5. Leaving foreign bodies in contact with it—drainage tubes or accidentally included foreign matter.

6. The use of antiseptics.

In operations for the removal of foreign bodies included in the joint the procedure has been as follows:¹

1. The track is excised as far as the capsule with knife or scissors, only bruised or soiled tissues being cut away. The wound is then swabbed out with 5 per cent. iodine in spirit.

2. With a fresh set of instruments the joint is now opened, blood clot shelled out, and the projectile, together with bits of cloth and loose bone fragments, removed. If the projectile is far from the entry wound, it often saves injurious handling, after excising the track, to enter the joint through a fresh incision, which may later be sutured completely, being presumably clean.

3. The joint is irrigated with about two pints of 5 per cent. saline to wash out blood, cloth, and bacteria.

4. The wound in the synovial membrane is approximated with sutures. The track, if large, may be closed somewhat, the object being to leave it a funnel shape, with its apex at the wound in the synovial membrane and its widest part at the surface. It is loosely packed with gauze soaked in 5 per cent. saline.

5. 10 c.cm. ether is injected into the joint with a needle and syringe at some other part.

6. The limb is wrapped in cellulose tissue, an excellent absorbing medium, fixed in the sectional splint, and slung while the patient is still under the anaesthetic.

Afterwards, the outer cellulose dressings are changed daily and the plug moistened with saline. In four or five days it slips out easily, and may be replaced by a small wick. Fluid always fills the joint for the first few days, but does not often require aspirating.

I have always left the joint undrained as long as possible, as a drained joint nearly always means a stiff joint. Once it is certain that the resistance of the synovial membrane to infection has been overcome, I open the joint by an incision above the patella, and a lateral incision each side as far back as possible. Rubber tubes split longitudinally—not holed, for a holed tube is soon anchored down by granulation buttons and completely blocks drainage—are inserted from the upper opening to each lateral one, passing through the joint. Good drainage is now a prior consideration to avoidance of injury to the synovial membrane. A few drops of saline are run down these tubes each day, but beyond this nothing is done. The knee-joint is too complex a cavity to offer any hope that syringing or continuous irrigation will in any sense wash it through; the only effect of these measures is to set up eddies which wash infection into places which it perhaps has not yet reached, and to start tracking along muscle planes. It is safer to ensure that such flow as there is is in an outward direction; this is done by free openings and really complete immobilization.

Resistance of the Knee-joint to Gas Infection.

Two cases were remarkable in that in each instance wounds of the thigh muscles and the knee-joint, occurring in the same leg and caused by the same projectile, gave rise in the muscular tissues to a virulent gas infection and in the joint only to a serous reaction. Another case arrived twenty-four hours after being wounded with several bits of bomb in the outer side of the right lower limb. Those in the leg and thigh showed a local gas infection. One piece had penetrated the external lateral ligament and was projecting into the joint, which was tightly distended with gas. The projectile was extracted by the entry wound. On the experience of former cases, the joint was not drained, but the gas and fluid were drawn off with a trocar and cannula. A tube and funnel were then joined to the cannula, the joint repeatedly washed out with saline, and ether injected. Recovery was without incident, and on evacuation to the interior the man was walking with an almost complete range of movements, which would certainly become perfect with massage.

Results.

Clean movable joints	...	...	33
Clean joints with limited mobility	...	...	5
Stiff limbs	...	...	17
Amputations	...	...	3
Deaths	...	...	2

Three of the 60 cases belong to Class E. Their discussion does not come under joint surgery, but I have included them so as to make the series a complete one of every fresh case treated in which the knee-joint was involved. Omitting these, there are one death and two

amputations in 57 cases. The death occurred on the eighth day from an acute dysentery. The knee-joint was not only clinically clean, but *post mortem* contained only serous fluid.

Of the amputations, in one there were multiple wounds of the left lower limb. On arrival there was a cellulitis extending from the ankle to the middle of the thigh. A large bit of shell had chipped the external condyle and head of the tibia, and there was pus in the joint. Four-hourly fomentations were applied to the whole limb for a week, rendering real immobilization impossible.

In the other case I blame myself for not having discovered at an earlier date that the joint was infected. There were small wounds all over the front of the right thigh which revealed nothing to the x rays. After fifteen days I operated and found a track containing mud and gravel leading into the suprapatellar pouch, and a mild infection of the joint. His low condition made amputation advisable six weeks later.

From the point of view of the classification given above the results are:

Class A (10 cases):

Clean movable joints	...	...	...	6
Limited mobility	...	...	...	1
Stiff limbs	...	...	...	2
Amputation	...	...	...	1

Class B (19 cases):

Clean movable joints	...	...	...	15
Limited mobility	...	...	...	2
Stiff limbs	...	...	...	2

Class C (7 cases):

Clean movable joints	...	...	...	3
Stiff limbs	...	...	...	4

Class D (21 cases):

Clean movable joints	...	...	...	9
Limited mobility	...	...	...	2
Stiff limbs	...	...	...	8
Amputation	...	...	...	1
Death	...	...	...	1

Class E (3 cases):

Stiff limb	...	...	...	1
Amputation	...	...	...	1
Death	...	...	...	1

Owing to consideration of space, the summary of cases accompanying this article has been omitted. The illustrations are the work of Orderly E. D. Wookey, to whom the author wishes to express his thanks.

REFERENCE.

¹ Colonel H. M. W. Gray: 'Treatment of Gunshot Wounds of the knee-joint, BRITISH MEDICAL JOURNAL, July 10th, 1915, p. 41.

THE TREATMENT OF GUNSHOT WOUNDS OF THE KNEE-JOINT.

WITH AN ANALYSIS OF SEVENTY CASES.

BY

CAPTAIN C. MAX PAGE, M.S., F.R.C.S., R.A.M.C.(S.R.).

THE outcome of wounds of the knee-joint during the present war has, on the whole, been a source of surprise and satisfaction.

The extent of the articulation makes any general infection of it the source of profound toxæmia, and its anatomical complexity renders surgical treatment, when necessary, difficult.

For these reasons civil experience has led to a profound distrust of the ability of this particular joint to deal with infective processes. This attitude was, it appears, based on an experience of the comparatively exceptional cases in which general infection had taken place in a practically closed joint. Intensive practice under war conditions, however, has shown that when rational measures are adopted at an early period, infection of the knee and other joints can in the presence of an open wound become limited and be dealt with by the natural defences in a remarkable way.

Nevertheless, for reasons not always avoidable, general infection of the joint does occur in a certain proportion of cases—in this series, 37.7 per cent.—and the results collected for one base over five months show that we have by no means arrived at a generally satisfactory method of

treatment, for of 845 cases the amputation incidence was 19.4 per cent. and the mortality 8.5 per cent.

While views essentially common have been established on the ideal primary procedure, which aims at the relative eradication of infection, it must be admitted that as to the treatment of established infection of the joint opinions are somewhat divergent. This is not surprising when the complexity of the factors governing treatment and the difficulties of establishing the relative merit of different procedures by crucial experiments is considered. Further, in the publications on the subject there has been a lack of detailed data which would assist in the formation of a judgement. I have therefore thought it worth while to define the factors which appear to me to influence success, to tabulate a series of cases treated consecutively on consistent lines, and to analyse the results obtained.

The cases were treated at a base hospital in France, consequently the experience is limited to a definite period and no valent opinion on the end functional results can generally be formed.

The series of 70 cases was consecutive; they were treated over a period of some seven months, and only cases submitted to operation have been included. Thus all cases with clean perforating wounds remaining clean which came under observation during the period are omitted. Cases in which amputation was carried out within twenty-four hours of admission on account of gas infection or gross injury to bone, main vessels or nerves, have also been excluded (9 cases). In a fair proportion of the cases the first operation had been carried out at a casualty clearing station. When this is the case it is noted in the general table.

The following statement gives a general outline of the cases and the results of treatment:

TABLE I.

Total number of cases	...	...	70
Cases of articular bone injury	...	59	= 88.8 %
Cases in which the missile lodged	...	51	= 72.8 %
Cases recovering without obvious infection of joint	...	45	= 64.2 %
Amputations	...	10	= 14.2 %
Deaths after amputation	...	4	= 5.7 %
Total deaths	...	5	= 7.1 %

CLASSIFICATION OF CASES.

For the purpose of considering the treatment and prognosis, these cases may be divided in the first instance into two main groups, namely: Group I, Wounds caused by a rifle bullet travelling at high velocity; and Group II, Wounds caused by shell fragments and distorted bullets. All joint injuries may be further subdivided from an anatomical standpoint into two classes, namely:

Class A. Those in which the injury is purely synovial.

Class B. Those in which articular bone injury is also present; it is convenient to classify three types of such injury, namely:

1. Gross comminution of an epiphysis or the patella.
2. Fissuring of an articular bone—local or extending from the diaphysis.
3. "Punch" fractures in the cancellous bone of the diaphysis.

Clinically, in the later stages the number of classifications is duplicated by considering as separate types those cases in which general arthritis does or does not develop. Further subdivisions in accordance with the degree or nature of the infection, the retention or not of the missile, seem at present unnecessary complications.

THEORETICAL BASIS OF TREATMENT.

In the stage under consideration here infection of the joint is the principal danger, and the orthopaedic results, important as they are, must be regarded as a secondary consideration.

Though cases occur (eight instances in this series) in which a small missile remains in or about a joint without inducing general arthritis, from general experience it will be granted that all wounds in which a missile of any size lodges are in some degree infected. Infection is also usually present in cases of perforation by shell fragments. It is of interest to note that in nineteen of twenty-five cases of general suppurative arthritis in this series the missile was retained; in four of the remaining cases the wound was caused by shell fragments. Only in typical rifle bullet wounds does experience justify the assumption that,

on the average, whatever the anatomical injury no serious infection of the wound track has been effected. In practice the conservative treatment by fixation and simple dressing of these latter cases (Group I) leads on the whole to good results. This is not to deny that if a radical operation had been performed the result might have been equally successful, but practical considerations make exclusion of the necessity for operation desirable.

In Group II suppression of the primary infection is sometimes effected by the natural mechanisms of defence, but more commonly local infection, and often general infection of the joint cavity ensue. In the cases of local infection the synovia behaves much like the peritoneum—for example, a track freely open into the joint may often be grossly infected and yet the outlying parts of the joint and the effusion are sterile, the joint cavity being filled with a clot ("lymph") containing cells having a defensive function (some interesting observations on the prognostic value of a differential examination of these exudates have been published by Captain Barlow¹); in such cases, if the reaction of the tissues around the wound has not been unduly prejudiced by the initial injury and the infection is not of unusual virulence, recovery may be completed without general suppurative arthritis, intra-articular adhesions being formed.

However, experience has shown that if, as a routine, expectant treatment be adopted in these cases, a general arthritis, calling perhaps for amputation, too frequently follows. We are therefore forced to attempt, at a period before extension of infection has taken place, to remove in as complete a way as possible the primary infective focus and any surrounding devitalized tissues. In practice this involves excision or erosion of the wound track and the removal of any missile which may have lodged; if the bone injury is such that subsequent ankylosis of the joint is assured, a primary excision is justified.

To judge by the results in this series an operation based on these lines can be performed with success up to two or even more days after the injury, but there can be little room for doubt that the failures would be reduced if such operations were thoroughly carried out within twenty-four hours following injury, and never later.

In view of the impossibility of deciding the degree of infection present by clinical examination at the stage under consideration, I think that all cases coming under Group II should be treated, as above suggested, by a primary radical operation.

As a further means of combating infection, repeated evacuation of the joint and its injection with various antiseptics has been widely advocated; aspiration is useful at certain stages for the purposes of bacteriological investigation or for the relief of exceptional intra-articular tension, but the removal of the defensive exudate as a routine and at regular intervals seems as unreasonable as to rub away the lymph and wash out the serous exudate in an early case of peritonitis—a procedure now generally recognized as harmful. The injection of any of the antiseptics in common use into the joint cavity seems to be an equally illogical procedure, calculated to do more harm than good to the natural defensive mechanism. In this series aspiration has only been used for exploratory purposes, and in no case has any form of antiseptic been injected into the uninjured part of the joint cavity.

Thorough fixation of the injured joint in the critical period during which infection may spread is, I think, of great importance. There is no evidence which justifies us in casting on one side a procedure aiming at the provision of complete rest for the injured part, in view of its success in kindred conditions.

Established Infection of the Joint.

In established infection of the joint, especially when due to the streptococcus, the results of treatment are often disappointing. When the complication of severe bone injury is present, immediate amputation is often the only course if life is to be saved. The majority of cases offer, however, ground for more conservative measures, and many different procedures have been advocated. Tube drainage of the joint on classical lines has not proved a success; the same may be said of methods of continuous drainage; of the Carrel treatment I have not sufficient experience to be able to form an opinion.

The exposure of the whole joint surface by means of a transverse section and fixation in full flexion still has its

advocates. Four cases in this series were so treated, with poor results. It appears that the gross disturbance of the natural relationships involved prejudices the defence in really severe cases; when the method is successful one cannot help thinking that the infection would have been equally well dealt with if less drastic measures had been adopted. Colonel Fullerton, A.M.S.,² has lately suggested formal excision of the joint at this stage. The results he quotes do not, however, afford conclusive evidence of the value of the method; in accordance with general surgical principles an operation involving such an extensive exposure of new surfaces in the presence of progressive infection seems unsound. In this series no cases were treated by the method, as it had given poor results in my hands in earlier experience. I have recently had the opportunity of seeing the end results of some cases so treated, and from an orthopaedic standpoint they left much to be desired. It should be remembered that a fair proportion of cases of severe general infection of the joint treated on conservative lines recover a useful range of movement, and anything like a routine employment of excision in the treatment of arthritis is to be deplored.

Recovery in these cases is essentially due to the activity of the natural mechanism of defence, and it is the business of the surgeon to assist these mechanisms and not to lay further burdens on them. Complete fixation is the first and essential step in this direction; in my experience this can best be effected by the use of plaster-of-Paris. In the early stages the application of heat to the joint area is a sound measure; it may abort suppuration and in some cases assists the defence. Operative measures should, I think, be limited to those imposed by the direct indications of the accumulation of fluid under tension. If a bacteriological examination of the joint exudate (not of the wound discharge) shows the presence of streptococci, early incision is indicated, as this infection spreads rapidly beyond the confines of the joint capsule into the cellular planes, leading to intense toxemia. After lateral arthrotomy a watchful attitude is maintained, the commonly occurring popliteal abscess and any other residual formations being dealt with as they are diagnosed. Further to assist the defence in these conditions, artificial immunization may be employed. This procedure was carried out in some cases in this series. It is always a difficult matter to appraise the value of such methods, but my impression is that they have often been the factor determining the success of conservative measures; in no case have they been harmful in their action. Captain W. E. M. Armstrong, R.A.M.C., was responsible for this form of treatment, and I append a note he has given me on the subject of immunization in septic wounds in general.

Note on Immunization Procedures Applicable to Septic Wounds.

The difficulties connected with the immunization of wounded patients are: The number of different organisms present, the difficulty of working in harmony with the surgeon, and the often very exhausted state of the patient.

Practically I have tried to meet these difficulties in the following manner:

1. The organisms present in wounds are usually streptococcus, staphylococcus, and members of the coliform group. The coliforms may perhaps be regarded as comparatively harmless, while the staphylococcus usually tends to localize and so is amenable to surgical methods of extirpation. The streptococcus is, however, very different, and as regards radical extirpation may be almost as troublesome as the tubercle bacillus itself. My efforts have, therefore, been almost entirely directed against the streptococcus.

2. The difficulty of working in harmony with the surgeon is very great. His proceedings in the dressing of wounds and removing foreign and dead material result in the patient receiving a series of autoinoculations which, being unstandardized and ill-timed, play havoc with an immunity mechanism which is already in a very hypersensitive state. On the other hand, the surgeon can be most helpful by his devices for immobilizing the affected parts. That this is one of the best methods of immunizing a patient has been abundantly shown by the excellent results obtained by the use of plaster-of-Paris. In fact, careful immobilization is often all that is required, and

inoculation methods have only been used when the fixation method fails, or is too slow in its results to save the patient.

3. The third difficulty is, I believe, a very real one. Many of the patients are so exhausted as to be incapable of that vital response which is necessary for effective vaccine treatment. I have tried to grapple with this difficulty by using passive methods of immunization. Actual treatment has been carried out by means of vaccines and Spengler's immune-body solutions. I seldom make autogenous vaccines. There is usually no time to do this, and even if there were, I prefer in a dangerous case to use a vaccine whose potency I know to one whose power can only be determined by trial trips on a patient who is too ill to be experimented upon. I use St. Mary's Hospital streptococcus vaccine, and I follow fairly closely the teaching of Wright. I have never produced in any patient a negative phase clinically recognizable, and I never give a second dose until I am quite sure that the first has exhausted its utility.

I have often obtained rather striking results, both general and specific, with Spengler's solutions. They can if necessary be used concurrently with vaccines.

The results obtained have already been stated by Captain Page. As implied above, I have only treated cases in which enlightened surgical methods have either failed or threatened to fail. Since crucial experiments are well-nigh impossible, one cannot speak in terms of absolute certainty. Nevertheless, I have little doubt that a few lives have been saved and a few limbs preserved by making use of knowledge of immunity phenomena to tip the balance in the patient's favour.

PRACTICAL PROCEDURE ADOPTED.

Prophylactic.

By prophylactic treatment is meant treatment before general infection of the joint has taken place, and ideally within twenty-four hours of the infliction of the injury.

In the case of injuries coming under Group I (typical rifle bullet perforations), no operation is undertaken. The joint is fixed on a back splint, or in plaster in a position of slight flexion at the knee and with the foot lying comfortably. The wounds are not excised, and are covered by a simple dressing. The fifteen cases so treated during the period of these observations have not been included in the tabulated cases with the exception of two, the only instances of this group in which general infection of the joint ensued. When painful intra-articular tension is present, the joint is aspirated once and evacuated as completely as possible. In such cases the primary exudate contains much blood; secondary serous exudates are not removed.

All cases in Group II (injury by irregular missiles) which came under observation within two, or sometimes more, days of the injury are submitted to operation with a view to removal of the infected and damaged area. An x-ray examination in two planes is made whenever possible; it often reveals unsuspected bone injury, and is a sufficient guide to assist in the removal of any foreign body which has lodged.

In cases of Class A (simple synovial injury) of Group II the wound track is completely excised without the removal of much skin, and any retained foreign body is removed. No attempt is made to suture the synovial membrane, but the skin edges are opposed if this can be effected without causing undue tension; when it is not possible the wound is lightly packed with sterile gauze. Any effusion into the joint cavity is usually evacuated during the course of the operation, but no deliberate attempt is made to do this unless the effusion consists mainly of blood.

In cases of Class B (articular bone injury present) of Group II the operative procedure is essentially the same, though the removal of bone in the wound track may present technical difficulties.

1. When gross comminution of the epiphyses is present, and subsequent ankylosis is assured, primary excision of the joint may be the most effectual procedure. Such an operation should only be undertaken within the first two days of injury. Leriche³ presents a strong case for the adoption of this method within the first twenty-four hours. In this series no case was considered to have come under observation early enough to justify the procedure, though excision of the patella was carried out in three cases.

2. When fissuring of the bone is in evidence, any completely detached fragment is removed and all bruised cancellous bone in the wound track is curetted away till a bleeding surface is met with. The bone wound is then packed if it continues to ooze as described below.

3. In the case of "punch" wounds of the cancellous tissue, removal of the whole wound tract can be satisfactorily effected with the curette and gouge. The foreign body is usually retained in these cases, and is dislodged from the end of the wound track. If bleeding from the cancellous bone persists, as it commonly does, after the completion of the bone operation, the bone cavity is firmly packed with dry ribbon gauze, a single wick being brought out along the wound track, and the skin wound closed on either side without tension. Gauze packs of this kind and those applied to more superficial gashes are left untouched for four or five days and then removed. They are sometimes lightly renewed for another day or so, but more often a simple surface dressing is alone applied at this period.

Fixation.

In all cases the joint is kept at rest till healing is in progress and pyrexia has been absent for about a week; gentle active movement is then encouraged. If plaster fixation has been used sufficient play will have developed in ten or fourteen days to admit of this, the splint being kept on altogether for about three weeks. The Thomas's knee splint, though convenient for wound treatment when large wounds in the thigh are present, does not fix the joint satisfactorily, nor is it easy to put the knee up in a position of flexion in this apparatus. A simple back splint is often convenient, but in difficult cases it is not sufficiently controllable, nor does it admit access to the area at

FIG. 1.—Interrupted plaster-of-Paris knee splint. The aluminium (or malleable iron) brackets which form the two lateral interruptions are joined together above by an arch passing in front of the thigh. The support of the back of the joint by fabric slings is also shown.

the back of the joint. An interrupted plaster-of-Paris splint (Fig. 1), in my experience, affords the only satisfactory method of controlling cases of excision, or those in which there is serious injury of the articular surfaces. The two sections are formed by plaster bandages. The upper section should extend to the level of the tuber ischii above, and the lower should include the foot in a comfortable position. The interruptions are formed by two laterally placed aluminium or malleable iron arches. In accordance with the position of the wounds a plaster back or sidepiece can be added. When such cannot be applied, as is common in cases of general infection of the joint, posterior support at the knee-joint level is given by two or three slings passing from arch to arch in the same fashion as in a Thomas's splint. Whatever form of fixation is used the limb can be rested on a pillow, though more freedom is given the patient if it is suspended, and this was usually done in this series.

General Suppurative Arthritis.

In the early stage of some cases the joint is hot and swollen without severe constitutional symptoms. In these circumstances, supposing the primary wound treatment to have been properly carried out, any sutures are removed, rigid fixation is maintained, and hot fomentations are regularly applied to the joint area. Not infrequently the condition will settle under this treatment without suppura-

tion. As soon, however, as a diagnosis of a more severe infection is made from the classical clinical signs or by bacteriological examination, arthrotomy is performed; in general, two vertical parallel lateral incisions are made into the most lateral parts of the subcrural pouch; posterior drainage is not attempted. If there is tension about the wound it is enlarged, or sometimes run into one of the lateral incisions. Any loose bone not already removed is taken away but no fresh section of bone is made, nor is excision of the primary wound or of the whole joint practised at this stage for reasons set forth above. At the completion of the operation the arthrotomy incisions are packed with sterile gauze down to, but not materially penetrating into, the joint cavity. These packs are left in for two to three days, or till such time as suppuration renders their removal easy; they are then lightly renewed till the infection is under control. Of secondary abscesses, one in the popliteal space tracking out from the popliteus bursa is most commonly seen. Any such secondary formation is allowed to develop definitely, and is then incised, evacuated, and packed with gauze for a few days. Carrel's method of wound treatment has been adopted in one or two cases only, and so no judgement can be formed, though it would appear that its value is based rather on the primary surgical technique employed than on the later.

Immunization is carried out in the most severe cases in accordance with the methods referred to above by Captain W. E. M. Armstrong.

Amputation may be called for at different stages on account of the rapid advance of the toxæmic symptoms. A circular supracondylar amputation is then aimed at, and is usually possible, unless there is serious extension of cellulitis into the thigh. All viable skin is conserved and the stump cavity is packed at the completion of the operation with plain gauze, which is left in place for four or five days.

ANALYSIS OF RESULTS IN SEVENTY CASES.

For the purposes of this series a successful result is considered to have been obtained when complete control of any infection present, as judged by the healthy condition of the wound and the entire absence of pyrexia, has been obtained. In only a minority of the cases was entire healing of the wound and complete recovery of function in the joint observed.

GROUP I.—Rifle Bullet Perforations.

As stated above, only two cases (34 and 49) of this kind are included in the series:

Case 34.—Comminution of the patella and fissuring of both tibia and femur. Patient developed signs of general streptococcal infection of the joint on the seventh day. The patella was excised. Recovery followed after three secondary incisions for residual abscesses.

Case 49.—Gross comminution of the internal condyle of the femur; entry at level of the joint line; explosive exit 3 in. higher up. Incision and removal of broken bone on fourth day; amputation on fifteenth for progressive toxæmia. Recovery.

GROUP II.—Shell Wounds.

Class A, *Synovial Injury only (11 Cases).*—All but one recovered without general infection of the joint. This case (No. 40) had a single gaping wound, 3 in. by 2 in., in the antero-external aspect of the joint. Death took place on the forty-fifth day from tetanus, four days after amputation had been carried out.

Class B, *Complicated by Bone Injury.*—The following table gives the general results of these cases, 160 in number, in relation to the three types of bone injury recognized.

TABLE II.

Type of Bone Injury.	No. of Cases.	Recovery without Infection.	Recovery after General Infection.	Recovery after Amputation.	Deaths.
1. Gross comminution of the diaphysis or patella	17	4	7	3	3
2. Fissuring of the articular bone	14	10	1	1	2
3. "Punch" wounds or grooves of surface	28	22	4	2	0

Nine cases of this nature were submitted to amputation on admission—that is, in general two to four days after injury, and are not included in the series.

The notable feature of these results is the unsatisfactory course of the cases in which there was gross comminution of the epiphysis. In no case of this type had a formal excision of the joint been carried out within a day or two of the injury, and as the results from the point of view of infection could hardly be worse, and as from an orthopaedic standpoint subsequent fixation of the joint was a necessary sequence whatever the treatment adopted, primary joint excision or erosion might be carried out with greater hopes of success.

The smaller number of cases of Type 2 gave better results though by no means ideal ones.

In case of injuries of Type 3 the recovery incidence was not unsatisfactory, and there are certain points in relation to the six failures which it is of interest to tabulate, as they emphasize the importance of the time factor in these cases.

TABLE III.

Case No.	Nature of Injury.	Days elapsing between Injury and Primary Radical Operation.
1	Foreign body lodged in internal condyle	Five.
34	Groove in external condyle of femur; foreign body retained	Three.
53	Tunnel in tibia; foreign body retained; left side. Other knee also infected	Four.
54	Entry wound in popliteal space; vessels and nerves exposed in wound. Foreign body retained at back of joint denting the bone	One.
38	Three foreign bodies in joint. Tibia and fibula grooved in front of their articulation	Three foreign body left inside); Five (completed).
51	Foreign body retained in external tuberosity of tibia	Four.

It will be seen that in only one of these failures was a primary operation carried out at an earlier period than three days after injury. In that case (No. 54) a radical operation was impossible, owing to the anatomical relations of the wound.

General Infection of the Joint (25 Cases).

The treatment of these was carried out on the lines laid down above except in four instances in which the joint cavity was exposed by a transverse incision and the knee fixed in a position of flexion. One case only recovered with conservation of the limb, two after amputation (in one case necessary after a secondary operation on the forty-third day to reduce the displacement), and one died.

TABLE IV.—General Outcome of Injuries of this Class.

Total number of cases of general arthritis	25
Missile retained	18
Synovial injury only	1
Bone injury:	
Type 1	13
Type 2	4
Type 3	6
Recovered after arthrotomy	13
Recovered after amputation	6
Died	6

The differential results in relation to the three classified types of bone injury are given in Table II, the outstanding fact being the frequency of general joint infection in the presence of gross comminution of the diaphyses or patella. The one case in which the primary injury was limited to the synovia was No. 40, and has already been described under Group II, A. There were three cases (2, 48 and 50), in which, after an operation had been performed at a casualty clearing station on the day of injury, the wound had been completely sewn up. Case 2 recovered; case 48 died, and case 50 recovered after amputation.

These results emphasize the importance of considering the early treatment of those cases in which severe comminution of bone is present. As stated above, it would seem that an excision of the joint undertaken within twenty-four hours of injury would be the method offering the greatest hope of success.

The results of the examples of primary excision of the wound and resuture in the presence of bone injury, without drainage of any kind, especially as the exact

nature of the primary operation is unknown, are too few to dogmatize upon; but I think some drain should be left in these cases for a few days, so that any infection left after the operation may have a better chance of remaining localized.

Amputations.

Amputation was carried out in ten cases, four of which subsequently died. It is generally a difficult matter, in dealing with these injuries, to determine the time at which conservative measures should be cast on one side and the member removed. In the presence of infection, in addition to gross bone injury or serious lesions of the soft parts, the problem is fairly simple. In other instances the degree and progression of toxæmia are usually the determinant factors. That satisfactory results are usually obtained when little or no bone injury is present is shown by the following table:

TABLE V.—Number of Cases of Each Kind of Primary Articular Injury Ultimately Needing Amputation.

Group II.	Nature of Injury.	Amputation.	Deaths after Amputation.
Class A ...	No bony injury present	1	1
Class B ...	Gross comminution of epiphyses	6	3
Class B 2 ...	Fissure of diaphysis	1	0
Class B 3 ...	"Punch" wounds and grooves of cancellous bone	2	0

The actual conditions for which amputation was performed in this series were:

Septicaemia	8
Secondary haemorrhage	1
Gangrene after ligation of the popliteal artery	1

The septicaemia or toxæmia was in all cases of streptococcal origin; the micro organism was only isolated from the blood in four instances. The cases so treated were Nos. 25 (5), 27 (5), 29 (10), 38 (53), 40 (40), 48 (24), 49 (15), 50 (16), 51 (29), and 56 (60); the figure in brackets after each case number gives the period in days after the injury at which amputation was carried out.

Death took place in cases 25, 29, 40, and 48, and was due to septicaemia in two instances, secondary haemorrhage in one, and tetanus in one.

Deaths.

The fatal cases were six in number—namely, cases 24 (22), 25 (6), 29 (18), 40 (45), 47 (7), and 48 (28); the figures in brackets give the number of days elapsing between the primary injury and death.

Severe bone injury (Type 1) was present in	3
Fissuring of the bone (Type 2)	2
A large exposure of the synovia, with bone injury	1

Four of these cases were submitted to amputation before death. Case 24 had previously had the other leg cut off for haemorrhage and fracture and died a few hours after a secondary haemorrhage from the popliteal artery on the side of the knee injury. In Case 47 the joint had been laid open and the knee put up flexed, and when the measure adopted failed to check the advance of toxæmia, the patient was not in a position to stand further operation.

SUMMARY AND CONCLUSIONS.

In dealing with wounds of the knee-joint the natural defensive powers of the part against infection should be borne in mind. To obtain fair play for the defence should be the aim of surgical procedures adopted. Primary prophylactic (that is, within twenty-four hours of injury) operations should be radical, and secondary operations undertaken on account of progressing infection, should, short of amputation, be planned on conservative lines.

The expectant treatment of wounds of the knee-joint is only justifiable in the case of typical perforating injuries due to a rifle bullet.

All wounds of the joint caused by shell fragments or distorted bullets should be considered as primarily infected.

The primary prophylactic treatment should consist in the removal of any foreign bodies present and in the excision of the whole wound track at the earliest possible

time after injury. Any delay beyond twenty-four hours will entail failure in a certain proportion of the cases.

The results at present are particularly bad in cases in which gross comminution of the diaphyses is present. A primary excision or erosion of the joint (within twenty-four hours) would probably improve the results in such instances by preventing the development of entomyelitis.

Repeated aspiration of the joint and the intra-articular injection of any of the antiseptics in common use are calculated to prejudice the natural defence.

It is safest to leave some drainage along the wound track after operation for a few days, certainly when bone injury is present. Any infection then left may become localized in the same way as occurs in the case of the peritoneum. A gauze wick makes a satisfactory form of drain.

Immobilization of the joint during all critical periods is essential. An interrupted plaster-of-Paris splint affords the best means of effecting this.

When general infection of the joint has taken place treatment by fixation, lateral arthrotomy, and immunization gives the best chance of saving the limb. Secondary abscesses are to be expected, and should be evacuated after their complete development. Neither cross section and flexion of the joint nor secondary excision of the knee are sound procedures.

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ON THE TREATMENT OF CERTAIN SELECTED CASES OF SEPTIC ARTHRITIS OF THE KNEE.

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THE septic knee-joint still presents one of the most difficult problems in surgery. Opinion has not crystallized as to the proper line of treatment. (1) Early "prophylactic" excision, and (2) amputation, have been strongly advocated, but in view of clinical experience the first method is not justifiable, whilst the second is a frank admission of failure to deal with the condition. It is not justifiable to do an early excision within twenty-four to forty-eight hours after the injury as a routine method of treatment, since experience at the base definitely shows that a certain proportion of cases recover after a localized suppuration within the joint, and even after a generalized infection with pus-formation.

Rest, fixation, lavage, antiseptic injections, serums, etc., all have their functions and scope within the first week or ten days after injury, and if they fail, then further treatment is required.

As regards amputation, it is admitted that in some very acute infections early amputation is the only hope of saving life. If a conservative line of treatment be pursued, and the joint kept rigidly fixed whilst local incisions, irrigations, etc., are used, then the best one can expect as to an end result, after many weeks or months, is a fibro-osseous union where one has no control over the amount of bone and fibrous tissue. All this time absorption is going on, the cartilages are eroding, the ligaments are being broken down, and the patient is at any moment liable to septic venous thrombosis with embolism, and few will escape without periarticular thigh and calf abscesses.

These complications are the inevitable result of lack of drainage in the presence of pyogenic organisms, and it is clear the whole problem of getting a case free from these complications is one of drainage. If one starts, then, from this basis, that the best one can offer such a case after a dangerous illness is a fibro-osseous union between the eroded bone ends and that the joint is almost inevitably lost, then the problem becomes simpler.

Delay in amputating, septic absorption, multiple septic emboli, were responsible for so many deaths in the early part of the war that it had become a working rule with many surgeons that the safest, quickest, cleanest method of dealing with a limb where the posterior pouches of the knee-joint are involved is amputation; thus life is saved at the expense of a limb with least bother to all concerned. Probably it is true this working rule holds good for the majority of cases, but, however perfect artificial limbs may be, and however cleverly used, it is difficult to believe that a stiff rigid leg, even a few inches short, where the hip and ankle-joints are normal is not infinitely superior and preferable to them; and though the cases are long and tedious and trying, yet the end result is worth having if the patient is satisfied and has a good useful limb in a few years. The problem, then, is: (1) To select suitable cases. (2) To drain completely at the earliest moment after one is satisfied that the joint is lost. (3) To get the sepsis overcome. (4) To get firm union of broad bony surfaces. It resolves itself, therefore, into doing an excision of the knee-joint in two stages in suitable cases.

The Suitable Case.

1. The patient must be young; certainly under 30 years, probably best not more than 25 years of age.
2. The favourable cases are lightly built men with small bones and without great muscular development. Fat and flabby cases are unsuitable.
3. The past history as regards general health must be good.
4. Courage and cheerfulness and a strong desire to keep the limb are most important factors. Querulousness and want of interest as to whether the leg stays on or not are contraindications.

The Local Damage must be Within Limits.

1. If the infection be an extremely virulent one then even immediate amputation may fail to save life, and no temporizing dare to be tried in this type of case.
2. If the bony damage is great, if the head of the tibia especially be shattered, then probably amputation is the best line of treatment. Further contraindications are (a) doubt as to the condition of the main nerves to the leg (the ankle action must be perfect to commence with, and be kept good all through the illness); (b) the presence of other serious gunshot wounds.

Taking these points into consideration, and offering unsuitable cases an early amputation as the best and surest treatment for their condition, there still remain many cases, boys with trivial injuries, where amputation seems a catastrophe, and for those cases one must try and get a better result.

It can be done. Time alone can settle whether it is worth doing, whether the end result is a comfortable limb or not. Certain it is that the patient is satisfied with the early result, and this more than anything else impels me to record experience and treatment of these cases.

The Joint is Lost.

1. From the clinical symptoms, the temperature, the pulse-rate, the nature of the discharge, and the general condition afford indications. Tenderness and oedema are sufficient guides; there is no need for definite periarticular abscess formation to prove that the joint is lost, and delay may mean danger of septicaemia and pyaemia, even after the joint has been laid open.

2. A pathological report on an examination of fluid withdrawn from the joint is a most valuable aid, but inasmuch as there is a percentage of cases which recover, even after the pathologist gives a grave prognosis, the clinical symptoms must remain the chief guide. The greatest value is as a stimulus against too great delay in operating in those cases in which the clinical symptoms lack definition and make one hesitate.

Procedure when Drainage is Necessary.

The septic knee-joint cannot be drained. When one considers the pouches, the ligaments, the spaces beneath the cartilages, this is obvious; therefore complete exposure of the surfaces which constitutes the joint must be obtained, and all abscesses which have resulted from leakage through synovial pouches must be freely opened.

This can be done by means of a Ω -shaped incision carried through the quadriceps tendon, by removal of the