PENETRATING WOUNDS OF MAJOR JOINTS*
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Ever since the advent and acceptance of the principles of asepsis, as established by Lord Lister, and the fundamental concepts of the healing of wounds put forth by Halsted, the interest of surgeons in trauma and repair has varied directly with the occurrence of war. In periods of peace a modicum of experimental and clinical work on this most basic problem in surgery continues, but with comparatively little attention by most surgeons. Rather their interest seems to be centered on the great panacea—elusive as the alchemists' dream of the conversion of base metals into gold—that will heal wounds in spite of neglect of the underlying principles of wound repair. Once Pandora's box is opened, however, and the woes of war suddenly unleashed, the problems posed by wounds become of paramount importance. Symposia are held and old truths hailed as great discoveries, and the currently fashionable wound anti-septics are exploited to their full. Yet what has been their fate, phenol, corrosive sublimate, iodine, Dakin's solution, B. I. P., the newer mercurials, the sulfonamides, and the antibiotics?

"The almost inherent urge to place some agent, with hopeful healing and anti-infective properties, in a wound seems to be deep-seated in the human breast and is as difficult to control as the better recognized human impulses. Time and experience have repeatedly demonstrated the inefficacy of such agents. Perhaps some day such an agent will be found but the search seems futile when it is realized that the key to wound infection in traumatic wounds is dead tissue, a fact which Botallo recognized almost four centuries ago, and which Lister fully appreciated."

Many of the anti-infective agents are of immeasurable aid in controlling infection and extending the scope of surgery, but they are always ancillary to thorough and careful surgery. It took the British three years to recognize this in World War I and in their Official History of the War the development of the methods used in treating wounds of joints is divided into four phases:

1. In the early stages of the war attention was focused on incision and drainage with large tubes. With the exception of a few simple perforating wounds, suppuration was the rule with a resulting high mortality, and an amputation rate of 60 per cent for knee-joint cases with only soft part injury, and 80 per cent for those complicated by fracture.

2. Early in 1915 the treatment outlined by Colonel H. M. W. Gray was adopted. This consisted of: (1) adequate immobilization of the joint, (2) excision of infected soft parts, (3) lavage of the joint cavity after removal of

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the projectile, and (4) closure of the capsule of the joint. If suppuration was present arthrotomy was performed and drainage established only down to the joint cavity.

3. In the summer of 1916 the Carrel-Dakin method of treating wounds was adopted by the British Army and for the first time the importance of early excision of infected tissues as an essential feature in wound treatment was realized.

4. In the Spring of 1917 early and free excision of the injured area was the standard method of treatment with primary or delayed closure of the wound. This resulted in 70 per cent healing by first intention in all wounds. In joint cases only 12 per cent suppurred, while the amputation rate fell from 25 per cent to 7 per cent and the death rate from 15 per cent to 8 per cent.2

In World War II, notwithstanding the knowledge already available, much had to be rediscovered. The absolute necessity of wide exploratory arthrotomy and careful débridement of all wounds involving joints, was not fully appreciated at first. This was probably due to our unfamiliarity with the British experience in World War I, and with our own findings at that time, as stated in an admirable article by Pool in the Medical Department of the United States Army in the World War,3 which was not published until 1927. We knew little, and that largely condemnatory, about primary resection of joints and the timing of secondary resection for suppuration. Yet these procedures had all been considered in detail by Pool.3

Early in 1943 the Ninth Evacuation Hospital came to the conclusion that all cases of penetrating wounds of joints should be widely opened, carefully débrided and the foreign bodies, debris and blood should be removed. Also the joint should be irrigated with saline, and the capsule closed. The closure of the capsule was thought to be so important, that if a gap existed a sliding flap of skin or fascia was employed.

Complete immobilization of the joint was of paramount importance and in the case of a knee joint this was accomplished by means of a hip spica. The delayed primary suture of the soft parts was performed four to seven days later. When penicillin became available this was placed in the joint in the dosage of 10,000 units at the conclusion of operation. It was repeated at 24–48 hour intervals thereafter for two or three doses, and the patient was also placed on systemic penicillin.4

At about the same time, this hospital unit, which was functioning near Naples, admitted a group of French soldiers with well-established suppurrative arthritis of the knee. A lower thigh amputation was necessary as a life saving measure in one instance and it appeared that this would be required in five other cases. At the suggestion of Colonel Etienne Curtillet, the French surgical consultant, five resections of the joint were performed. This seemingly radical procedure had been advocated 75 years ago by Ollier.5 The sepsis subsided and healing was prompt in all five cases, only one case failed to develop solid fusion.6 These conceptions of treatment were immediately extended to all the hospitals in the Naples area by the teaching and work of Lieutenant Colonel Oscar Hampton and Major Champ Lyons with the cooperation of the various
ORTHOPEDISTS, and further, the principle of re-debridement in the presence of sepsis was established by them. As a result of this early experience a detailed description of the treatment of penetrating wounds of joints was included in Circular Letter Number 2 of the Surgeon of the Seventh Army just prior to the Southern France Campaign. The response was more than gratifying and reports came from both the forward and base installations that these wounds healed cleanly when so treated and the only ones that became septic were those that had been neglected or in which débridement was inadequate, usually by new and inexperienced surgeons. Two of the Evacuation hospitals reported their results of arthroty and débridement of penetrating wounds of the knee joint in detail. Of the 227 cases treated by them, two were suppurating at the time of the initial débridement—one 10 and the other 14 days old. None of the others showed any signs of infection when evacuated to the rear three to seven days after débridement. There were no amputations in this group.

In the ancient and modern history of military surgery, there has accumulated enough experience in the treatment of knee-joint wounds to give us confidence that our problem, to a limited extent, is solved. We now realize that if these wounds are given the proper primary treatment, suppuration will rarely develop.

The same happy outlook cannot be said to apply to wounds of the hip joint. There has always been considerable difficulty in obtaining accurate statistics on the incidence of wounds of this joint. The proximity of the hip to the femoral and iliac artery, as well as to the bladder and rectum, makes it likely that in many instances death supervenes promptly. This may account for the fact that compound penetrating wounds of the hip-joint were not as common a finding in the forward Army hospitals, as were the knee-joint wounds. On the other hand it is safe to assume that a projectile may produce tears of the capsule of the hip-joint, or lesser fractures of the head and neck of the femur, and still remain undetected as hip-joint injuries.

Regardless of the number of compounded wounds of this joint that are seen in either war or in civilian practice, they are likely to be tragic when they occur.

We have been unable to find any worthwhile contributions to the literature on this subject since the published work of Lagenbeck and Otis 75 years ago. Lagenbeck had collected 132 cases during the Franco-Prussian war, and had seen or treated most of them. He speaks of three forms of treatment:—

the conservative, resection of the head of femur and disarticulation of the hip. His conservative treatment was definitely the most effective. There were 88 cases in this group, 63 proved fatal. A mortality rate of 71 per cent! Resection of the head of femur was attended by a mortality of 83.9 per cent, while disarticulation at the hip joint as a mode of treatment caused death in each instance.

A review of his cases in the conservative group leaves the impression that his treatment consisted in the main of probing the wound, immobilization and
hot poultices. There is no mention of débridement as we know it today, and no wide exposure of the joint.

Many of his recorded cases were not suspected of having hip-joint involvement during the early period after injury. They were transported to distant hospitals, and it was only after the manifestations of suppuration became obvious that the diagnosis was made. In spite of his figures he favored primary resection of the head of the femur before suppuration had a chance to develop. His belief was that under these circumstances the mortality rate would be lower than in the conservative group.

Otis was very sanguine on the subject of hip-joint wounds in general. He hardly saw a case of recovery of a gun-shot fracture of the hip-joint by expectant treatment, which did not leave a doubt in his mind in regard to the correctness of diagnosis. (This was of course before the days of x-ray.) He arrived in consequence at the conclusion that the expectant treatment must be rejected in all cases, as soon as the nature of injury to the hip-joint became evident. He also favored resection of the head of the femur as the treatment of choice.

In the British medical history of World War I there was an estimated mortality of 60 per cent for all wounds of the hip-joints. Débridement, closure of the joint capsule, and removal of the femoral head if badly comminuted, were advised as the primary treatment. Where sepsis was already established the head was excised routinely and wide drainage obtained. If excision failed, the leg was amputated through the hip-joint. The end results in all cases who survived without amputation were poor, with a grave loss of function and severe crippling.

The medical history of the U. S. Army in World War I devoted little or no attention to its experience with hip-joint wounds, other than to point out their serious nature. The very lack of comment implied an inability to answer the problem. In contrast, the treatment of knee-joint wounds was clearly detailed, and today serves as a model. Any improvement in results, in the treatment of knee-joint wounds in World War II must be credited to the general advances in the surgical adjuvants, and not to changes in the underlying surgical principles.

It became evident to one of us (F. B. B.), as Surgical Consultant of the Seventh Army in France, that the surgical principles which were being so successfully applied to knee-joint injuries, were being ignored in wounds of the hip. Unlike the knee, a thorough exploration and débridement of a hip-joint is a formidable procedure in a severely wounded patient. And yet, if the principle of débridement is valid for the knee, all the more reason it should be applied to the hip with its deep location, its many adjacent muscle bellies and planes, all favoring the development of infection.

It had been observed that on the rare occasion when a hip-joint was explored it was through enlargements of the wound of exit or entrance, which naturally gave a limited exposure to the entire joint. Unlike the knee, the hip is so deeply placed that a simple anterior, lateral or posterior incision will not
lay bare all its secrets. The operator could not end his procedure with the sense of satisfaction that all devitalized muscle had been excised, and that the area had been thoroughly cleansed and freed of all foreign debris.

If he glimpsed the capsule of the joint it was at the bottom of a deep hole, and only a limited portion was in his field of vision. The intricate pattern of overlying muscles does not lend itself to bold incisions, which require only an inch or two more in length to get a good look at the pathology. Boldness of this sort would result in damage that in turn might produce ischemia, or paralysis and atrophy to muscle groups.

In March, 1944, several Evacuation Hospital surgeons in the Seventh Army were requested to perform arthrotomies on all suspected penetrating hip-joint wounds. The operation was to be performed initially, or within a 72-hour period, whenever the condition of the patient permitted. The arthrotomy was to be a formal procedure which would give wide exposure to the joint. Considerable thought was devoted to the type of incision which would give the best exposure, and yet avoid being too destructive. It was agreed that the Smith-Peterson incision was best suited for this purpose, and that if the posterior and inferior portions of the joint needed attention that the Langenbeck or Kocher incisions could be employed separately or in addition. The wounds of entrance or exit were to be incorporated in the incision if convenient, and otherwise they were to be debrided individually.

In April, 1945, one of us (J. E. T.) had his first opportunity to put this plan into effect. The first case was most convincing in two respects. First, that the Smith-Peterson incision gave excellent exposure of the anterior and superior aspects of the joint, and that palpation of the remainder of the capsule would determine the need of an additional posterior incision. Second, the extensive deep destruction to the gluteal muscles could never have been properly débrided by means of any other incision. An infection developing in this situation would have extended directly into the opened joint.

Within a four-week period leading up to the end of the hostilities in Europe, we operated on nine hip-joint wounds. Seven of the nine cases had penetration of the joint capsule, and the remaining two had contusions of the capsule without frank penetration. Contusion of the capsule was considered by Langenbeck to have serious potentialities.

Six of the patients were American soldiers, and three were German prisoners of war. (We have a limited follow-up on all the Americans which has been added to the case reports. No information on the Germans has been obtainable.)

In six cases the typical Smith-Peterson approach was used, and in one a modification of it sufficed. In this latter case it was only necessary to lengthen the wound of entrance on the antero-lateral aspect of thigh, up to the anterior superior iliac spine, and then for an inch along the crest, only detaching the tensor fascia muscle. In two cases the Langenbeck incision was employed.

The nature of the Smith-Peterson incision demanded that its horizontal portion be closed in all layers. The tension was so great on the re-sutured
gluteus medius muscle, that the overlying skin was closed to give it additional support. The remainder of the wound was left wide open, with the expectation that a secondary closure would be performed within a week at some hospital in the rear.

Drainage was used in only one case, the drain was brought out through a posterior stab wound, splitting the gluteus maximus muscle in the line of its fibers.

Dry, fine mesh gauze was used as a dressing over the raw wounds, and in each instance a hip spica was applied. Every case, when possible, was evacuated to the rear within a 48-hour period. The purpose of early evacuation was to have the patient in a permanent installation, in the event suppuration developed.

![Fig. 1-A.—An x-ray of pelvis in Case 1, taken 21 months after injury. The slight upward shift of left half of pelvis can be seen.](image)

All of the patients in the following case reports were admitted to the 9th Evacuation Hospital while it was functioning in Germany during April and May of 1945.

**CASE REPORTS**

**American Soldiers**

**Case 1.** J. E. K. This patient received a perforating rifle wound at 11 A.M. on April 3, 1945. Admitted on April 3, 1945. The wound of entrance was in the left inguinal region and the wound of exit in the left buttock. The abdomen was soft and there was no evidence of rectal injury or injury to the femoral vessels. X-ray revealed an extensive comminuted fracture of the left ilium involving the acetabulum.
The patient was treated for shock. He was brought to operation at 3:45 P.M., April 4, 1945, almost 29 hours after injury. Pulse 100. Operator J. E. T.

Pathology. The wound of entrance was just medial to the anterior superior iliac spine. The bullet had entered the abdominal wall and had passed extra-peritoneally to pierce the ilium, shattering it into one large fragment and several smaller ones. It traversed the superior lip of acetabulum in its path, unroofing the joint. In emerging from the ilium it destroyed the gluteus minimus and maximus over a diameter of about 3 inches, leaving a large defect. The superior gluteal vessels had been completely divided. There were many small loose bone fragments, but no debris, just old blood clots.

Fig. 1-B.—A spot film of left hip in Case 1. The hip-joint shows extensive arthritic changes and is painful, but there is 25 degrees of flexion.

Procedure. Using a Smith-Peterson incision, the antero-superior aspect of the joint was exposed. The above pathology was outlined. The capsule of the joint was opened by means of a "Y"-shaped incision. The head of femur was examined and found to be uninjured. The joint was then thoroughly irrigated with warm saline, and closed with interrupted chromic gut sutures. The defect in the joint where the superior lip of the acetabulum had been destroyed, could not be closed by a muscle flap of gluteus minimus. This muscle was completely lacking in blood supply and had to be removed in its major part. The severed superior gluteal vessels were ligated. The wound was thoroughly
irrigated and 10,000 units of penicillin were instilled into the hip joint. Closure was performed by re-attaching the gluteus medius to the iliac crest, and suturing the overlying skin with interrupted fine wire sutures. The vertical portion of the Smith-Peterson incision was not sutured.

The wound of entrance was incised down to fascia, and a local debridement was performed. The wound of exit was located in the left buttock four inches from the mid-line and on a level with the greater sciatic notch. It was enlarged laterally revealing a large defect of gluteus maximus that communicated directly with the space left by excising the gluteus minimus muscle. It was impossible to obliterate the cavity. The wounds were left open, dry fine mesh gauze was applied to the raw surfaces. No drains. A plaster hip spica was applied.

Follow-up. Secondary closure was performed in England, in April 1945. He was evacuated to the United States on June 1, 1945, with his wounds healed and in a double hip spica which was removed during June 1945. He wore a brace and was ambulatory from July 1, 1945. The brace was discarded in February 1946. He was discharged from the Army on December 10, 1946.

He was examined by one of us (J. E. T.) on January 16, 1947. He is now gainfully employed at a desk job. His main complaints are pain in the hip, and to a less extent pain in the left knee and left flank. He uses a cane and walks with a definite limp.

On examination all his wounds are found to be cleanly healed. There is 3/4" measured shortening on the left side, in measuring from the umbilicus to the medial malleolus. When measuring from the anterior superior iliac spine the left leg measures the same as the right. The shortening is due to the upward shift of the fractured ilium and acetabulum.

The motion at the hip is limited to 20 degrees flexion, 5 degrees extension, 5 degrees internal rotation, and 5 degrees external rotation. The extension at the knee-joint is complete, and he can flex the knee to 90 degrees. There was marked atrophy of the left thigh and left buttock, there was only slight atrophy of the left calf.

X-ray examination of the pelvis to include the left hip reveals extensive healed comminuted fractures of the left ilium which involves the acetabulum. Definite encroachment on the pelvis is shown by the medially displaced acetabulum and pubic fragments. There is upward displacement of the acetabulum, plus cartilage absorption of the articulating surface of both the head of the femur and the acetabulum (Fig. 1).

Comment—This case illustrates a very severe type of penetrating wound of the left thigh, where a comminuted fracture of the ilium communicated with the hip-joint. The damage to the gluteal muscles was extensive, including early ischemic necrosis of the gluteus minimus due to destruction of its blood supply. Debridement of this wound could never have been accomplished as easily or as completely through any other type of incision. It is felt that if this patient had been given the usual conservative treatment with wound debrideaments, he would have been an excellent candidate for deep wound infection and secondary suppurative arthritis.

Functionally his result is poor, and he may come to hip fusion to control pain. On the basis of World War I experience he may well have been included in the 60 per cent mortality group.

Case 2.—H. H. S. The patient received a bullet wound of left upper thigh on April 9, 1945. He was admitted six hours later. X-rays revealed a comminuted fracture of the neck of femur and greater trochanter. He came to operation 22½ hours after injury. Operator J. E. T.

Pathology—The wound of entrance was situated on the antero-lateral aspect of middle third of left thigh. In coursing upwards the bullet traversed the base of the neck of left
femur to lie, finally, just beneath the skin of left buttock about three inches lateral to the anus. The greater trochanter was also comminuted. In its course it destroyed about two-thirds of the tensor fascia muscle, and locally destroyed portions of the deep surface of the gluteus maximus muscle. The fracture lines extended into the joint proper.

Procedure—Smith-Peterson incision employed with the wound of entrance included in the vertical portion of the incision. The devitalized tensor muscle and the destroyed portions of the gluteal muscles were excised. Some clothing and bits of steel jacket from the bullet were also removed. The capsule of the joint was opened through a Y-shaped incision on its anterosuperior aspect and the fracture was seen to communicate with the joint. Actually the bullet had traversed the trochanter at an extra-capsular point.

The joint was irrigated with warm saline, and the capsule closed with a lock stitch of continuous chromic gut. 10,000 units of penicillin were injected into the joint. The bullet was then excised from beneath the skin of the buttock.

A posterio-lateral incision, splitting the fibers of gluteus maximus, was made, and a rubber tube drain inserted to a point just posterior to the fracture line. (To be removed in three days.)

The Smith-Peterson incision was closed in layers, except for the distal half of its vertical portion.

The hip was reduced by the Ledbetter maneuver and a plaster hip spica was applied.

Follow-up.—A letter received from patient on December 8, 1946, is as follows:

"I received your letter asking me about my hip wound. Well it sure turned out better than I ever thought it would. You asked me a few questions in your letter, I'll do my best to answer them.

"The first thing, my hip is healed and well. After I was operated on in the 112 Gen'l, I was put in traction. Ten days after they operated, the wound was well healed, but the bone itself would not knit. I was in traction 10 weeks and sent back to the States, here I was put in skin traction for three weeks, then up on a full leg brace, which wasn't so good. I was sent to Percy Jones Hospital after that, oh yes, this brace was gotten at Winter Gen'l Hospital in Kansas. After one month at Percy Jones they operated again and put in a steel plate which turned out all right so far.

"As for working I haven't done anything yet. I tried a few things back here on my Dad's farm but that's out. My leg is an inch short and throws me off balance to carry anything. So I have to look for some other sort of a job. My knee has only 90 degree bend and hip partially stiff.

"I am home now on Terminal leave, which is up the 15th of December, far as disability pension I wouldn't know as yet."

Comment.—This case illustrates a bullet wound causing a severe compound fracture of the greater trochanter of femur, and the fracture line extending into the joint. The deep-seated destruction of muscle, and the clothing carried into the depths of the wound would have been difficult to discover with a simple type of incision. Suppuration of the hip joint would have been a likely complication following the conservative form of treatment.

Case 3.—D. P. This patient received a shell fragment wound of the upper left thigh on April 19, 1945. He was admitted and operated on the same day. Operator: J. E. T.

Pathology.—X-ray had shown two large shell fragments adjoining the hip, one of which looked as though it might have penetrated the capsule. Actually one fragment was found lying on the antero-superior aspect of the capsule but had not penetrated it. The other one was found medially beneath the sartorius muscle.

Treatment.—Smith-Peterson incision. The shell fragments were removed and the destroyed muscle tissue debrided. The joint capsule was not opened. The Smith-Peterson incision was closed except for the distal half of its vertical portion. A hip spica was applied.
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Follow-up.—A letter received from the patient's father on Dec. 5, 1946, states that the patient underwent no further surgery. He was discharged from the Army and is now attending school. His hip is said to have 20 per cent limitation of motion.

Comment.—This case was subjected to more surgery than was needed. The capsule of the joint was contused and not penetrated. It is inevitable that a certain per cent of negative explorations will occur.

Case 4.—T. A. M. This patient received a bullet wound of the right anterior thigh on April 23, 1945, at 5:30 A.M. Primary operation on April 24, 1945, at 2:30 A.M. 21 hours after injury. Operator: C. F. Stewart.

Pathology.—A simple debridement of the wound of entrance was made and the tract was explored. The entrance was just lateral to the femoral vessels on the anterior thigh, and an x-ray had shown the bullet at the level of the neck of femur. It was thought that it was lying anterior to the capsule just below the sartorius muscle. A vertical counter incision was made between the sartorius and the tensor fascia muscles. At the end of two hours of search the procedure was abandoned. The wounds were left open and dry dressings were applied.

Course.—On April 25, 1945, check-up x-rays, which included a lateral view, suggested that the bullet had penetrated the joint capsule, and was lying against the neck of femur.

Secondary Operation on April 25, 1945, at 3 P.M. Operators: C. F. Stewart and J. E. Thompson. The original counter-incision was extended upwards and converted into a Smith-Peterson approach. The antero-superior aspect of the joint was exposed. The capsule was opened with a V incision on its anterior surface, and the joint filled with 5 to 10 cc. of bloody fluid. On the anterior surface of the head was a minor crushing injury to the cartilage, not sufficient to require débridement. The bullet was then found embedded within the substance of Bigelow's ligament opposite the superior surface of the femoral neck. It was partially within the joint. The bullet was removed and the openings in the capsule were closed with a continuous lock-stitch of chromic gut after irrigating the joint with warm saline. 10,000 units of penicillin were instilled into the joint.

The wound was then closed in layers except for the vertical portion of the Smith-Peterson incision which was not sutured. A hip-spica was applied.

Follow-up.—A letter was received from this patient on Jan. 15, 1947. He was still in the army as of that date. He states that his only subsequent operation was for secondary closure of his wounds. He is now suffering from slight stiffness at his hip-joint, with occasional pain in the hip and back.

Comment.—This case beautifully illustrates the problems of penetrating hip-joint wounds as encountered and treated in the past. It emphasizes the time consumed in trying to trace the path of a foreign body which has penetrated deep into the tissues around the hip-joint. It shows the inadequacy of using an ordinary débridement incision to give the proper exposure. The knowledge gained by the preceding cases was of great help in deciding that a secondary operation was necessary, particularly after the x-rays were reviewed and new ones were obtained.

Case 5.—S. D. S. This patient received a bullet wound of the left thigh on April 24, 1945, at 11:45 P.M. The wound of entrance was on the antero-lateral aspect of the left thigh in the upper third. X-ray showed a fragmented bullet which seemed to be in the hip-joint.

Operation was performed on April 25, 1945. Operators: G. Crawford, J. E. Thompson.

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It was decided to approach this case using only the vertical portion of the Smith-Peterson incision, as the bullet was seen by x-ray at a point just anterior and inferior to the neck of femur. The incision was made to pass through the wound of entrance, and extended deeply between the sartorius and rectus femoris on the medial side and the tensor muscle laterally. The capsule of the joint was exposed and incised in the line of its fibers. The bullet fragments were removed both from the capsule and curetted from the substance of the neck of femur.

The joint was irrigated with warm saline, and snugly closed. 10,000 units of penicillin were instilled into the joint. The upper half of the incision was closed and the remainder left open. A hip spica was applied.

Follow-up.—A letter from the patient on December 12, 1946, stated that his wound was sensitive but completely healed. He has occasional pain and stiffness of the hip-joint, particularly when he walks or stands too much. Upon his discharge from the Army he was allowed 30 per cent disability. He now has an easy civil service job.

Comment.—The exposure using this type of incision was quite difficult in that it required considerable heavy retraction and only a limited view of the anterior part of the capsule. The many arterial branches entering the tensor muscle in its distal half added to the difficulty. The operation would have been easier, and the exposure improved by detaching the origin of the tensor muscle from the anterior superior spine and the infra-spinous portion of the crest of the ilium. This modification of the Smith-Peterson incision would be perfectly adequate to approach the antero-inferior portion of the hip-joint.

Case 6.—N. M. This patient received a bullet wound of the left buttock on May 4, 1945, at 9:30 P.M. and was admitted on May 5, 1945. X-ray revealed the bullet adjoining the neck of femur on its posterior aspect. Operation at 5 A.M. on May 6, 1945, 32 hours after injury. Operator: G. Crawford.

A posterior approach was utilized as described by Langenbeck, passing through the wound of entrance. The fibers of the gluteus maximus were split, and the gluteus medius retracted anteriorly. The bullet passed through the pyriformis muscle to enter the joint. The capsule was incised and the bullet removed. A small fractured area of the rim of the head of femur was debrided and the joint was irrigated with warm saline. The capsule was closed and 10,000 units of penicillin were instilled into the joint.

The soft tissues were not sutured. A hip spica was applied.

Follow-up.—The only information that could be obtained about this patient was that he was back at regular duties with the Army of Occupation in Europe in February, 1946. This fact would indicate that his disability was minimal.

Comment.—This case illustrates the adequacy of the posterior approach for selected cases where the pathology is limited to the posterior aspect of the joint. It is a much less destructive incision.

German Prisoners
(No Follow-Up Obtainable)

Case 7.—E. S. The patient received a perforating bullet wound of left thigh at 4 P.M. April 5, 1945. He was admitted at 1 A.M. April 6, 1945. Examination revealed a wound of entrance just below and medial to the left anterior superior iliac spine, the wound of exit was in mid-left buttock. There were other irrelevant wounds. The clinical signs pointed definitely to joint involvement.

Operation.—April 6, 1945, at 2:20 P.M. 22½ hours after injury. Operator: J. E. T.
Pathology.—The bullet had traversed the thigh and buttock just superior to the capsule. No penetration of the capsule could be found. The gluteal muscles were quite healthy looking and only a moderate amount of debridement was necessary.

Procedure.—Smith-Peterson incision. The capsule was opened with a V-incision, the joint was inspected and found to be negative. Several small fragments from the bullet were removed from the soft tissues outside the capsule. The capsule was snugly closed with a running lockstitch of chromic gut. Penicillin 5000 units were instilled in the joint. The incision was closed in layers except around the wounds of entrance and exit. A hip spica was applied.

Comment.—This case had no actual penetration of the hip-joint in spite of the clinical signs, which were probably due to contusion of the capsule. There was very little deep destruction of soft tissues, so that the end result will not be materially benefitted by the Smith-Peterson incision.

Case 8.—K. G. The patient was admitted on April 11, 1945, with a penetrating bullet wound of the left buttock. An A. P. x-ray view was taken and the bullet was interpreted as lying in the soft tissues of the buttock.


First Procedure.—A transverse incision was made through the wound of entrance in the line of left buttock crease. Considerable time was spent in an unsuccessful effort to find the bullet; only a gutter fracture in the outer table of ilium was discovered. Further operation was abandoned.

Postoperative x-rays were taken on April 12th and 13th. A lateral view taken on the latter date gave fairly definite evidence that the bullet was imbedded either in the capsule or in the joint itself.


Procedure.—Smith-Peterson incision. The anterior and superior surfaces of the capsule showed no evidence of penetration or trauma. The bullet could not be seen or felt. A bi-manual examination with a finger in each of the anterior operative and posterior wound of entrance revealed that the bullet, after creasing the outer table of ilium, had entered the base of acetabulum at about 7 o'clock (in the recumbent position).

The capsule of the joint was incised from the base of neck to acetabular rim along its superior surface, and then converted into a Y by an additional incision posteriorly inclined to get sufficient exposure. The base of the bullet was exposed, lying partly in capsule and partly in the joint. It was separated and cushioned from the femoral head by the “Labrum Glenoidal,” in whose substance it was also imbedded, and which it had partially divided at one point along its periphery. The bullet was removed and two small clots evacuated, no further evidence of joint damage could be detected.

The capsule was closed with a continuous lock-stitch of chromic gut. The Smith-Peterson incision was completely closed in layers, relying on the posterior wound for drainage. A hip spica was applied.

Comment.—This case illustrates joint involvement can be missed, particularly where x-rays are misinterpreted or the views are not satisfactory. The Smith-Peterson incision distinctly facilitated the location and removal of the bullet. Suppuration would very likely have developed, as one of the complications, if conservative treatment had been followed:

Case 9.—L. N. The patient was admitted at 3:20 A.M. on April 23, 1945, with a gun shot wound of the buttock. X-ray examination showed the bullet lying within the neck of femur at the level of the capsule attachment near the posterior cortex.

JOINT WOUNDS

Pathology.—The bullet entered the left lower buttock 8 cm. from the midline, and pierced the hip joint through the superior gemellus 1 cm. lateral to the rim of the glenoid. It penetrated the head of the femur through a small round hole and passed down the neck of femur just beneath the cortex.

Procedure.—Incision was the postero-lateral approach of Langenbeck. The gluteus maximus tendon was partially incised near the trochanter and the incision extended toward the postero-superior iliac spine splitting the muscle fibers. The origin of gluteus medius was slightly freed from the trochanter and the muscle retracted anteriorly. The joint capsule was exposed and opened inferior to the pyriformis muscle. It was opened with a right-angled incision. The bullet was removed by unroofing the tunnel in the head and neck of femur.

The joint was lavaged with warm saline, and closed with a continuous lockstitch of chromic gut. 10,000 units of penicillin were placed in the joint. The exploratory wound was closed in layers. The wound of entrance was debrided and left wide open. A plaster hip spica was applied.

Comment.—This posterior approach of Langenbeck gave beautiful exposure after the origin of gluteus medius was partially detached. The best exposure of the head was obtained posterior to the pyriformis, instead of anterior to it as described by Langenbeck.

SUMMARY

A penetrating wound of a joint, aside from its destructive effect on the joint mechanism, is likely to result in suppuration unless the utmost care is exerted towards its prevention. This sequence of events occurs in any joint, large or small and seems to have a direct bearing on the delicate blood supply to the cartilaginous surfaces of the joint. A wound that combines the destruction of cartilage with the introduction of foreign debris is even more likely to develop this unfortunate complication.

Suppuration involving the hip or knee-joint at times is attended with such severe sepsis that life is threatened. The same threat to life is rarely seen following suppuration of the other major joints such as the shoulder, elbow, wrist and ankle, but the same principles of prevention and treatment of these joint wounds should be followed.

Warfare presents the opportunity to see joint wounds in sufficient numbers and variety to permit an organized surgical attack on the problem, in an effort to reduce the morbidity and mortality.

<table>
<thead>
<tr>
<th>Source</th>
<th>Era</th>
<th>Cases</th>
<th>Suppuration</th>
<th>Amputation</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Army</td>
<td>1914</td>
<td>25%</td>
<td>60-80%</td>
<td>15%</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1916</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1917</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U. S. Army (Pool)</td>
<td>1918</td>
<td>8.8%</td>
<td></td>
<td>7%</td>
<td>8%</td>
</tr>
<tr>
<td>U. S. Army</td>
<td>1945</td>
<td></td>
<td>0.9%*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(two evac. hosp.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* These two cases were suppurring on arrival at the hospital. One injured 10 and the other 14 days prior to admission.
A glance at Table I reveals that in 1917 the mortality rate following knee-joint injuries had dropped to 8 per cent as reported by the British Army; while in 1918 the incidence of suppuration as reported by the U. S. Army Medical Dept. was 8.8 per cent.

Pool outlined in detail the treatment of penetrating wounds of the knee joint from his experience in World War I, and today it serves as a model. The principles of treatment which he advocated were employed by several Evacuation Hospitals in the U. S. Seventh Army during 1945. In reporting 227 penetrating knee-joint wounds, it is to be noted that only two cases developed suppuration. Although the follow-up is incomplete, none are known to have died or to have required amputation. In brief, the underlying principles of treatment are as follows: (1) Wide formal arthrotomy through the wound of entrance or exit if convenient, but the essential point is good exposure of the inside of the joint so that all devitalized bone and cartilage, debris and foreign bodies can be removed. (2) Copious irrigation of the joint with warm saline. (3) Separate debridement of the wound of entrance and exit. (4) Complete, water-tight closure of the joint capsule at all points. Where a defect of capsule exists, it must be closed by a sliding flap of skin or fascia, or even a free fascial graft if necessary. (5) The skin is left open to be closed secondarily on the 4th to 7th postoperative day. (6) If a compound fracture of the patella exists, the patella in most instances should be excised. (7) The only addition to the treatment as formerly outlined by Pool, was the local and systemic use of penicillin, and the emphasis on complete postoperative immobilization of the knee-joint by means of a hip spica instead of a high thigh cast.

<table>
<thead>
<tr>
<th>Source</th>
<th>Era</th>
<th>Number of Cases</th>
<th>Number of Cases Followed</th>
<th>Total Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Langenbeck (Franco-Prussian War)</td>
<td>1870–71</td>
<td>132</td>
<td>131</td>
<td>77.2%</td>
</tr>
<tr>
<td>Otis (Civil War)</td>
<td>1865</td>
<td>386</td>
<td>386</td>
<td>85%</td>
</tr>
<tr>
<td>British Army (World War I)</td>
<td>1914–18</td>
<td>?</td>
<td>?</td>
<td>60%</td>
</tr>
<tr>
<td>Madier (French Army)</td>
<td>1914–18</td>
<td>39</td>
<td>37</td>
<td>37%</td>
</tr>
</tbody>
</table>

A glance at Table II shows the high mortality attending hip joint wounds as seen in previous wars.

In World War II, hip-joint injuries continued to be a serious problem with appreciable numbers suppurating and developing profound sepsis. It became apparent that the surgical principles which had been applied so successfully to knee-joints were not being carried out for the hip. Its deep location made it difficult to approach, debridements were as a result usually incomplete, and inspection of the joint capsule was inevitably rare. In addition minimal injuries to the capsule; head, neck and femoral trochanter were often overlooked early after injury, because one's attention was not specifically focused on the joint itself.
In March 1945 it was suggested by the 7th Army Consultant that all suspected hip-joint wounds were to be submitted to a formal arthrotomy. The Smith-Peterson approach was to be used by preference; and where it was desirable to expose the joint posteriorly, the postero-lateral approach of Lan-genbeck was to be employed.

We encountered nine penetrating hip-joint wounds during the month of April 1945. The pathologic findings were as follows:

a. Fractures involving ilium and acetabulum .......... 2 cases
b. Fracture of the neck and greater trochanter of femur 1 case
c. The capsule penetrated and the bullet found imbedded in capsule and partly within joint, with minimal damage to the head or neck of femur ............... 3 cases
d. Bullet lying completely imbedded in the neck of femur 1 case
e. Simple contusion of the joint capsule ............. 2 cases

Six cases were American soldiers, and three were German prisoners of war. No follow-up has been obtainable on the Germans, but letters have recently been received from all the Americans. None of the six cases suppurated, none had to be amputated and there were no deaths. None have draining sinuses, the wounds being completely healed. Five out of the six complain of some pain and have some degree of limitation of motion. One of the most severe cases was personally seen and examined, he walks with a marked limp, has a moderate amount of pain and only about 25 per cent motion at the hip joint. X-ray examination shows an upward shift of acetabulum secondary to mal-union of a comminuted fracture of the ileum. There is also marked arthritic change about the joint (Fig. 1).

CONCLUSIONS

In conclusion it is thought that the complications of penetrating joint wounds will be reduced to a minimum by adhering to the following principles of treatment:

1. Operation at the earliest possible moment after injury.
2. Wide exposure of the joint, by means of a formal arthrotomy, in order that the capsule and inside of the joint can be thoroughly inspected.
3. The joint should be irrigated with saline and completely cleansed of all devitalized bone, cartilage and foreign debris.
4. The joint capsule must be closed "water-tight" at all points.
5. Complete immobilization of the joint postoperatively.
6. Penicillin locally and systemically.

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December, 1847


DISCUSSION.—Dr. Frank B. Berry, New York: Six cases is not a large series, but I think six cases of wounds such as you saw in the last patient, all of which are thoroughly healed without having undergone sepsis, are noteworthy in wounds of the pelvis and hip joint. I think this principle of debridement can be applied to civilian life. More than 20 years ago when I was a junior on the staff, I opened a knee joint for a bullet wound with compound fracture, as described by Doctor Thompson, debrided it and sewed it up tight. Twelve days later the patient had complete mobility of the joint. I was impressed with this.

Doctor Pool, who was with us, had a reprint of his father’s to guide us, and when we were confronted with these cases we early established the principle of opening and debriding all wounds of the knee joint. I talked it over with Doctors Taylor and Thompson, who are here, and with Doctor McNeil of the Sacramento Unit, and we decided that up to three days, if we were not able to do it at first, we would similarly perform formal arthrotonies in hip joint wounds, realizing that in wounds involving joints, if suppuration does not result immediately, there are certain natural defenses. Hence, during the latter part of the war we elected to try this procedure. Instead of sending patients back to face a period of sepsis, we sent them back with clean, even though damaged joints, which could be handled by the orthopedists in general hospitals, who could then proceed with these patients who were not septic.

When we were in Naples we were detached from the American Army and assigned to the French. This gave us six months to follow and study our patients as we were not obliged to evacuate our severely wounded. We were confronted with six patients with suppurating knee joints. We went around to our American friends but could not get any help on how to handle them, except to immobilize and amputate when necessary. We did have to amputate in one instance to save life. The French surgeons said, why not resect these joints? Inasmuch as the French did not supply prostheses, we were confronted with the necessity of choosing between amputees without prostheses, or joint resection and stiff leg, so we elected to resect these patients.

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