would have completely disappeared. The treatment caused considerable pain, and was followed by serious ankylosis of the joint near the fracture.

As I have often said, the surgeon who has begun the treatment must warn the patient that he cannot be responsible for the treatment of another surgeon. Now, the treatment for a serious fracture, and especially for articular fractures, includes attention for a very long time after the limb has recovered its functions.

CONCLUSIONS.

The various views I have here expressed are often ill-understood by the medical profession. They should study them, and it is their duty to communicate them to the lay public. The public must be made to understand the difficulties involved in a study of fractures. They must know that radiographs have to be interpreted. They must know that the reduction of fractures is not an absolute rule, and is often not indispensable. They must know that absolute rest is not the necessary test of every sound treatment for fractures. They must know that a fracture is not a simple lesion, but that it includes complications owing to displacement, and owing to rupture of tendons and muscles. They must know that there is no mathematical solution for the repair of fractures.

It is always difficult to put the public on its guard against the rooted belief that it knows and can understand everything relating to medicine. But in the case of fractures the doctor must be especially on his guard, because nothing will uproot the conviction of the public, that it can understand every secret in connexion with the treatment and the repair of bones.

In the course of the many lectures on medicine that it is now fashionable to deliver to the public, it would be better to enforce these ideas than to persuade one's audience that they can be of use in rendering first aid to the injured.

Had these several ideas been familiar to the judge and jury, the verdict against the English doctors would have been impossible. It was based on a series of false ideas regarding fractures and especially on two beliefs—that for every fracture there is a routine mathematical treatment, whose effects are referable to a known immutable law, and that it is right to blame a medical man for not having rendered implicit obedience to the absolute laws laid down for the treatment of fractures.

REFERENCE.

¹ Les Erreurs de la Radiographie, Congrès français de Chirurgie, 1907, Dr. Lucas-Championnière.

An Address

ON

ARTHRODESIS AND TENDON TRANSPLANTATION.

DELIVERED AT THE MEDICAL GRADUATES' COLLEGE
AND POLYCLINIC.

By ROBERT JONES,

SURGEON TO THE ROYAL SOUTHERN HOSPITAL AND THE LIVERPOOL
COUNTRY HOSPITAL; LECTURER ON CLINICAL SURGERY
TO THE LIVERPOOL UNIVERSITY.

UNTIL comparatively recently the operative surgery of paralysis in children, both spinal and cerebral, has been limited to an occasional subcutaneous tenotomy, and the subsequent treatment has been largely guided by makers of orthopedic appliances. Too little effort has been made in the past to bring the resources of our surgical art to assist, and if possible to supplant, the mechanical methods. With the advent of the operations of arthrodesis, tenoplasty, and tendon transplantation, new avenues are open to the surgeon's enterprise and new possibilities for the relief of the hitherto hopeless amongst the paralytics. Nerve anastomosis is too recent a procedure to admit of our estimating its value. Arthrodesis and tendon transplantation, however, have been sufficiently practised to permit of our forming an estimate of their limitations and possibilities, and we can now with some authority indicate the causes of our failures and point to the essentials of success.

ARTHRODESIS.

Since I advocated the operation of arthrodesis to English surgeons I have performed it in over 500 cases. Many of my early results which seemed so promising at first proved later on to be disappointing; but it was the occasional success which encouraged me to persevere in searching for the faults which I was to avoid in order to ensure permanently successful effects.

By arthrodesis we endeavour to ankylose a joint with the least possible sacrifice of bone. The joint thus fixed is quite healthy, usually preternaturally mobile, and the muscles which should govern it are either wholly or in part paralysed. With exceptions which I shall mention, the operation of arthrodesis should be limited to those articulations wholly dependent for their usefulness upon outside appliances, and which offer no opportunity for a successful tendon operation.

The object of an arthrodesis when applied to the lower limb is to make a stiff joint sufficiently firm to bear body weight without yielding. When this result is attained it is the best that can be expected, for it means that the patient is able in the future to dispense with supporting frames of every kind. A less successful result than this, however, may fully justify the operation. The ankle, for instance, may be so improved in shape and position that less costly and less complicated apparatus can be used with better effect.

The surgeon fails if, wanting a bony ankylosis, he succeeds in securing merely a yielding fibrous one; but on several occasions I have noticed that a short fibrous ankylosis has given overstretched muscles an opportunity of acting, and this to the uninitiated might look like a recovery of motor cells.

The chief cause of my early failures was that I operated on children who were much too young, and the first important principle I would emphasize is that arthrodesis is best performed in children over 10, and should never be performed in children under 8. To neglect this, which I would call a fundamental law, is to court failure. Operations on younger children result in feeble fibrous ankylosis, and later on, from the sacrifice of too much cartilage, irregularity of growth. I cannot remember one case of a child operated upon under 4 years of age where bony union has been secured. In children under 7 less than a fourth have yielded satisfactory stability, but in children over 10 the fixations are practically universally good. Indeed, the youth of 10 or 12 is as good a subject for arthrodesis as is the adult, and if proper precautions are taken at the time of operation and afterwards the immediate results permit of no relapse. The deformity at the ankle due to irregularity of growth is usually a pure varus, and armed with a knowledge of its possible occurrence the surgeon can always place successful obstacles in its way. The same kind of perverse growth is apt to follow early operations of bone removal in club-foot and in arthrodesis at the knee for tuberculous degeneration. These awkward and compromising sequelae will be avoided if the surgeon determines not to operate on the very young, and if he watches, with a view to correction, the subsequent conduct of the joint. This is not all. If an arthrodesis is to be done at the ankle for equino-varus, then both the deformities of inversion and extension should be fully corrected by wrenching before the operation of fixation is undertaken, otherwise an increasing adduction of the foot will occur with growth.

Of all joints, the most amenable to arthrodesis are the ankle, the mid-tarsal, and next to these the knee-joint, whilst in rare instances it may be advisable to fix the shoulder-joint. The hip, wrist, and elbow are, in my opinion, not fitted for bony fixation.

For demonstration purposes I will take the ankle-joint, and refer to the procedures which I adopt in order to meet the demands of a particular deformity. One first inquires into the condition of the muscles, the age of the patient, and the length of time which has elapsed since the paralysis originated. If the patient is under 8, if there is any power in the stretched muscles, if complete paralysis of the stretched muscles has not lasted over two years, arthrodesis should not be done. I have seen several cases in which the paralysis seemed to be complete make a recovery under appropriate methods, even three years after the onset. In those cases where a mere contractile flicker in muscles is noted, and where power has not increased for many years, by applying to their

treatment certain principles to which I shall refer later complete recovery can be relied upon. It is, therefore, of the utmost importance that the ankle joint should not be fixed until we know—

(a) That the paralysis is complete, and depends on the destruction and not on the temporary disorganization of motor cells.

(b) That at least two years has elapsed in the case of muscles suspected to be completely paralysed.

(c) That apparently paralysed, but really overstretched, muscles have first undergone appropriate treatment.

We will suppose that the child brought to me is only 4 years old. He has been paralysed for two years, only retaining feeble tibial control, not sufficient to increase the deformity which is the result of posture, his calf muscles overact and are contracted. Before telling the parents that in four years an arthrodesis must be performed a preliminary effort should be made to place the apparently paralysed muscles in the best possible position to recover. This means the elongation by the Beyer method of the tendo Achillis and the placing of the foot in the everted position and at right angles with the leg, the object being to relax the elongated muscles. If any contraction of deep ligaments or plantar fascia exist these must be corrected by tenotomy and wrench, and if adduction at the mid-tarsal joint is noted abduction must replace it. Everything in short, must be done to overcorrect, and retain in overcorrection, the deformed foot before any operation on bone is performed. For this preliminary treatment to succeed it is necessary that not for one day should the foot when placed in the corrected position be allowed to relapse into the old position of deformity. And herein lies the problem—how can we afford to the foot this necessary security? We all know that when we apply splints parents of all classes temporarily remove them on various pretexts, and amongst the poor folk children are often even allowed to take their splints off at will and walk. It is because of this real difficulty I advocate that we should not trust to splints alone, but should operate to retain the foot effectively in good position without in any way interfering with the integrity of the joint. With this end in view I have for some years excised skin areas, and by a very simple device the foot is thus held in position by shortening the skin on the convex aspect of the foot. An assistant holds the foot in the overcorrected and everted position, and I hold in each hand a pair of forceps which nip the skin at some distance from one another; these I approximate, and so learn how much skin I can remove in order to hold the foot in a correct position. An oval flap of skin between the forceps is then removed, and the wound accurately stitched. When this stitching is completed the foot will, if necessary, remain in the overcorrected position without support. Further, the peronei tendons should be exposed and shortened, and the same should be done in the case of the flexors of the ankle and extensors of the toes. By the combination of these procedures, tenoplasty, and skin excision we can be assured that the muscles which should govern the ankle, but are overstretched, are kept in the best possible position for recovery, and in a comparatively short time one can predict either success or failure. May I venture again to emphasize the fact that the time that paralysis has existed will alone not instruct the surgeon unless the paralysed or overstrained muscles have been subjected to proper treatment? In other words, muscles which would remain apparently paralysed for years may, under suitable fixation, recover in a few months. This point I will again refer to in dealing with muscle transplantation. If it be found that power returns to some or all of the muscles, the question of arthrodesis may be dismissed, and instead, by a continuance of massage, and maybe by tendon transplantation, recovery must be sought. If the paralysis, however, remains, mechanical appliances must alone represent our surgical effort until the patient has arrived at an age when arthrodesis can be safely done. The case, say, being one of equino-varus with adduction at the mid-tarsal joint, we make an incision on the outer side along the length of the astragalus, exposing the ankle and the mid-tarsal joints. With a gouge all the cartilage is carefully removed from the astragaloid surface of the tibia and from the malleoli, and a wedge is taken from the astragalus, with its base to the outer side so large that when the bones are brought together the foot will be at right angles and slightly everted; a wedge is also taken

from the mid-tarsal joint with its base outwards, and the foot is then fixed in a position of slight abduction.

In operating on the ankle it is well to be sure that if a wedge has to be removed it should be taken from the astragalus, as this does not interfere with the tibial epiphysis and growth of the shaft; it is also advantageous that accurate apposition be obtained.

Operations on the knee are less frequently performed, and the patient has to decide between a stiffened joint and a splint which will give him the choice of moving the knee or not, as he pleases. The well-to-do, who can command the best apparatus, would generally prefer mechanical help. The poor, to whom splints are unavailable, or who live out of the reach of the mechanic, often elect an ankylosed joint. I have a number of poor people who trudge about without inconvenience with both knee and ankle stiff. The surgeon knows he can make the operation successful, but must leave entirely to the patient the decision as to which condition he prefers.

I have only performed arthrodesis of the shoulder in 5 cases. In 3 the union was bony, and in 2 fibrous. As Vulpius says, the arm should be kept well abducted and rotated inwards, as this facilitates the raising of the hand to the face and head. Unless the elbow can be kept permanently flexed, the operation is not indicated in those cases where the muscles governing it are affected. The object of the operation is to fix the humerus to the scapula at an obtuse angle so that the shoulder may be governed by the trapezius, serratus, and any other available muscles, and the arm can therefore be made to move with the shoulders. If the muscles governing the shoulder blade are paralysed, then arthrodesis of the shoulder is of no avail. There is a type of case, not at all uncommon, in which the muscles of the hand are acting, but the shoulder girdle and elbow are flail. It is necessary to fix the arm in acute flexion so that the functioning hand may be of use. This can be done by what I call the excision of skin flaps, fixing the forearm to the arm, which is infinitely preferable to an arthrodesis of the elbow.

Many complaints have been made by most excellent surgeons of the difficulties in bringing about bony union in arthrodesis of the ankle, and I have often experienced the difficulty myself. Now that I operate on older children and am careful of my apposition, I no longer dread a fibrous union.

Many devices, mechanical and physiological, have been tried to facilitate and render more sure a true synostosis. My friend Mr. Stiles, of Edinburgh, having performed his arthrodesis, drove a nail through the os calcis into the tibia. Karewski fixed the joint with ivory pegs. For reasons based on the arguments of the late H. O. Thomas, in dealing with ununited fractures, I have tied a rubber band above the ankle and below, sufficiently tight to obstruct the venous circulation. This old practice, which Thomas named "damning the fracture," has lately been most erroneously associated with the name of a distinguished German surgeon, Helferich. Were it possible to be sure of hastening bone formation, a knowledge of the method would be most valuable to the surgeon. We must all have noticed, as did Ollier, of Lyons, that irritation of the epiphysis due to chronic inflammation sometimes lengthened bone. Ollier, putting this knowledge to practice, endeavoured, and with a certain degree of success, to lengthen short legs by scarification and pegs. The late Professor Hoffa, basing his practice on the experiments of Mass and Schmidt, painted his arthrodesed joints with iodine, and advocated the procedure. Mass and Schmidt found that, by painting the extremities of young rabbits from birth with iodine, the bones thus painted became larger and heavier than those of the opposite side.

To sum up, therefore, we come to the conclusion that arthrodesis, properly performed, is a very valuable means at the surgeon's disposal, and that failures which have been reported are generally due to neglect of fundamental principles.

(a) The operation should not be performed on children under 8.

(b) It should not be performed until the surgeon is satisfied that the muscles are paralysed beyond hope.

(c) The preliminary preparation of the foot by wrench and tenotomy must correct all deformity.

(d) The operation should be so planned that at its

completion the bones lie in apposition to the foot, which should be placed in an overcorrected position. This is effected by the excision of skin flaps, by the shortening of lengthened tendons, and by the removal of graduated wedges of bone.

(c) The wedge should never be taken from the tibia, lest the tibial epiphysis be injured.

Splints should be applied and retained until union is pronounced to be complete, and appliances should be worn until the surgeon has evidence that the ankle can bear body weight without fear of yielding.

TENDON TRANSPLANTATION.

Tendon transplantation offers us many opportunities for speculations which we have no time to indulge in to-night. The physiological and psychological problems involved are of intense interest. My purpose, however, is to endeavour to lay before you some of the reasons why failures are so often reported, and to try and help from an experience of over 260 operations to make a successful issue more likely. I shall not do this by an analysis of cases, as some of my patients have been operated upon many years ago and others only a few days since. In my early cases, groping largely in the dark, the results of operations were not encouraging. I can, however, endeavour to describe the indications for operation, and point out those factors which in my experience have made for success and those which predestine failure. To do this usefully I will enter later upon the discussion of certain practical principles relating to tendon elongation and their effect upon opponent groups, and this in order to avoid fallacious conclusions as to the results of transplantation.

The object of tendon transplantation is twofold, to correct deformity and to improve or restore function. Rarely does it happen that failure is so complete as neither to improve the utility nor the appearance of a foot. The prudent surgeon, both for his patient's sake and his own, will use every available art to ensure an improvement in the position of the foot, with a knowledge that should the transplantation fail in function, at least a more useful and normal looking foot will be secured. In my opinion, the indications for tendon transplantation are:

- (a) To fortify a weakened group of muscles.
- (b) To supplant a completely paralysed muscle, or group of muscles.
- (c) To obstruct an overacting spastic group.
- (d) To deviate tendon action when perverted—as in transference of the tendo Achillis to the outer side of the os calcis in congenital club-foot to prevent inversion of the ankle.
- (e) As a help in partial arthrodesis.

When I began to transplant I did so into tendons, but for a considerable time I have inserted direct into periosteum or an equivalent firm tissue, and in a few cases direct into bone by tunnelling or grooving. On occasions I have transplanted the complete bony insertion of a tendon as in the case of the patellar ligament and Achilles tendon.

In my earlier cases the results, as in those of arthrodesis, were disappointing. Even now with my extended opportunities and experience I cannot be so certain of a good result as when I elect to make a flail joint stiff. My early operations, however, were made when I had not realized principles which I now hold to be essential to success, and cases which seemed to promise well at first soon began to show signs of relapse. Were it not for two or three encouraging results out of fourteen or fifteen early failures, I should long ago have ceased to operate. The two or three successes, however, meant everything to me; they meant, in the first place, that, given certain conditions to be found out by the surgeon, a transplanted tendon could be made to do the work required of it. Nearly every writer who deprecates the operation will admit the occasional success. The recognition of the possibility of success is alone sufficient to justify tendon transplantation as a surgical procedure. As a guest of the French Congress of Surgeons in Paris, last October, I listened to a very able address by Professor Kermisson, largely sceptical of the value of tendon transplantation. He referred to the case which, at first brilliant, later on relapses. I maintain it is necessary to find out why a case at first successful should later disappoint. There are to my mind only two answers to this question, either that

the after-treatment has been faulty, or that a mistake has been made in ascribing to the transplanted tendon a result produced by other causes. A transplanted tendon which begins to act should never be allowed to relapse. When relapse does take place, it shows that the efforts of the weak muscle in the discharge of its new duties has not been sufficiently appreciated and helped forward. Instead of being carefully nursed it has been allowed to become overstretched, either by the action of opponent groups or by erroneously applied body weight. To prevent this the transplanted muscle should be energetically massaged, and the foot should be so fixed that body weight is deflected from it. For a muscle to continue to contract well it must have a certain elastic tension and a normal tonicity, and, as was pointed out a quarter of a century ago by H. O. Thomas of Liverpool, an overstretched muscle while the strain is continued loses its function. This question of lengthened tendon goes to the root of the question of relapse, for it is quite possible to render powerless strong healthy tendons if they be overstretched.

If, for instance, we follow carefully the histories of certain drunkards with drop wrist, we shall find that in some of them direct stretching of the extensors from weight and posture, and not pressure on the musculospiral nerve, is the cause of the paresis. Experimentally I have investigated and confirmed this theory, first promulgated by Thomas. In drop wrist of many years' standing due to poliomyelitis, continuous and prolonged hyperextension of the hand for many months will completely restore the muscular balance, and in conjunction with my friend Mr. Tubby I have elsewhere given instances where after seventeen and nineteen years the overstretched extensors have regained their contractility. In further illustration of this point I would relate three cases. A girl of 13 who had been afflicted for years presented a complete paralysis of the shoulder and upper arm, but had free use in the hand (the upper arm type of Erb). There was no power of extension or flexion at the elbow, and the electric reactions denoted complete paralysis of biceps and brachialis anticus. As is my custom in such cases, I removed a large diamond-shaped flap from the upper and lower arm, and attached the forearm to the arm, so that the elbow was fixed at an acute angle, and the patient was thus enabled to use her hand for many useful purposes about her neck and face. Many months afterwards my colleague Mr. Armour, on examining her, found the skin slightly stretched, but noted that the girl could flex her forearm several degrees. In fact, restoration of function had taken place in the paralysed brachialis anticus and biceps by allowing structural shortening to take place in the bodies of the muscles. A second case, three years paralysed, and similarly treated and tested, resulted after four months in complete muscular restoration. Now I would draw your attention particularly to a third case, similar in most respects to the other two, where the paralysis had lasted seven years, but during the whole of this time a flicker of contractility had been noted in the biceps, so slight as to have no effect upon the forearm, which lay limp and extended. I slung the forearm in a position of acute flexion, and sealed it in such a way that for some months its position could not be changed. Some power was soon manifested in both the biceps and brachialis anticus, and by degrees the arm was lowered to the position of right angles. It was then found that from that position the arm could voluntarily be acutely flexed with moderate power. The patient's doctor at this stage, thinking the arm was well, took the sling off. The sequel was most instructive: the weight of the forearm so stretched the recovering muscles that the arm again lay limp, extended, and powerless, and function was regained only when the flexion treatment had been continued for a sufficient length of time. The bearing of these cases on the question of tendon transplantation is obvious, and may thus be formulated:

- (a) A muscle, if stretched for a sufficiently long period, will cease to act.
- (b) An overstretched muscle will regain its power if relieved from strain.

If the surgeon fails to grasp these facts fully he is apt to make two serious mistakes. First, he does not discriminate the muscle paralysed because of destruction of a motor cell from a muscle not functioning because

of overstretching. Secondly, he does not realize that recovery is not due to the action of a transplanted tendon, but to the functional restoration by posture of a hyperextended muscle. My third case shows clearly how gravity may overcome even a considerable degree of muscular restoration, and is a complete answer to those surgeons who wonder how an immediately brilliant result may end in failure.

I have on many occasions observed the recovery by posture of muscles which have been pronounced hopeless after electrical examination. These observations have been confirmed by Hoffa, Koch, Lange, König, and others. Koch has shown by histological examination that in useless muscles regeneration of muscular fibres is possible. He adduces instances of muscles microscopically and macroscopically showing complete degeneration which have recovered elastic tension.

There are many ways of deflecting strain from a newly-implanted tendon. Hoffa did it by shortening the inactive or paralysed tendons. Others trust entirely to posture in splints. Personally I see that the deformity of the foot is overcorrected before any operation is performed, and as soon as the tendon is transplanted, as in arthrodesis, I remove an oval skin flap from the paralysed side so large that when the edges are sewn together the foot remains fixed in an overcorrected position. The removal of the skin flap, I venture to suggest, gives us considerable help in removing strain from the transplanted tendon. The foot by this means, as I have before said, remains in the desired position in spite of any outside influences.

The causes of my early failures may be thus summarized:

- (a) Inadequate tension of the reinforcing muscle.
- (b) Inadequate preliminary correction of deformity.
- (c) Early adhesions of transplanted tendons.
- (d) Insufficient freeing of the tendon.
- (e) Overdeflection of the transplanted tendon.
- (f) Overstrain upon the transplanted tendon.

Latterly I have avoided operation upon children of too early an age. I usually wait until they are 5. If we operate younger than this, the children can give no help in the after-treatment by exercise and resistance. By manipulation, by the wrench, or by tenotomy the deformity must be overcorrected, and in obstinate cases the foot should be kept for some time in an overcorrected position. How absurd it is to expect a newly-implanted tendon not only to hold its own against powerful opponents, but to be sufficiently strong, in addition, to unravel a deformity! On occasions, in order to give my newly-placed tendon a favourable chance, I have divided all its active opponents—a harmless and useful device. The sheath of the transplanted tendon should be as often as possible spared, and should accompany the tendon to its new destination. We must remember that the blood supply of the tendon is from its belly—bone insertion—and from its sheath, and if deprived of its blood supply union is very slow and feeble. The suture fixing the tendon should be tight. Silver found from experimental study that it is practically impossible to tie a suture tightly enough to cause necrosis, and that many relapses occur from the tearing of sutures which have insufficiently held the tendon. When the tendon is fixed to the periosteum it should be tightly sewn, but it should not be pulled so forcibly that it will not become slackened slightly by overcorrection of the foot. We must always remember that an overstretched tendon is in danger of rapid atrophy. Tendons which are not acting may be shortened to help the bracing up of the foot and to restore the function of those which have been overstretched. The overcorrected position of the foot should be maintained for some weeks, and when the patient is allowed to walk the body weight should be so deflected that the transplanted tendon is saved from strain. Before body weight is allowed on the foot massage and voluntary movement of the tendon will have been diligently employed.

If these principles are regarded we may estimate a large percentage of recovery, but, alas! how rarely can we secure for a foot the prolonged exercise free from body weight so essential to the bringing about of an ideal result. If the technique has been good, the after-treatment correct, and the transplanted tendon begins to act, improvement should be uninterrupted. Hubscher of Basle,

referring to implantation of the biceps and sartorius into the patellar periosteum, says that, though immediate results are marvellous, sooner or later these may be partially or wholly lost. If regard be paid to after-treatment one need not fear loss of function. If success is not continued when once begun, either the surgeon or the patient must be to blame.

Bearing closely upon this comes the question of strengthening the implanted tendon, which withers quickly if it suffers undue strain. What is the test of the recovery of the tendon? The tendon has recovered when the patient is able by a voluntary effort to make it forcibly act, and when it can successfully withstand the action of gravity. If a weak tendon has been inserted to replace a strong one, the after-treatment must be anxious and prolonged. Directly bearing upon this question of the test of recovery in a muscle and the systematic strengthening of a weak tendon, I would refer surgeons to the so-called relapsing congenital club-foot. It is well known that if an extreme case of club-foot is rapidly overcorrected by hand or wrench, so completely, indeed, that the surgeon without the slightest effort can move the foot from equinovarus to calcaneo-valgus, such a foot may easily relapse. Textbooks do not inform us why this is, but the explanation I offer will appeal to you as being simple and correct. The deformity recurs because the overstretched flexors of the ankle have not had time to shorten, and they behave as if paralysed; the foot gradually, therefore, as in poliomyelitis, gravitates into equinovarus. Such deformity will never recur if the surgeon watches his little patient until, by an act of volition, he is able quite easily to overcorrect his own foot.

Again, given a certain degree of power in a transplanted tendon, by appropriate treatment this should be continually increased. Some years ago I operated on a boy with a slipping peroneus longus tendon and was surprised to find it almost the size of his tendo Achillis. I found later the reason why it was so hyperextended. At a preparatory school he delighted to exhibit its noisy movement over the malleolus at a penny a performance for the amusement of his school companions. This is suggestive as to what may be done by appropriate after-treatment in the case of a weak but acting transplanted tendon.

The tendon must be well freed by amply tunnelling the soft structures through which it is to pass. The tunnel should be made in the one plane without the exercise of force on the surgeon's part. The exercise of force means the tearing of structures and the formation of adhesions, which will spoil our efforts. There should be no angular deflection on the part of the reinforcing tendon, which would most surely be fatal to its action.

If during an operation we are in doubt as to the vitality of a muscle, we will observe that the healthy muscle is dark and red and the afflicted muscles pale pink, fatty or yellowish-white.

CONCLUSIONS.

In tendon transplantation one must insist on—

1. The overcorrection of deformity as a preliminary act.
2. The removal of skin flaps to secure the uninterrupted continuity of the overcorrection.
3. The direct and not angular deflection of the tendon.
4. The free tunnelling in the one plane through the soft tissues.
5. The firm suturing into periosteum or bony groove.
6. The careful choice, tension, and nursing, of the transplanted tendon.
7. The maintenance of a hypercorrected position until voluntary power is assured to the tendon.
8. The deflection of body weight during walking from the reinforcing tendon.

In addition to these, it may sometimes be well to shorten all the paralysed tendons and prevent the overaction of their opponents by tenotomy.

In all my cases of arthrodesis and tendon transplantation I employ the tourniquet, and of course insist upon scrupulous asepsis. The surgeon and his assistant should either be masked or absolutely silent during the operation, and india-rubber gloves should replace the surgeon's skin, which can never be accounted surgically clean. It is practically impossible to speak without spitting, and a carious tooth will readily start an infection. The knowledge of the ease with which, by talking, we can infect

gelatine 2 ft. from us should check those dissections which we foolishly carry on over the wounds we inflict.

All my hospital transplantations are treated as out-patients, and return to their homes on the day of operation, and no difficulties of any kind arise therefrom.

With the limited time at my disposal, I have thought it best not to discuss individual operations nor to dwell upon statistics. I have preferred to lay before you certain principles which I hope may prove useful. Both arthrodesis and tendon transplantation are, if properly appreciated and applied, valued surgical assets. They give us an interest and encouragement in our treatment of paralytics which we sorely needed. Failures, and we are bound to experience many, should prove our welcome counsellors, and we should be unsparing of our efforts to learn from them all we can.

THE MOST ANCIENT SPLINTS.

BY

G. ELLIOT SMITH, M.A., CANTAB., M.D., CH.M.SYD., F.R.S.

PROFESSOR OF ANATOMY, THE EGYPTIAN GOVERNMENT
SCHOOL OF MEDICINE, KASR-EL-AINY, CAIRO.

[WITH SPECIAL PLATE]

It is a well-known fact that among the ancient Egyptians excellent results were often obtained in the treatment of fractured bones, but it has never been explained what measures the archaic surgeons adopted to secure this success in the practice of their art.

I have been fortunate enough to have had the opportunity of examining two sets of splints which had been applied to fractured limbs almost at the dawn of Egyptian history—roughly, about five thousand years ago. These are certainly the oldest splints which have come to light in any part of the world, and, with the exception of flint knives used for circumcision* in Egypt in prehistoric times, they are the earliest surgical appliances ever discovered.

These interesting objects were found by the Hearst Egyptian Expedition of the University of California in charge of Dr. George A. Reisner. The enlightened generosity of Mrs. Phoebe Hearst, the great benefactor of that institution, has enabled Dr. Reisner to make scientific investigation rather than the mere collecting of museum exhibits the paramount object of the work of the expedition; and to the thoroughness with which this aim has been pursued we are indebted for the discovery of these splints, which throw a new light on the early history of surgery.

During the progress of the Hearst Expedition's work at Naga-ed-dér (about 100 miles north of Luxor), Mr. A. C. Mace excavated a cemetery of rock-cut tombs made in the time of the fifth dynasty.† In these tombs were found the two sets of splints which form the subject of these notes.

By one of those curious coincidences which occur at times in the experience of every one who systematically examines large series of specimens, both of these sets of splints—the only known splints that had been applied to living‡ patients earlier than the Christian era§—were

* In my examination of the bodies found in the prehistoric cemetery at Naga-ed-dér (Hearst Expedition's excavations), I found that all the men were circumcised. In a tomb of the ancient empire at Sakkara, the operation of circumcision is represented in a series of wall pictures; the surgeon is using a flint knife. Although it is not possible to say with certainty that any particular knife found in an archaic tomb has actually been used for surgical purposes, it is safe to say that some of them were intended for such a use.

† There are still great discrepancies in the estimates of the dates of these ancient Egyptian dynasties. Professor Breasted, following the Berlin school of archaeologists (which reduces the periods of time to the lowest possible figure), gives the date of the fifth dynasty as 2730-2625 B.C. Professor Flinders Petrie gives the date as 3721-3503 B.C. Even if we adopt the lowest estimate of age, these splints are more than 4,500 years old.

‡ I have described (Report on the Unrolling of the Mummies of the Kings Siptah, Seti II, Ramesses IV, Ramesses V, and Ramesses VI, *Bulletin de l'Institut Égyptien*, 8e Série, T. 1, 1907, p. 49) a set of splints applied to the right forearm of King Siptah of the nineteenth dynasty, which had been broken by plunderers of his mummy long after his death and was set with splints by the priests of the twenty-first dynasty, who rewrapped his body, which the robbers had stripped.

§ I have described sets of splints found on the two forearms of a girl of the early Christian period (perhaps seventh century). See the first *Bulletin of the Archaeological Survey of Nubia*, 1908. Mr. Mace tells me that in an early Christian cemetery at Naga-ed-dér, excavated by the Hearst Expedition, he found a fractured patella set with splints. This is now in one of a large series of boxes (in the Anatomical Museum of the Cairo School of Medicine) which have not yet been unpacked.

found at the same time and in one cemetery. These sets of splints have been in the Anatomical Museum of the Cairo School of Medicine for the last five years, and, although they have been seen by innumerable visitors, no account of them has ever been published, because it was our intention to reserve the description of them for the reports of the Hearst Expedition's work. But at the urgent recommendation of Mr. Edmund Owen I have sought and obtained permission from Dr. Reisner to publish these notes and photographs now.

Mr. Mace's photographs showing the condition of the two tombs from which these splints came will be published in the Hearst Expedition's Reports, and one of these showing the splints themselves *in situ* is reproduced here to illustrate the exact position in which they were found (Fig. 1). One of the sets of splints I replaced in the exact position in which they were found (and photographed by Mr. Mace) for the purpose of taking the photograph reproduced here as Fig. 2. In the case of the second set of splints their linen wrappings have become so stiff and brittle after five years in a museum show-case that they cannot be put into their original places without damaging the bandages. The manner in which they are shown in Fig. 3, however, is perhaps more instructive. It shows the position of the bones in relation to the splints and it is easy to imagine the exact appearance of the supporting pieces of bark when they were put together to form a tube around the damaged limb.

SPLINTS APPLIED TO A COMPOUND FRACTURE OF THE FEMUR.

This case is the fracture of the shaft of the right femur almost exactly at its mid-point; the subject was a girl about 14 years of age. A piece of bone 52 mm. long and 13 mm. wide had been detached from the back of the shaft at the seat of the fracture (Fig. 4). As this was missing and also for other reasons to be mentioned later the fracture must have been compound.

The broken limb was set with four splints passing from just above the fracture to a point well below the knee (Figs. 2 and 3). Each consisted of a rough, slender strip of wood, which had been wrapped up by means of a carefully-applied linen bandage (Fig. 5, B) before being fixed to the limb. The splints were held in position by means of two bandages, each tied in a reef knot (Figs. 2, 3, and 5, A), one above and the other below the knee. As the result of a natural process of decomposition and, even to a greater degree, of the damage done by insects, the great part of the linen bandages has disappeared, and even what is left of them is in a very much disintegrated condition and is very fragile. Sufficient remains, however, to indicate exactly what had been done by the surgeon to prepare and apply the splints. The most important and most carefully prepared splint was applied to the antero-mesial aspect of the limb (Fig. 2; in Fig. 3 it is to the right side of the bone). It consists of a rough strip of wood, which has been sawn or roughly shaped with an adze, but not planed. It is 40.3 cm. (about 1 ft. 4 in.) in length, 2.9 cm. (about 1½ in.) in width, and 7 mm. (about ⅞ in.) in thickness. Only 7.2 cm. (less than 3 in.) of this splint was above the seat of the fracture, but 16 cm. of its length was below the knee.

It was carefully wrapped in two layers of linen bandage, wound obliquely around the wood in such a manner that the direction of the obliquity of the superficial layer was at right angles to that of the deeper layer (Fig. 5, B). The bandage is 35 cm. (about 1½ in.) broad, and is composed of somewhat loosely and irregularly-woven threads, of which there are 14 per cm. in the warp and 32 in the woof.

A short distance below the site of the fracture there is a large pad of linen, 8 cm. long and 31 cm. thick, attached to this splint; its upper border is 9 cm. from the upper end of the splint (Figs. 2 and 3). This pad is composed for the most part of a bandage, wound in a circular manner around the splint, but on its inner aspect there is an unattached sheet of linen, folded to form an oblong mass (55 × 35 mm.).

The femoral surface of this pad is discoloured by a rust-like stain, which my own investigations, and especially the large series of exact observations made by Mr. Frederic Wood Jones, M.B., my collaborator in the anthropological work in Nubia, enable me to recognize as