from contamination beneath the surface, but the surgical principles are the same as one finds in lacerated wounds. Coller says:



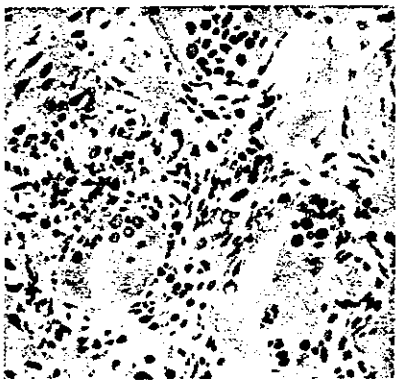


Fig. 3, left. Photomicrograph of biopsy specimen taken from wound 24 hours after operation at time of delayed closure. (Courtesy of Coller and Valk, *Ann. Surg.*, 1940, 112: 260.)

Fig. 4. Same as Figure 3.

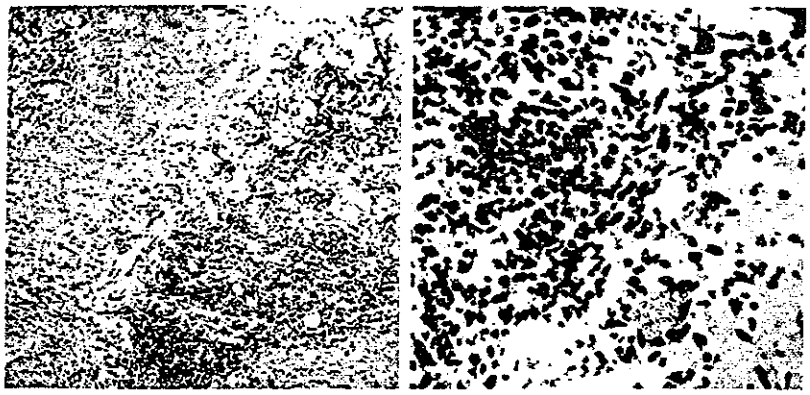


Fig. 5, left. Photomicrograph of biopsy specimen taken from wound surface 48 hours after operation at time of delayed closure. (Courtesy of Coller and Valk, *Ann. Surg.*, 1940, 112: 260.)
Fig. 6. Same as Figure 5.

"Fraser, in 1918, reported an incidence of 9.7 per cent failure in 41 cases of primary closure as compared with 4.5 per cent failure in 63 cases of delayed primary suture. He also reported 31 bacteriologically negative wounds from 35 contaminated wounds after 48 hours' treatment by delayed primary closure employing a flavine pack in the wound. In 1918 delayed primary closure of all soft-tissue wounds, excepting those in the scalp, face, and hands, was advised by the surgeons of the American Expeditionary Force. The best results were obtained when the wounds were closed within 50 hours."

Coller's method is to suture loosely the muscles and fascia beneath the fat and the skin. After careful cleansing and débridement of the fat and subcutaneous tissues, fine silk sutures are inserted in the skin but left untied, and the wound is packed from each end with acriflavine gauze down to the fascia. In 24 to 48 hours the pack is removed and the sutures are tied. He presents a series of 21 cases treated in this manner, with only 1 minor infection. I have had the opportunity of using this method 8 times successfully. Coller presents microscopic sections of the wound edges in 24 hours and states that the sections show a residue which consists of fibrin, in the meshes of which are polymorphonuclear leucocytes, wandering cells, some necrotic tissue, and many fibroblasts (Figs. 1–6). As cultures taken from the wound at the time of operation and at the time of closure do not show destruction of the bacteria by this method, it must mean that two important surgical principles are involved: (1) the release of tension in the wound by leaving it wide open; and (2) the stimulation of the reparative process of the wound or the creation of bacteriostasis by the presence of gauze soaked in acriflavine. He believes that after the coagulation of the fibrin the resistance of the wound is greatly increased because of the sealing off of the capillary and lymph spaces, which tends to keep infection localized or below the clinical horizon.

In discussing the paper of Coller, McClure suggested that part of the success of this method might be due to the inhibitory effect of the air upon the growth of anaerobic organisms, as well as its bacteriostatic effect on the aerobic bacteria.

One might summarize the problem of primary or secondary closure of lacerated wounds as follows: Primary closure may be attempted if the patient is healthy, the skin clean, the instrument creating the damage relatively clean and sharp, and if the patient is seen well under 6 hours after the injury. The surgeon performing the operation must use meticulous care in lavaging the wound and in gentle excision of all traumatized areas. Sutures must be inserted in order to avoid dead spaces, but with care that there shall not be tension when the secondary edema occurs following the operative procedure. Plaster encasement or adequate splinting should be utilized to prevent muscle pull and production of hematomas. Delayed primary suture should be performed in the event that the aforementioned criteria are not present.

Fig. 7. Immediate postoperative appearance. The fenestrated, immobilized plaster encasement was necessary because of a fracture. (Courtesy of Farmer, *Ann. Surg.*, 1939, 110: 952.)

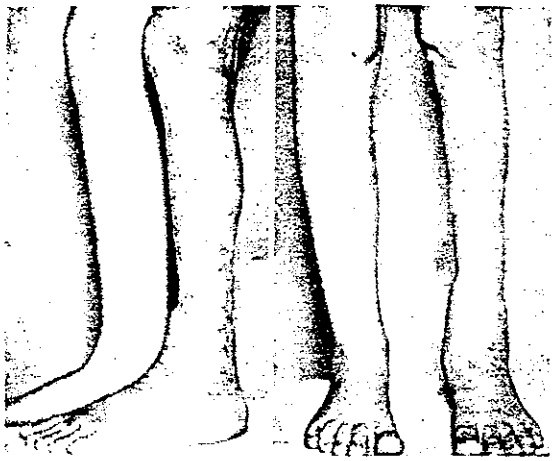


Fig. 8. Front and side views of final result. (Courtesy of Farmer, *Ann. Surg.*, 1939, 110: 952.)

It is obvious that there is a third type of injury which I have not mentioned because it seems evident to me that one would not attempt either primary or delayed primary suture; that is, the type of injury in which there is extensive tissue damage and in which it is evident that the wound must be débrided and left wide open for healing by granulation. In this type, immobilization of the neighboring joints is often a necessity in order to prevent constant trauma by muscular action. Because of its severity, the lesion may need various therapeutic measures. Dakinization or vaseline gauze packing, as by the Orr method, may be the therapy of choice. Early skin grafting is advisable as soon as the granulations permit.

AVULSED WOUNDS OF THE EXTREMITIES

Farmer has postulated what seems to the author to be an adequate theory of the cause of failure in avulsed wounds. He states that when the skin and subcutaneous fat are avulsed, thrombosis of the venous and lymphatic vessels is produced by the trauma. On the other hand, the arterial vessels are not as easily injured, and they continue to pump blood into the traumatized zone. When the pressure of the incoming blood overcomes the normal tissue pressure, necrosis occurs as the smaller arteries begin to thrombose. We are accustomed to see a similar pathological process in the pregangrenous stage of acute cholecystitis. All surgeons are conversant with the appearance of the bluish gall bladder which is swollen and edematous and which one is apt to call beginning gangrene. Sections of such gall bladders, however, show the tissue full of extravasated blood. The initial process has probably been a venous occlusion due to pressure of an impacted stone in the cystic duct. As the tissue pressure increases, the artery gradually becomes thrombosed and then, and not until then, does active gangrene occur. Fortunately for the gall bladder omental adhesions are apt to bring relief from some of the tissue tension.

If Farmer's theory is true, his method of treatment is a real advance in the handling of avulsed wounds. He believes in the excision of all of the avulsed skin, for he says that if a portion of the skin is left attached the arteries will continue to pump blood into the skin and subcutaneous tissue and gangrene will result. When the skin has been removed, the assistant carefully débrides the underlying structures, removing all dead or traumatized tissue. Farmer advises the cleansing of the raw area with aseptic rather than antiseptic fluids. Thus soap and water and saline are the solutions of common choice. The surgeon removes

Fig. 9. The result 2 weeks after accident. (Courtesy of Farmer, *Ann. Surg.*, 1939, 110: 952.)

the avulsed skin. It is held on a firm flat surface and the fat is removed by scraping or by cutting with curved scissors well into the dermis. After the combined procedure of débridement of the deeper structures with complete hemostasis and excision of the subcutaneous fat, the skin is then sutured accurately into the defect from which it was removed. To prevent dead spaces, quilting sutures are used in addition to the circumferential sutures, and the graft is perforated with numerous small stab wounds. The primary dressing is of normal saline. Firm pressure is obtained by bandaging, and a plaster encasement insures immobility. The dressing is changed in 10 to 14 days unless there is a special indication for an earlier examination (Figs. 7–10). It was the author's privilege to see a number of cases reported by Farmer, and the results were far superior to anything he had seen in similar wounds treated by other methods.

There may be one refinement which could be added to Dr. Farmer's method. J. Staige Davis has shown that skin may be preserved for a reasonable period of time by refrigeration. Also, it has been stated that during refrigeration the differences between the portions of the skin that would normally

Fig. 10. The condition some months after accident. (Courtesy of Farmer, *Ann. Surg.*, 1939, 110: 952.)

live and the portions that are too severely injured to survive are demonstrated. Davis says:

"The idea is prevalent that skin grafts of all kinds must be applied either immediately or within a comparatively short time after cutting. Years ago the writer [Davis] became interested in the preservation of skin grafts, and has experimented with the refrigeration of various types. He soon became convinced that there was no hurry in applying skin grafts and that they could be preserved quite simply. If the grafts were to be used within 24 hours, wrapping them in sterilized dressings moistened with normal salt solution to keep them from drying and storing in the ice box were sufficient. If longer periods were required the grafts were stored in jars of sterile oil, vaseline or sterile albolene in the coil compartment of a mechanical refrigerator. The grafts when removed from vaseline or albolene are as pink as when they were put in, and look quite fresh. They are either wiped gently with sterile gauze to remove the vaseline or are washed with ether before being placed on the granulations. It was noted that while the refrigerated grafts would take and the blood supply become established it was fully a week, and sometimes longer, before any new growth of epithelium is observed from the skin margins and that this growth seemed slower than from immediate grafts of similar type. Microscopically no definite change was observed in the graft refrigerated, as above described, even after several months. Immediate autografts are always to be preferred, but refrigerated autografts have a distinct field of usefulness, and excess material can be preserved in suitable cases and used as required. Refrigerated small deep grafts are permanently successful and have been successfully transplanted after several weeks."

The usefulness of Davis' method in avulsion injuries can readily be seen, because there are

Fig. 11. High power photomicrograph showing edema of the superficial granulating area with slight degree of infection. Numerous blood vessels can be seen.

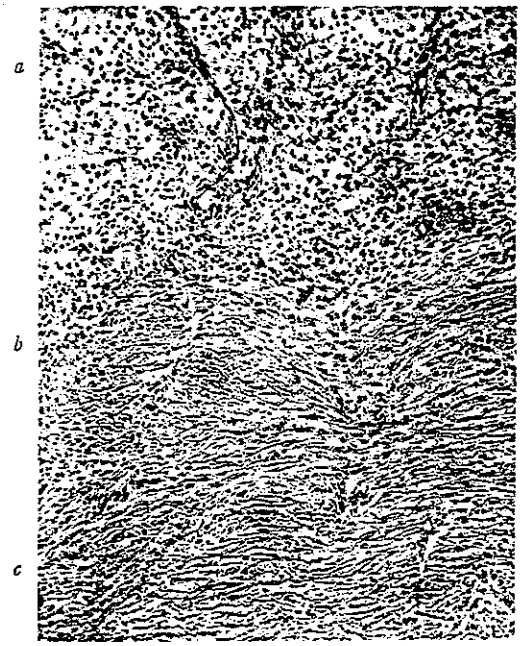


Fig. 12. High power photomicrograph of section at junction of granulation and scar tissue. *a* indicates the superficial granulation tissue; *b* the junction of the scar and granulation tissue; *c* the scar tissue.

some cases in which the muscle damage may be so great or the patient seen so late after injury that immediate skin grafting would be inadvisable. However, if one can preserve the uninjured skin and transplant it at a later time, a great saving can be made in hospital days and in suffering for the patient.

Avulsion injuries of the dorsum of the hand must be treated according to the depth of the injury. When tendons are exposed, immediate covering is essential. The insertion of the hand into an abdominal flap is advantageous when the injury is deep; when it is superficial, Farmer's method could be carried out by removing the avulsed skin and replacing it as he described. When the skin has been too severely traumatized, a full tissue graft taken from the thigh can be readily used. The replacement of the avulsed skin, even if split longitudinally as described many years ago by the Mayos, usually results in failure if any portion is left attached. Full tissue grafts may be readily utilized in similar injuries of the dorsum of the foot, provided the avulsed skin is not satisfactory.

In avulsed wounds that cannot be closed immediately and in which for any reason skin grafting is delayed for over 2 weeks, it is advisable to excise the underlying scar tissue rather than merely to remove the superficial granulations by curette. After several failures from delayed skin grafting following curettement of the superficial granulations, I dissected through the underlying scar tissue, which appeared red and healthy on the surface and was surprised to find rubbery firm avascular scar tissue extending often to a depth of 0.4 to 1 centimeter before healthy tissue appeared. Sections taken of this tissue reveal definitely the lack of vascular supply necessary to stimulate epithelization. The grafts appear healthy for a week or 10 days and then gradually melt away (Figs. 11 to 14).

Chemotherapy. In discussing the treatment of lacerated and avulsed wounds of the skin and soft tissues it has not seemed necessary to stress the use of sulfanilamide or similar preparations, either by oral or parenteral administration, because these drugs are being used throughout the country at large. Nor does it seem advisable at this time to recommend the local administration of these drugs at the site of injury. The experimental and

clinical results of local administration of sulfanilamide are as yet too uncertain either to advocate or condemn. When they have been used, it has been noted that there is an increase in the serous exudate, and this might be distinctly inadvisable if skin grafts are contemplated.

TENDON INJURIES

Tendons, like innocent bystanders, are subject to accidental injuries involving other structures. Extensive wounds of the skin and subcutaneous tissues frequently cause tendon damage as well. This is especially true of areas such as the dorsum of hands and feet, wrists and ankles, where the covering is thin and the bed unyielding. The most dangerous location for tendon injuries is in the flexor creases of the fingers and palm. This area is frequently traumatized by sharp cutting instruments and the tendons severed. If infection is not prevented, the extension of the pus along the tendon sheath will not only create slough of the tendons but may allow the infection to extend along the deeper spaces of the hand with irreparable injury. The possibility of tendon injury, therefore, must be borne in mind when apparently superficial wounds are treated; and repair of tendons, when injured, should be undertaken at the earliest possible moment consistent with good surgery.

The decision between primary and secondary suture of tendons calls for keen surgical judgment. In cases seen within 4 hours of injury primary suture may be done with reasonable expectation of an excellent result. This assurance is lacking, however, when dirt has been ground into the wound or the tendon extensively contused and devitalized. Primary suture is hazardous also if there is a question of contamination with human acclimatized bacteria or if antiseptics have previously been poured into the wound. In all such cases and in injuries more than 4 hours old, attention should be directed solely to cleansing and healing the wound, and the damaged tendon left for secondary suture at a later date.

When primary suture has been injudiciously performed and infection ensues, the patient is

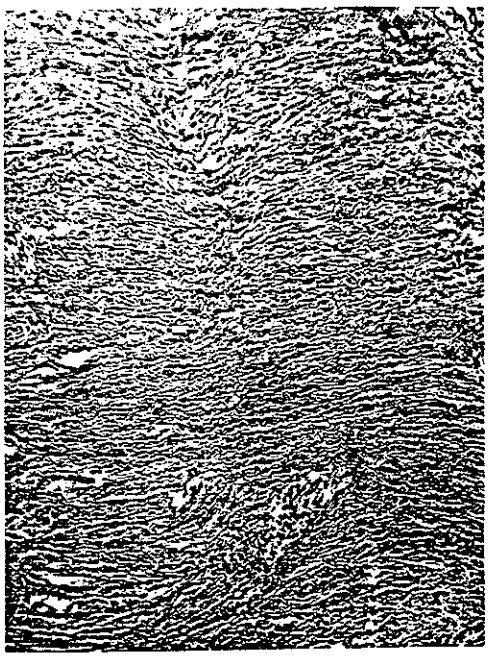


Fig. 13. Dense scar tissue in the region of the deeper area.

far worse off from the standpoint of eventual rehabilitation than if the tendon had been left for secondary suture because just so much tendon tissue will have been lost and scar tissue formed. Function is traded for deformity—a poor bargain.

Atraumatic handling of tissues, the avoidance of chemical antiseptics, and the use of fine silk sutures placed without tension are sound surgical principles worthy of particular emphasis in tendon repair. Tendon is a relatively avascular structure, its meager blood supply coming from a delicate sheath or from the surrounding soft tissues. At the time of repair, if the already damaged tissues are needlessly subjected to the additional trauma of rough handling and strong antiseptics or if the blood supply is impoverished by tense sutures, one must not be surprised should infection, with all its disastrous consequences, result.

Kanavel, Bunnell, Koch, Mason, and Loyal Davis have contributed largely to the knowledge of the physiology and histology of tendon repair and have presented for us definite clinical therapeutic measures based on sound

surgical principles. They have shown that connective tissue union takes place first between the apposed ends of a severed tendon. This process commences promptly after suture, is complete in 3 or 4 days, and is dependent upon restoration of continuity of the tendon sheath or surrounding soft tissues. In favorable cases tendon cells then grow across this connective tissue bridge and establish a complete tendinous union in from 10 to 14 days. The tendon at first shows distinct thickening at the site of repair and adherence to the surrounding structures, but in the course of a few weeks it becomes thinner, the adhesions are stretched, and freedom of motion is gradually established to a greater or lesser degree.

Bearing this in mind, one can appreciate the vital importance of an atraumatic technique in tendon repair, the use of fine, nonabsorbable, nonirritating sutures placed without tension, the elimination of exposed knots, and the accurate reposition of sheaths as well as tendons. Following repair, the parts should be splinted in the position of greatest tendon relaxation for a period of 2 to 3 weeks before active or passive motion is attempted. Physiotherapy, when initiated, must be under the direct supervision of the surgeon who, alone, is responsible for the end-result. Too often the importance of this period of rehabilitation is minimized, the after-care being placed in the hands of enthusiastic but inexperienced assistants. Such a practice cannot be too strongly condemned.

The principles discussed thus far apply to tendon repair in general. Secondary suture calls for special consideration. No attempt at secondary repair of tendons should be made in less than 3 to 4 weeks after injury in a wound which was closed and had healed *per primam*. If a mild wound inflammation or a mild staphylococcic infection was present, 6 to 8 months should be allowed to pass, and in the case of a severe infection or if a streptococcus was cultured it is safer to wait 12 to 18 months before a secondary tendon suture is undertaken. These time limits, are, of course, not absolute, but they serve as a fairly reliable guide to the condition of the tissues and the chances of relighting an infectious process.

Scar tissue in which the tendon ends have become embedded must be carefully but thoroughly removed by sharp dissection. Sometimes, when subcutaneous tissue is scanty and scar tissue excessive, a full thickness or pedicle graft must be transferred to fill the defect left by this dissection, in order to have sufficient subcutaneous fat surrounding the tendon to prevent re-formation of dense scar tissue adhesions. In this event actual tendon suture must be postponed until a later date.

The tendon ends must be completely freed of adhesions back as far as normal tendon sheath and any portion which cannot be freed will have to be excised. This excision may make it impossible to re-appose the ends of the tendon without tension. If this proves to be the case, tendon suture should not be attempted but a free tendon graft, complete with its sheath, must be obtained from another part of the body and used to fill the gap.

The exercise of sound judgment in the selection of cases for primary suture and courage to delay primary to secondary suture with a clear comprehension of basic surgical principles will, therefore, go far toward improving the results of treatment in acute tendon injuries.

SUMMARY

1. Hemorrhage and edema can cause extensive tissue necrosis in severely contused wounds. The early releasing of incisions may be necessary.

2. The criteria for and against primary suture in lacerated wounds and the technique to be followed are presented.

3. In order to prevent gangrene of the flap in avulsed wounds, an operation is described by which the skin is débrided and implanted as a full tissue graft in the defect. The possibility of preserving, by refrigeration, skin that cannot be immediately utilized is discussed.

4. The process of repair of sutured lacerated tendons is presented. The indications for and technique of primary and delayed suture are described.

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