secretion has been advocated to accelerate the process of bone repair. Thymic and pancreatic extracts have had very strong advocates, but there is nothing that I have found in the literature on the subject, or have discovered by personal test, that indicates any constant action with such glandular extracts. On the other hand, people who have definite glandular irregularities, such as parathyroid or thyroid deficiencies, may have union retarded thereby, and it is obvious that a restoration of the normal glandular balance will be of benefit in such cases. This is most commonly seen in diabetics, where the giving of insulin makes the healing of bone take place in the normal time. Certain systemic diseases affect the rate of healing of fractures, such as syphilis, scurvy, and active rickets. Union takes place when adequate treatment has been given for these conditions.

Pathological Bone.—Fractures through pathological bone usually do not heal in a normal manner. The explanation is probably that the action of the haematoma cavity walls is interfered with—for example, if the fracture is through a secondary cancerous deposit the great mass of the potential cavity wall is formed by cancerous tissue, which will grow itself instead of forming potential bone. On the other hand, fractures through bone cysts, or even giant-cell tumours, sometimes heal up rapidly and completely with bone, but in such cases we are dealing with cavity walls formed by mesoblastic tissue. Fractures of bones affected by osteitis fibrosa cystica are slow in healing because of the poverty of mineral content of the bones, and in Paget's disease fractures are slow in uniting owing to the lack of mesoblastic tissue in the bone.

Compound Condition of Fracture.—In these the working of the chemical factory is upset because a wall is missing and fluid escapes. The success of the Winnett-Orr method is probably due to the fact that the petroleum jelly pack provides the missing wall of the chemical factory. When the artificial wall is supplied healing takes place behind it on the lines described above.

Injudicious Operations, Metal Plates, etc.—Since an operation on a closed fracture converts it into an open one, all operations must be considered injudicious, unless there is a very compelling indication for their performance. It would seem advisable to delay operation until part of the processes enumerated at the beginning of this paper have taken place. Radiographically, and clinically, the introduction of metal is shown to interfere, in part at least, with bone union. *In vitro* experiments indicate that the chemical changes enumerated as taking place in the artificial haematoma are delayed if metal is introduced with the blood, muscle, etc., in the incubator. The haematoma does not become so acid; the calcium is not absorbed, etc. C. P. Stewart has suggested that part of this retardation may be due to interference with enzymic action. Stainless steel does not have the disadvantage of other metals in the *in vitro* experiments for at least nineteen days; but after that time if it is introduced into a new artificial fracture it will produce the retarding effects of other metals. Stainless steel pins for femoral neck pegging should therefore not be used a second time without repolishing.

Sepsis.—While infections of fractures most commonly occur in the compound variety, they sometimes arise in closed fractures by way of an infected blood stream. Delayed union, if not non-union, usually results.

The statements I have made refer only to fractures of the long bones and not to fractures in certain situations, which present particular problems. Also, I would like to emphasize that, while the causes of non-union may

be manifold, the vast majority are due to imperfect anatomical reduction and to lack of adequate immobilization.

Summary

The normal healing process of a fracture is considered from different points of view—radiographically, histologically, and chemically—and relevant *in vitro* experimental findings are stated.

Causes of non-union are taken to be failure of the normal process, and are examined under various headings.

TREATMENT OF UNUNITED FRACTURES*

BY

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Although the treatment of ununited fractures follows definitely established lines, one cannot entirely dissociate this from the cause. For instance, if a patient has delayed union or non-union of a fracture, and the Wassermann reaction is positive, an essential preliminary is to prescribe a full course of antisyphilitic treatment. Unless this is done the delayed union may pass to the stage of non-union, and the results of the surgical treatment of this are definitely more uncertain when the constitutional condition has not been recognized and treated. Again, in fractures where local sepsis has been present the surgeon should inquire as to the nature of this. It is important to know whether the wound healed with or without severe constitutional symptoms and whether there have been "flares" or recurrence of infection since the primary healing of the wound. After the war my colleague, Mr. A. M. Hendry, reported four cases of delayed gas gangrene. The wounds had been healed for several years, and there was no clinical evidence that these organisms were present in the tissues when subsequent operation on bone was performed. In view of these possibilities I regard it as important that the nature of the original infection should be ascertained, so that the patient may be immunized by sera or vaccine previous to any operative procedure. Even in mild cases it is wise to wait six months after healing of the wound before operating, and in all cases it is safer to excise all scar tissue and remove any foreign body which may be present—before operation to restore continuity of the bone is undertaken.

Another consideration that will influence us in the treatment of non-union is the condition of the limb. Every effort should be made to restore the tone of the muscles and other tissues by massage, physiotherapy, active exercise, etc., as the prognosis, I am sure, is influenced by this.

The next question which arises is the treatment of non-union in cases that are complicated by a lesion of one of the main nerves. This is a problem that was common in war surgery but seldom presents itself to-day. Our experience has been that in cases in which there is a loss of one or more inches of nerve, suture of the nerve should have priority to operation on bone, for two reasons. First, because recovery after nerve suture takes longer than bone union, and, secondly, because the presence of non-union may allow end-to-end suture of the nerve, which may not be possible after continuity of the bone is established.

* Read in opening a discussion in the Section of Orthopaedics and Fractures at the Annual Meeting of the British Medical Association, Aberdeen, 1939.

Method of Treatment

Anyone who reads the literature will be as familiar as I am with the many methods that have been advocated in the treatment of non-union of fractures. From personal experience I am not in a position to assess their relative values; I therefore propose to confine myself to a survey of my own outlook and methods of dealing with this condition. Feeling very sure, however, that active surgical intervention with introduction of foreign material in the treatment of simple fractures has been responsible for many cases of non-union, I must first condemn that method as unwise for the treatment of the established condition. The records of Guy's Hospital show clearly that the method of plating of fractures has lost favour in the home of its birth, and all who work in orthopaedic hospitals see the tragedies to which it not infrequently leads.

As regards the treatment of non-union, the first question that arises is whether union of the fracture will increase the usefulness of the limb, and, secondly, whether surgical intervention is justifiable. We learned during the war that where there was non-union of the lower third of the ulna and ankylosis of the inferior radio-ulnar joint, re-establishment of union of the ulna was a disadvantage to the patient. While the ulna was ununited the movements of pronation and supination took place at this false joint, but unless the inferior radio-ulnar joint was free these movements were lost when continuity of the bone was established. This probably led Baldwin of San Francisco to advocate the operation of production of a false joint in the lower third of the ulna in cases in which destruction of the inferior radio-ulnar joint interfered with pronation and supination. This operation is still recognized as a valuable contribution to orthopaedic surgery.

The question whether operation is justifiable in old-standing cases of non-union is always difficult. I have radiographs and photographs of a postman who was conscripted and was admitted to a military hospital in 1918 with an ununited fracture of the tibia and fibula of eighteen years' duration. He had a fibrous union with practically rectangular posterior displacement of the lower fragments, but walked with a suitable boot without pain. No surgical treatment was advised.

We see many other cases in which operation to reunite the fracture would not be the operation of choice. Let me refer to some of these:

1. *The Old Lady with the Ununited Fracture of the Neck of the Femur.*—If her complaint is difficulty in walking, an osteotomy of the McMurray type would probably be the operation chosen. If it is pain due to an arthritis of the hip or false joint, the question of excision of the head would be considered.

2. *Fracture of the Scaphoid with Some Limitation of Dorsiflexion and Secondary Radio-carpal Arthritis.*—If pain is the predominant symptom, excision of the scaphoid might be the operation of choice, but if limitation of movement is the complaint operation would not be advised.

3. *Ununited Fracture of the External Condyle of the Humerus.*—Owing to the displacement of the fragment following this fracture, non-union is common. The fracture, usually occurring in children, is often associated with increasing cubitus valgus. Movements of the elbow remain free, but in later life the patient may come complaining of an ulnar neuritis. In these cases the non-union of the fracture should be ignored. If deformity is the complaint it can be corrected by an osteotomy of the lower end of the humerus, which might also cure the ulnar neuritis; but if pain is the chief complaint, the operation would be transposition of the ulnar nerve to the front of the elbow.

Cases of Non-union requiring Operation

In some cases removal of the fragments will give the best functional result. I am satisfied that in old-standing cases of non-union of the patella and olecranon removal of bone and re-establishment of continuity of the extensor apparatus is the most satisfactory method of relieving pain and improving function. In cases of pain associated with non-union of the internal malleolus, removal of the fragment is preferable to operation to re-establish union.

Ununited Fracture of the Long Bones

Having dealt with cases of non-union of the long bones in which restoration of continuity was not desirable, and having admitted that I am not familiar with many of the methods advised for the treatment of this condition, I propose to confine myself to the surgical methods which I personally adopt to promote union in these cases. The war taught me that a gap in continuity of bone could only be bridged successfully by means of an autogenous bone graft. We learned that the method established by

Diagram illustrating subcortical exposure of the site of fracture.

Albee of utilizing a graft consisting of periosteum, cortex, and endosteum, and inserting this into a gutter prepared for it in the correctly aligned receiving bone, would, if given adequate contact and post-operative fixation, result in re-establishment of continuity. I believe that this is true to-day, and where a gap in the bone has to be bridged I regard an autogenous bone graft as essential. I have, however, learned that, in cases in which there is non-union without loss of bone, the bone graft is not necessary to obtain union. This observation is based on experience of the treatment of flail joints during the war. Restoration of stability in the flail shoulder and the flail elbow, where there was much loss of bone, presented a

new problem. In opening a discussion on this subject at a meeting of the British Orthopaedic Association in 1919 I advised that the ends of the bones should be exposed and freshened, not by the usual subperiosteal method, but by removal of cortical bone together with its periosteum and muscular attachments. This left us with the freshened bone surfaces which could be approximated, and also islands of living bone which, when sutured in relation to the joint, increased the area of living bone contact. This experience has entirely altered my method of approach to the surgery of bone, and I have found it of particular value in the treatment of ununited fractures. The principles of the method are:

1. A direct incision to bone.
2. Define the bone outline by means of two light Lane's elevators, inserted subperiosteally about one and a half inches above and below the site of fracture.
3. Expose the fracture by removing bone consisting of a thin layer of the cortex together with its periosteum and muscle attachments intact.
4. Remove the fibrous tissue at the site of fracture and, as the fragments are angulated outwards, raise similar living fragments of bone from the distal side.
5. Open the medullary cavity and make sure that the ends of the fracture are truly freshened.
6. Reduce the fracture and suture the islands of living bone in relation to the line of fracture so that they have contact with both fragments.
7. Maintain fixation of the fracture until consolidation is established.

The following table of twenty-two consecutive cases reviewed for me by my colleagues, F. G. Allan, A. M. Hendry, and R. C. Murray, record the results obtained:

Summary of 22 Consecutive Cases of Non-union Treated by Subcortical Method

No.	Bone	Simple or Compound	Duration of Non-union	Prev. Op. to obtain Union	Graft used	Evidence of Union
1	Tibia	Simple	4½ years	Graft ; wire	No	Clin. and X-ray
2	"	Compound	12 months	No	No	"
3	Femur	Simple	5 "	No	No	"
4	Tibia	Compound	5 "	No	No	"
5	Radius	"	8 "	No	No	"
6	Humerus	Simple	5 "	No	No	"
7	Femur	"	16 "	Yes	No	"
8	Tibia	"	12 "	No	No	"
9	"	Compound	18 "	No	Yes	"
10	Radius	Simple	6 years	Plate	No	"
11	Tibia	"	11 months	No	No	"
12	"	Compound	10 "	No	Yes	"
13	Femur	Simple	8 "	No	No	"
14	Tibia	Compound	18 "	Plate	Yes	"
15	"	Simple	2 years	No	No	"
16	"	"	15 months	No	No	Clin. (X-ray not avail.)
17	Ulna	Compound	12 "	No	Yes	Clin. and X-ray
18	Humerus	Simple	10 "	No	No	"
19	Tibia	"	11 "	No	No	"
20	"	"	11 "	No	No	"
21	Humerus	Compound	13 "	Bone peg	No	"
22	"	Simple	11 "	No	No	"

Tibia, 12; femur, 3; humerus, 4; radius, 2; ulna, 1. Total, 22. Simple, 14. Compound, 8. Previously operated upon, 5. Infected after previous operation, 2. Treated by subcortical method alone, 18. Treated by subcortical method plus graft, 4.

The points to which I would draw your attention in this table are:

1. That the tibia was the site of non-union in twelve out of the twenty-two cases; the others being, humerus four, femur three, radius two, ulna one.
2. Fourteen of the fractures were originally simple, and in five of these previous operation to establish union had been performed. In two of these infection had followed operation. Eight of the fractures had been compound.
3. The duration of non-union varied from six years to five months.
4. In eighteen cases sound bony ankylosis was established by the subcortical method alone. In four cases this was supplemented by the use of a sliding bone graft.

Non-union of the Tibia following Osteomyelitis

Although not strictly an ununited fracture, non-union of the tibia, with deformity and loss of a considerable portion of the shaft as a result of osteomyelitis, has presented an analogous problem. The loss of bone may be so great that adequate contact of an autogenous bone graft is not possible, and the shortening of the tibia could not be overcome by this means. In these cases we have found that by transplantation of the fibula in two stages shortening can be reduced and stability of the limb restored. By operating in two stages we again have the advantage of being able to utilize a graft in which an adequate blood supply is maintained during its transposition.

The ununited congenital fracture of the lower third of the tibia is still to me the most difficult problem, and where the fibula is also ununited I have had no surgical success by any method. In two out of six cases of which we have records, where the fibula was intact, transposition of this bone has resulted in restoration of continuity of the tibia.

Summary of Conclusions

That the Wassermann reaction should be ascertained in all cases of delayed union or non-union of fractures.

That the degree and nature of previous infection should be investigated in cases of compound fracture.

That the question whether restoration of union of the fracture will improve function should have careful consideration. In some cases restoration of union may reduce the functional usefulness of the limb; in others an alternative operation, such as removal of fragments or osteotomy, may be the operation of choice.

That a gap between the bone ends can only be bridged by means of an autogenous bone graft.

That when non-union is present with the fragments in contact, uniformly successful results can be expected by the use of the subcortical method described.

That in cases of loss of bone resulting from osteomyelitis of the tibia, transposition of the fibula by the two-stage method can be relied upon to reduce shortening and restore stability to the limb.

That the results of surgical treatment for congenital non-union of the tibia are very unsatisfactory.

The Eugenics Society announces the following lectures to be held at the rooms of the Royal Society, Burlington House, Piccadilly, W.: Tuesday, October 17, 5.15 p.m., Mr. Alexander Block, "Demographic Aspects of the Housing Problem"; Tuesday, November 21, 5.15 p.m., Dr. C. P. Blacker, "Principles of Eugenic Prognosis"; and Friday, December 15, 5.15 p.m., Dr. Lionel Penrose, "Eugenic Aspects of a Survey of 1,280 Cases of Mental Deficiency."