A Clinical Lecture

ON

TENDON TRANSPLANTATION.

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[With Special Plate.]

BY

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THE operation of tendon transplantation, which is also known under several other names, such as tendon grafting, tendon implantation, and transference of muscle power, has gradually come to occupy a most important place in orthopaedic treatment. It is well, in dealing with such a subject as this, to refer to its origin and to mention briefly the pioneers who conceived the ideas which their successors have developed. In 1882 Nicoladoni¹ introduced the operation in the treatment of infantile paralysis; unfortunately, he appears to have first tried it in an unsuitable case, in which it proved to be unsuccessful. For this reason he did not follow up the idea any farther. Ten years later Parrish² in America and Drobniak³ in Germany both revived it. Since that time the Americans, particularly Bradford, Lovett, Whitman, and Goldthwait, have worked extensively at the subject, as also have Hoffa,⁴ Lange,⁵ and Vulpius⁶ in Germany. Our own country has taken its share in the development of the various methods: Little, Tubby, Jones, and, in this city, Montgomery, have all worked along lines which have defined the possibilities and the limits of the operation.

The transference of muscle power may be used: (1) in order to restore a movement which has been entirely lost through injury of the peripheral nerve supply or as a result of poliomyelitis; (2) to redistribute the power acting about a joint; and (3) to diminish the effect of the non-paralysed muscles which by their unopposed action are producing deformity. The removal of a distorting force is an important result of the operation, often as important as the transference of positive power. I propose to demonstrate seven groups of cases in order to illustrate the varied uses to which tendon transplantation may be put. In peripheral nerve palsy, such as occurs after division of the musculo-spiral nerve, it is possible to set down details for a complete tendon-transplantation operation which, when properly carried out and followed by correct after-treatment, can be relied upon to restore the lost function as effectively as possible. The treatment of infantile paralysis, however, is not a subject in which one can lay down definite rules as to the utilization of the various muscles as transplants. The loss of power in the muscles, in this disease, varies so much in distribution and in intensity that each case must be carefully studied in detail and the precise extent of the loss of power noted before any operative programme can be drawn up. It is not my intention to refer to the treatment of infantile paralysis in the early stages of the disease, and I have only to say that the operation of tendon transplantation is not to be advocated until it is beyond doubt that the affected muscles are paralysed beyond recovery. Correct splinting day and night with constant physio-therapy are to be utilized for a period judged to be sufficiently long. After such time, if no change is seen and no response can be elicited by any form of electrical stimulus, tendon transplantation, either alone or associated with other methods, may be advocated. A transplanted muscle does not, as is sometimes stated, increase in power by the greater demands made upon it in its new position. On the contrary, it is never so effective as in its normal place. As a result of tendon transplantation the active power present is actually lessened but more usefully distributed.

Indications for Operation.

The operation is chiefly indicated when the paralysis is limited to a group of muscles and where other muscles, of not antagonistic action, are available for transplantation. Very extensive cases with only a few weak muscles remaining are not suitable for the operation. In the case of transplantation about the ankle the operation must not be expected to do more than redistribute power. It will not produce stability of an ankle and foot which are inclined to "capsize" as soon as weight is put on them. The normal movements of the subastragaloid joints, added to those of the ankle-joint,

permit such a variety of motion that they have been said to allow of what the engineer calls "universal" movement, such as is found in a ball-and-socket joint. The movements essential for locomotion are those of dorsiflexion and plantar flexion of the ankle-joint. After an attack of infantile paralysis the balance of the muscles is disturbed and the power diminished. When such conditions exist it is often found that too much uncontrollable movement is present and that the whole of this movement cannot be retained if stability is to be provided. In these cases it is therefore desirable to retain the essential movements of simple flexion and extension of the ankle and to fix the subastragaloid joints, which include astragalo-scapoid and astragalo-calcaneal joints, by arthrodesis.

Technique.

As a preliminary measure to all tendon-transplantation operations, it is essential to correct all deformity. For example, in a case of paralytic equino-varus which has existed for some time it may not be possible, because of secondary contractions, to place the foot in a correct position. There may be contraction of the calf muscles necessitating elongation of the tendo Achillis before the equinus can be corrected; there may also be considerable shortening of the plantar fascia requiring fasciotomy in order to straighten out the sole of the foot.

Secondary changes in bones and joints following the prolonged malposition may call for wrenching and fixation in an overcorrected position for a time before the tendon transplantation can be embarked upon. For three days before operation the preparation of the skin is carried out. After thorough soap and water cleansing and trimming of nails the skin is well dried. A solution of iodine in rectified spirit (resublimed iodine 1/2 oz., potassium iodide 1/2 oz., rectified spirit one pint) is painted over the whole of the affected limb, which is then covered in a sterile cloth and bandaged. The iodine application is repeated on the day previous to operation, and, unless the operation is to take place during the early part of the morning, a further application is made on the morning of the day of operation. As to the theatre technique, all persons entering the theatre are required to wear boot-covers or theatre shoes, sterile gowns, caps, and masks, whether they expect to come close to the operation area or not. The limb which is to be operated upon is enclosed by sterile gauze, bandaged so as to cover the whole limb, including the foot or hand. The iodine solution is again applied to the gauze covering the operation area. The gauze is now cut along the proposed line of incision. After the skin incision is made skin towels are clipped to the edges of the wound so that the skin is entirely shut off. The skin knife is set aside and used only for any further skin incision which may be required; a second knife is used for the deeper dissection. Sutures, ligatures, and swabs are handled in forceps, and, so far as possible, none of these articles nor any part of the wound is touched even by the gloved fingers.

The best results are obtained by transplantation of the entire tendon, and not by transplanting slips of tendons. The transplant should be fixed as close to the insertion of the paralysed tendon as possible, suture to the actual bony insertion and periosteum giving the most satisfactory results. If the transplant is not sufficiently long to reach this position, the paralysed tendon is buttonholed and the transplant passed through and firmly sutured to it. The transplanted tendon must not be taken round corners; it must run in as straight a line as possible to its new insertion. To accomplish this, long incisions or multiple incisions are needed. Following operation, the limb is fixed by splints or in plaster-of-Paris in such a position as will ensure as much relaxation as possible of the transplanted tendon with no strain on the suturing.

After-Treatment.

Six to eight weeks' complete fixation is given, and at the end of this period removable supports are provided which can be taken off for treatment. In the physio-therapeutic department the re-education of the muscles is commenced. In some cases it proves a simple matter for the patient to produce the new action of the transplant, to be able to produce it at will, and soon to dissociate it from the action of muscle with which it was formerly associated. In other cases, particularly where antagonists have been transplanted, it is a matter of slow and patient work before such a result can be arrived at. A start is made by placing the limb in such a position that contraction of the transplant will be able to take place with no "load"

against it. Stimulation of the transplanted muscle by faradic current is carried out, and a small contraction produced. A gradual increase produces a small movement, which is demonstrated to the patient. He is taught to produce this movement voluntarily, and gradually to dissociate it. He begins to learn that a muscle which formerly everted, when he contracted it, now inverts, or that a former flexor now extends. As he becomes able to produce the new movement voluntarily a little resistance is offered to the performance of it, and so, by slow degrees, he develops the new power.

Illustrative Cases.

The first cases I wish to show you are patients in which the musculo-spiral nerve has been divided and where nerve suture was impracticable or where recovery has not taken place after suture was performed. In these cases, after trying several minor variations, I have found the following transplantation to produce the most satisfactory results:

(a) Pronator radii teres transplanted to the long and short radial extensors in the middle third of the forearm.

(b) Flexor carpi radialis transplanted to the three thumb extensors. In order to produce the best effect from this transplant I am in the habit of splitting the terminal two inches of the flexor carpi tendon. The outer half is then sutured to the extensor ossis metacarpi and extensor brevis pollicis tendons and the inner half to the extensor longus pollicis tendon. I find this arrangement to be mechanically more effective than passing the entire flexor carpi tendon through the three thumb tendons.

(c) Flexor carpi ulnaris transplanted to the common extensor of the fingers.

You will observe with what ease and strength the wrist and fingers can now be extended and flexed, and the way in which these patients have, with our help, educated themselves to dissociate the action of the transplanted flexors from the rest of the flexor group (Figs. 1 and 2). These results are extremely gratifying, so much so that it is safe to say that the results of a good tendon transplantation, in this class of case, are much to be preferred to a moderate recovery after nerve suture.

The second group of cases illustrates the treatment of paralysis of the adductors of the foot with overaction of the peronei and valgus deformity following anterior poliomyelitis. With these cases I usually transplant the peroneus tertius, or brevis, or both, and sometimes also the extensor longus hallucis, which generally escapes in these patients, and fix them to the scaphoid at the point of insertion of the paralysed tibialis anticus. If the extensor longus hallucis is so utilized the hallux is prevented from acquiring the "hammer" deformity which follows loss of its long extensor, by arthrodesing the interphalangeal joint in a straight line (Fig. 3).

The next cases illustrate the opposite condition to the preceding. In these there has been peroneal paralysis with consequent varus deformity following the unopposed action of the tibialis anticus and posticus. Here the tibialis anticus has been transplanted outwards and fixed to the periosteum of the cuboid. The everting action of the transplant is well seen (Fig. 4).

The fourth group demonstrates the result of transplantation in the treatment of talipes of the calcaneus variety—usually a calcaneo-cavo-valgus. In these cases it is my practice to arthrodes the subastragaloid joints and to transplant the flexor longus hallucis and peroneus longus to the insertion of the tendo Achillis and the os calcis. By means of these procedures you will see that the foot can be given a good shape and the general function very greatly improved (Figs. 5 and 6).

Talipes cavus, associated with overaction of all the long extensors of the toes consequent on loss of power in the short muscles of the sole, has been successfully treated in many cases by transplantation of the long toe extensors into the heads of the metatarsal bones. After such an operation it is seen that instead of pulling across the metatarsophalangeal joints and forcing down the forefoot, these tendons now lift it and by their action straighten out the cavus deformity. The whole of the five tendons are transplanted, being approached through three incisions, one over the hallux, one between the second and third toes, and the last between the fourth and fifth toes. In each case the tendon is cut as long as possible and passed through a hole bored transversely through the neck of the metatarsal just behind the head. The tendon is pulled through and sutured to itself, forming a loop. The contracted plantar fascia is divided.

The sixth group of cases demonstrates the use of trans-

plantation in the treatment of recurrent dislocation of the shoulder-joint, a method which I referred to in a paper read at a British Orthopaedic Association meeting in 1920.⁷ This distressing condition, which is extremely difficult to cure, has been treated extensively by means of operations on the joint capsule, such as plecting and excision of sections, with subsequent suturing to diminish its size. In many hands these methods had not produced very satisfactory results; for a time there was improvement, but after varying periods redislocation occurred. I therefore determined to try the method of Clairmont and Ehrlich,⁸ who devised an operation by which a portion of the deltoid is transplanted so as to sling up the head and neck of the humerus. The posterior strip of the deltoid, about one inch wide, is separated down to its insertion and passed through the enlarged "quadrilateral space" of the axilla, and the tendon fixed high in front of the joint. Clairmont fixed it to the separated edges of the anterior part of the deltoid. In performing the operation it seemed to me that the tendon would lie closer to the joint and give it more support if sutured up to the subscapularis tendon, and this modification I always carry out. I have performed this operation on seven occasions during the past four years; the most recent case was done seven months ago. With one exception there has been no recurrence. In that case the patient was a professional Rugby football player who came down on the outstretched arm and redislocated the shoulder. He had previously had a capsule operation which was followed by recurrence in a few months. After the transplantation he played football for a whole season, during which the joint remained stable before the unfortunate fall, which would have been sufficient to dislocate a perfectly normal shoulder.

The last group of cases demonstrates the transplantation of hamstring tendons to the front of the knee to replace a paralysed quadriceps extensor. Tubby reports, in his well-known book, that in nearly half the cases in which he performed this operation there was recovery of power of full extension of the knee both in standing and sitting. Many surgeons, however, even amongst those of large experience, are unconvinced of the good results which may be achieved by this transplantation, as is evidenced by the following quotation from a lecture given by H. A. T. Fairbank, which was reported in the *BRITISH MEDICAL JOURNAL* of April 9th, 1921:

"I am open to conviction, but I have still to see a shifted biceps contract alone at will and produce extension of the knee-joint. I have seen it contract with the flexors and interfere with the action of its fellows, but this is a very different thing from this muscle producing extension at the will of the patient."

Several patients I now show to you demonstrate the power of the transplanted biceps and semitendinosus to act voluntarily, producing full extension of the joint. They are able to hold it in this fully extended position, bearing the weight of the leg and foot, for periods varying from half a minute to two minutes, which is as long as you or I would care to hold out an extended knee (Figs. 7 and 8).

I think that the cases I have now shown you provide convincing evidence that tendon transplantation has a definite place amongst our orthopaedic methods, and a demonstration of the fact that, in properly selected cases, it is an operation which can be strongly recommended to our patients.

REFERENCES.

- ¹ Nicoladoni: *Arch. f. Klin. Chir.*, 1882, iii. ² Parrish: *New York Med. Jour.*, October, 1898. ³ Drobnik: *Zeit. f. Chir.*, Bd. 48. ⁴ Hoffa: *Arch. f. Klin. Chir.*, S. 1, 1. ⁵ Lange: *Deut. med. Woch.*, 1908, iv. ⁶ Vulpius: *Orth. Clin. Joachimsthal*, 1904, i. ⁷ Ollershaw: *Journ. Orthopaed. Surg.*, May, 1920. ⁸ Clairmont and Ehrlich: *Arch. f. Chir.*, 1909.

IN connexion with the recent articles on the attempt to climb Mount Everest and the use of oxygen by the climbers, we have received a letter from Messrs. Oppenheimer, Son, and Company, Ltd., suggesting that the apparatus called oxinhalator, made by them, might be of use. They furnish a reference to the *Medical Annual*, 1910, from which it appears that the substance used to furnish oxygen ("Sodox") is a peroxide of sodium, which possesses the property of emitting absolutely pure oxygen in contact with water. The apparatus appears to be an adaptation of one invented by M. G. P. Jaubert, and first shown to the Academy of Sciences in April, 1912, by Professor Moissan. It has useful applications under ordinary atmospheric conditions, and was, we learn, used in the Pike's Peak expedition to yield small quantities of oxygen, but for the task of climbing Mount Everest we are advised that the weight would be too great, and that the water needed to decompose sodox would be sure to freeze.

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FIGS. 1 and 2.—Complete musculospiral paralysis after tendon transplantation.

FIG. 3.—Paralytic talipes valgus after transplantation of peroneus brevis to inner side. The line of transplanted tendon can be seen.

FIG. 4.—Paralytic talipes varus. The tibialis anticus has been transplanted to the outer side and is here seen in action during dorsiflexion of the ankle.

FIG. 5.—Paralytic talipes calcaneo-cavus before operation.

FIG. 6.—Paralytic talipes calcaneo-cavus. Same foot as Fig. 5 one year after subastragaloid arthrodesis and tendon transplantation.

FIG. 7.—Paralysis of left quadriceps extensor. Biceps and semitendinosus tendons transplanted to patella. Leg with muscles relaxed.

FIG. 8.—Showing extension of knee by transplanted biceps and semitendinosus.