THE INITIAL TREATMENT OF WAR WOUNDS INVOLVING THE KNEE-JOINT

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This paper will be more intelligible if it is introduced by definitions of a few of the terms employed in war surgery. For example:

1. A perforating wound is that which goes through and through and which has, therefore, no retained missile.

2. Conversely, a penetrating wound has a wound of entrance but none of exit. The missile is retained.

3. Débridement consists of the excision of the injured and contaminated tissues, either soft or bony, of a wound track. It implies, as a rule, the removal of the missile and of other foreign bodies, such as clothing.

4. A primary suture is a complete closure done at the time of an initial operation.

5. A delayed or retarded primary suture is a complete closure done from three to five days after an initial operation.

6. A secondary suture is a complete closure done ten or more days after an initial operation. Both delayed primary and secondary sutures imply that, at the initial operation, a wound has been left open for drainage.

7. Bullet wound signifies a wound made by a revolver or machine gun. Shrapnel balls are practically a thing of the past.

8. Shell wound signifies a wound made by a fragment of the casing of a high-explosive shell.

This study of knee-joint wounds is based on cases coming to an Evacuation Hospital, cared for either by myself or by one of my associates. All were fresh from the battlefield, with the primary dressing still in place. On the average they have come to the operating table fifteen hours after being wounded, three hours and thirty-seven hours being the two extremes.

I. STATISTICS ON TYPE OF MISSILE

In this respect the cases may be differentiated:

<table>
<thead>
<tr>
<th>Type of Missile</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bullet wounds without fracture</td>
<td>6</td>
</tr>
<tr>
<td>Bullet wounds with fracture</td>
<td>18</td>
</tr>
<tr>
<td>Shell wounds without fracture</td>
<td>22</td>
</tr>
<tr>
<td>Shell wounds with fracture</td>
<td>42</td>
</tr>
</tbody>
</table>

II. STATISTICS ON TYPE OF WOUND

<table>
<thead>
<tr>
<th>Type of Wound</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perforating without fracture</td>
<td>14</td>
</tr>
<tr>
<td>Perforating with fracture</td>
<td>10</td>
</tr>
<tr>
<td>Penetrating without fracture</td>
<td>10</td>
</tr>
<tr>
<td>Penetrating with fracture</td>
<td>46</td>
</tr>
<tr>
<td>Gutter without fracture</td>
<td>4</td>
</tr>
<tr>
<td>Gutter with fracture</td>
<td>4</td>
</tr>
</tbody>
</table>
3. STATISTICS ON TYPE OF FRACTURE

<table>
<thead>
<tr>
<th>Fracture Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture, femur</td>
<td>30</td>
</tr>
<tr>
<td>Fracture, tibia</td>
<td>6</td>
</tr>
<tr>
<td>Fracture, patella</td>
<td>10</td>
</tr>
<tr>
<td>Fracture, femur and patella</td>
<td>4</td>
</tr>
<tr>
<td>Fracture, femur and tibia</td>
<td>4</td>
</tr>
<tr>
<td>Fracture, femur, tibia and patella</td>
<td>6</td>
</tr>
</tbody>
</table>

4. SUMMARY OF STATISTICS

Let me condense these findings in this way:

1. Shell wounds (72 per cent.) are more common than bullet wounds.
2. Fracture in the joint (68 per cent.) is more common than non-fracture.
3. Penetrating wounds (70 per cent.) are more common than perforating.
4. Penetrating wounds usually fracture. In other words, a missile which hits the bone usually stops (82 per cent.).
5. Fracture of the femur is the most common fracture (48 per cent.).
6. The most frequent lesion, then, is a penetrating shell wound with fracture of the femur.

5. GENERAL RULES FOR TREATMENT OF ALL WOUNDS OF KNEE-JOINT

Certain general rules apply in the initial treatment of all wounds of this joint. I would offer the following:

A Röntgen-ray examination should precede every operation.

Every knee-joint operation should be done with a tourniquet. Preliminary extrusion of blood with an Esmarch bandage, winding from the foot upwards, is desirable. A dressing is to be applied, at the conclusion of an operation, before the tourniquet is removed.

In case an error in diagnosis is made whereby an intact joint is inadvertently opened, one should immediately suture the false opening.

A culture should be made of every opened joint. Immediate information may be had from a smear. (I regret to say that this rule was broken in many of the cases in this series.)

Ether is not an antiseptic. If joint irrigation is necessary, saline solution serves every purpose. The retention of antiseptic fluids in a joint is contra-indicated.

Wicks, rubber tubes, or strands of silkworm gut may be placed in the periarticular tissues to the synovia but should not enter the joint.

At the time of operation a definite policy of treatment and of after-treatment should be adopted. The incision to be used, the necessity of resection or of amputation, the matter of open capsule or of closed capsule, the decision for or against post-operative mobilization—these must be items in an intelligent, clear-cut scheme. Otherwise, a surgeon
may spend some time in careful débridement, only to find that amputation above the knee is necessary. Another may not have determined whether he is trying for a movable or for a stiff joint.

Cases are best kept under the observation of the operator for at least ten days after operation.

6. NON-OPERATIVE AND OPERATIVE TREATMENT OF CLEAN, PERFORATING BULLET WOUNDS

The method of treatment of a fresh wound of the knee-joint depends primarily on the presence or likelihood of sepsis. Frank sepsis seldom occurs in the early hours after injury; latent sepsis is to be feared if the preoperative period has been long or if the missile is dirty. Shell fragments are more prone to cause sepsis than are bullets. Secondarily, treatment depends on the existence of fracture, the retention or non-retention of the missile, on the scope of the wound and on the general condition of the patient; for these factors modify the amount of débridement, the nature of an incision, the time to be expended.

If the presence or likelihood of sepsis is of primary consideration, our cases divide themselves summarily into two classes:

1. Perforating bullet wounds, usually clean, and
2. All other wounds, prospectively septic.

Bullet wounds of the knee cause joint infection in only about ten per cent. of the cases in which this lesion prevails. Yet bullet wounds in soft tissues are rarely sterile,* so that we must fall back on the established fact that the knee-joint itself can overcome low-grade infection. Bullets cause less splintering of bone than do shell fragments.

I believe, therefore, that in the absence of acute inflammation, a knee-joint which exhibits a perforating wound, without extensive fragmentation, caused by a bullet, may be left alone. Otherwise, with every penetrating or perforating wound, the knee-joint should be opened.

Usually, however, even the simple, perforating bullet wounds are accompanied by a considerable bloody exudate into the joint cavity. It is well, then, to adopt one of the two following methods:

(1) One may aspirate, make a culture of the aspirated fluid and immobilize on a posterior wire (Cabot) splint. After a few days active movement may be inaugurated. Reaccumulation of fluid suggests, of course, further aspiration. Oncoming sepsis in the joint is a signal for free incision.

(2) One may excise the peri-articular tissues about the entrance and exit wounds, allow the joint exudate to escape and immediately suture tightly the three layers—synovia, capsule and skin. It is legitimate, before suturing, to wash the joint cavity through a catheter.

* Of one hundred consecutive cases, many of which were bullet wounds, B. Welchii was recovered in eighty-five.
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7. OPERATIVE TREATMENT OF ALL OTHER TYPES OF WOUND

a. General Outline of Operative Technic.—An operation, roughly, comprises the following steps:
   2. Removal of Esmarch bandage.
   3. Preparation of operative field.
   4. Débridement of missile track, both soft tissues and splintered, unattached bone fragments. Each fragment is removed which has the ear-marks of a prospective sequestrum. Evacuation of fluid and blood clot.
   5. Removal of missile, if it be present, together with bits of foreign material carried in with the missile. It is seldom difficult to find the missile in this particular joint. It is fair to say that a clean missile—a bullet—imbedded in bone is often tolerated. Yet even missiles of this category would best be removed unless their removal involves marked bone destruction. It is of paramount importance to remove such foreign material as bits of clothing.
   6. Irrigation of the joint. Personally, I irrigate only septic or dirty joints.
   7. Complete or partial closure of synovia, capsule and skin.
   8. Application of dressing and sometimes of a splint. The customary dressing is dry gauze or gauze wet in Carrel-Dakin solution.

b. The Several Incisions.—In opening a joint it is essential to procure a complete approach to all injured areas. Whenever possible, one should make first a liberal lateral incision well outside the patellar edge, incorporating in the incision the entrance wound of the missile. If this be done, a single incision may suffice for the several operative steps. Sometimes, in long ranging wounds, this is impossible and the incision is made through the exit wound or through uninvolved tissue.

If a single lateral incision gives inadequate access, a second lateral incision may be made beyond the opposite patella edge. Better still, one may employ the familiar U-shaped incision, cutting the patellar tendon close to its insertion, but cutting it in a somewhat oblique direction in order to give a broad surface for later coaptation. A missile lying free in the joint may usually be extracted through a single lateral incision.

Never hesitate to make a U-shaped flap for cases of extensive injury. Never fail to resuture the patellar tendon. In so far as is expedient resuture the lateral aspects of the flap.

A median incision, splitting the patella longitudinally, has not been used in any of the cases in this series.

c. Débridement.—To procure adequate débridement one must always follow the missile track. It may be found desirable, secondarily, to remove a missile through a counter-incision; but do not acquire the habit of merely cutting down through clean tissue over a foreign body.
For a missile lodged proximally in condyle or tuberosity, the ideal operation is to débride the track to the bone and to chisel out both missile and adjoining bone en masse. A margin of an eighth of an inch of good bone should be removed with the missile. This method is preferable to that of first removing the missile and then attempting to remove dirty bone with a curette.

d. Fractured Patella.—Avoid resection of the patella. Dirty bone along the edges of the track may be rongeured away. If the broken fragments are large, suture the periosteal edges with catgut. For extensive destruction perform a subperiosteal resection.

e. Resection.—In the past, primary resection of the knee-joint has been common both in clean and in infected cases. This teaching has been supplanted by the following:

Avoid primary resection of the knee-joint. It is indicated only for complete or nearly complete destruction, in clean cases, of the lower end of the femur or of the upper end of the tibia. A movable joint seems to be a possibility if two-thirds of either or both of these surfaces remain intact. After resection the knee-joint should be immobilized at an angle of 35 degrees.

f. Amputation.—One must consider primary amputation, rather than simple drainage or resection, for a streptococcus infection of the joint or even for a gas bacillus infection. For other less critical infections, amputation, if necessary, may be done as a secondary operation. Primary amputation, in short, is demanded for two conditions only: Severe joint infection and for complete blood-vessel destruction in the popliteal region.

8. Closure

a. Primary Suture.—If our operation has been other than amputation we are confronted with the question of joint closure. The operative wounds may be closed by primary, by delayed primary or by secondary suture; or they may be left open for a more protracted period for the sake of drainage. We are advised by the army authorities that the capsule, but not the outlying soft tissues, should be closed by primary suture when possible. When, then, is it possible?

Primary suture is possible except when there is:

(a) Infection with streptococcus, staphylococcus, gas bacillus or other similar noxious organism, shown by smear or by culture.

(b) Extensive destruction of capsule.

(c) Large or dirty missile, especially a fragment of shell.

It is possible but not definitely indicated when there is a large amount of fluid and blood clot in the joint.

b. Delayed Primary and Secondary Suture.—If primary suture is contra-indicated, one must then decide, for each individual case, whether the
joint may be closed by delayed primary suture, by secondary suture or must be left open more or less indefinitely. Setting aside the mechanical difficulty of loss of capsule, the question becomes one of the time required to abort or eliminate infection or to get rid of superfluous blood clot and fluid. In other words, a joint must be relatively sterile and relatively empty before it may be closed; suppuration must have ceased; especially must the discharge from the joint give a negative culture for streptococcus.

Delayed primary suture gives an end result as good as that of primary suture. By delayed primary suture the end result is attained more speedily. Delayed primary suture largely eliminates the difficulty of diagnosing prospective sepsis. In my experience the danger of infecting a clean joint, which has been left open, is nil. For these reasons, in my own cases, I am leaning more and more away from primary suture towards delayed primary or secondary suture. I close by primary suture only two types of lesion: (1) Wounds, with little or no fracture, which are sterile on smear. These are usually penetrating bullet wounds. (2) Joint resections.

To these narrowed limits some of my associates would not agree. They are inclined to adhere more rigidly to the specifications set forth under 9, a. And it is true that one sees cases like those described as Cases 9 and 10 make an excellent recovery after being closed by primary suture.

c. Frank Sepsis.—Yet when I am in doubt I leave an opening. If frank sepsis exists, it is desirable to have liberal drainage at either side of the patella—so liberal that it drains both the lateral aspects of the joint and the suprapatellar pouch. Drainage may be needed for a considerable time and one must be on his guard against pocketing in the posterior portion of the joint, in the calf of the leg or in the thigh. If frank sepsis does not exist, a shorter incision at one or the other side of the patella suffices—preferably an incision on the side of the entrance wound which exposes, if such exist, injured bony areas. If the incision has been extensive, if one has used, for instance, a U-shaped incision, it is customary to resuture in part. The synovia may be closed with continuous catgut, the capsule with interrupted catgut, the skin with silkworm gut. The patellar tendon and that portion of the capsule immediately adjacent should always be resutured.

Drainage through the posterior aspect of the knee-joint, as an initial procedure, is indicated only when the wounds of entrance or exit involve this region. If such involvement is present, and wicks or tubes are placed to the capsule posteriorly, one must bear in mind the possibility of secondary hemorrhage. Personally, I use no wicks or tubes in the popliteal space. A wide-open, posterior wound, in itself, has sufficed.

So much for the question of closure. It is closely affiliated with the problem of mobilization and immobilization.
A tightly closed synovia connotes temporary immobilization. With two exceptions, an open synovia connotes immediate, conscientious, systematic movement. The exceptions are these:

a. If there is extensive destruction of joint surface, it is necessary to immobilize, even though the synovia is not completely closed. Conversely, in the presence of slight bone injury, if one is aiming for a movable joint, immediate movement is advisable.

b. If there is complete fracture of the patella or if there is an injury or an incision which severs either the patellar or quadriceps tendons, it is necessary to immobilize, even though the synovia is not completely closed.

The exceptions we have noted are illustrated by Case II or by Case 12.

Let me make this rule more specific, more emphatic, by looking at it from the reverse direction. Temporary immobilization (splint) is indicated for: a. Closed synovia, including non-operative cases (Case 2), joint resection, and all other cases closed by primary suture (Case 7). b. Complete fracture of the patella or injury or incision which severs either the patellar or the quadriceps tendons (Case 5). c. Extensive destruction of joint surface (Case 12).

Mobilization (no splint) is indicated for: a. Septic joints. b. All cases, except those enumerated above, treated by delayed primary or by secondary suture (Case 8).

Immobilization is happily secured by a Thomas splint slightly bent at the knee or by a posterior wire (Cabot) splint. The Thomas splint affords traction; the Cabot splint does not. Simple cases should be immobilized for at least three days. Thereafter, movement must be gradual. Too free movement leads to accumulation of fluid in the joint.

Undue distention of the joint capsule at once suggests aspiration. Too little effort is made to relieve synovitis or haemarthrosis in this way. One may aspirate on slight provocation and culture. If the aspirated fluid shows gas bacillus, staphylococcus, streptococcus or other virulent organism, the joint must be opened. Diplococcus alone does not warrant opening a joint. Yet, even in the absence of the more virulent organisms, I have not infrequently made an incision, to be closed a few days afterwards. My results have been satisfactory. Here again, I lean towards delayed primary suture.

If mobilization has been elected, it must be begun within a few hours after the operation, as soon as a patient is out of his anaesthetic, and must be performed systematically and conscientiously. If the joint is allowed to rest immobile for two or three days—even for twenty-four hours—it becomes recalcitrant. It resents any attempted movement—becomes red, swollen and tender. Usually the attempt must be temporarily or permanently abandoned. On the day of the operation, then, and from two
to four times a day thereafter, under supervision, the patient is instructed to lie flat on his back, lock both hands at the posterior surface of the lower thigh and elevate to a right angle both leg and thigh, the knee being in extension. Thereupon, with the thigh still upright, the leg is allowed to drop until it is at least horizontal; better still, it is allowed to drop until the heel is within a few inches of the bed. During this movement, at first, the surgeon must place the palm of his hand under the heel to give partial support.

Most patients are fearful of this procedure. They complain, however, of stiffness rather than of severe pain, and with initial coaching, assistance and encouragement, can easily be taught to perform the manoeuvre. A patient should be made to walk, with a cane, on the second or third day after operation. The first day he takes a few steps, the next day he walks around his bed, the third day, perhaps, the length of the ward. Once only I have seen a slight chill and an elevation of temperature (104 degrees) follow this procedure. The following morning the temperature had subsided.

After delayed primary or secondary suture has been performed, one must regulate motion carefully. We have here a condition analogous to that described in Case 13.

Mobilization is especially important in septic joints. Immobilization of a septic knee is often a forerunner of amputation. Adequate drainage of a quiescent knee is so difficult that a profound and obstinate sepsis, with joint erosion, is apt to develop. Pus pockets are discovered. Septicæmia ensues.

Per contra, mobilization cures sepsis. Active joint movement squeezes out joint pus in a surprisingly effective way and, in many instances, leads to a rapid subsidence of acute symptoms. Mobilization prevents stiffness. Employed from the beginning, it gives mobility without undue discomfort after a relatively brief interval—often after a few days. The result is quite in contrast with that of a splinted patient, with his stiffened, sensitive knee, who must recover strength, reacquire, if possible, motion in his joint, and undergo, at best, a protracted convalescence.

The following case reports illustrate a few of the methods advocated and some of the results secured in this series:

**CASES I and II.**—*Method employed for simple perforating bullet wounds.*

**Case I.**—Perforating bullet wound passing through crural pouch. Five hours old. No culture. *Operation.*—Entrance and exit wounds excised. Closed tightly. Thomas splint. Movement begun after five days. Normal convalescence. Reported three weeks later that he was walking and had no material symptoms from knee.

**Case II.**—Perforating revolver bullet passing beneath patella. No fracture. Slight haemarthrosis. Eighteen hours old. No culture. *Operation.*—None. Aspiration not deemed necessary. Thomas
CARLETON R. METCALF

splint applied. Discharged from hospital two days later. Knee doing well.


(If this patient had been under my care, I should have employed a lateral incision and have held the man until the time was ripe for delayed primary suture; a U-shaped incision suggests temporary immobilization.)


In Case V the culture from the joint was negative.


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Gradual motion begun in joint after three days. Discharged from hospital ten days after operation. No untoward symptoms.


Cases IX and X.—Disillusionment sometimes encountered after primary suture.

Case IX.—Perforating shell wound, entering opposite internal condyle. Twelve hours old. Röntgenogram shows slight fracture of internal condyle. Operation.—U-shaped incision. Fluid and blood-clot evacuated. Loose fragment of internal condyle removed. Wound closed tightly. No culture taken. After-treatment.—Three days after operation violent inflammatory reaction in knee. Culture from aspirated fluid shows streptococcus. Amputation at mid-thigh. (This patient had also a penetrating wound of the spinal canal from which he developed a fatal attack of meningitis.)


Case XII.—Exception to the rule that an open synovia connotes