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REHABILITATION OF INJURED AIR CREWS

BY

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Flying accidents are associated with peculiar injuries, many of which are rarely encountered in civilian practice. When the flight of a machine is suddenly arrested by impact with the ground it is only to be expected that those portions of the body which are in contact with or are attached to the machine will be subjected to the greatest stresses. The incidence of injuries of the feet and legs is high because they are less well protected against missiles than the rest of the body, and the small bones of the feet are liable to be fractured by impaction against the rudder-bar. In the days when machines were not fitted with safety harness the skull was often smashed against the instrument panel. The safety harness has saved many lives, but is associated with another injury—compression fracture of the spine due to hyperflexion at the level of the retaining straps. Gunshot wounds produce a number of interesting peripheral nerve lesions. Petrol has caused many cases of severe burning of the face, hands, and legs, for some of which tannic acid treatment has proved quite unsuitable. Internal derangement of the knee-joint is a frequent cause of disability, due to lesions of the menisci and of the lateral and cruciate ligaments. The treatment of these casualties aims at the restoration of complete or maximal function, and the criterion of treatment is the category of the patient when he returns to his unit. He may be fit for full operational or restricted flying duties or fit only for ground duty. Every effort is made to make him fit enough to take to the air again, and many patients who might be discharged to ground duty are kept in hospital until maximal function has been regained.

If function is to be restored in the shortest possible time muscular wasting and joint stiffness must be prevented. Union of a fracture in perfect alignment means little to a patient until he has regained the synergic activity of his muscles, and recovery from paresis of a muscle group is of little avail if the joint which it activates has become stiffened. Muscles cannot be synthesized, and their power and tone can only be regained by voluntary contraction and relaxation. Progressive remedial exercises form a basis for treatment, but the willingness of the patient to contract and relax the affected muscles at all hours of the day, wherever he may be, is the real key to success.

The value of organized rehabilitation of orthopaedic casualties has already been established by such pioneers as Mr. H. E. Griffiths at Greenwich, Dr. H. E. Moore at Crewe, and Mr. E. A. Nicoll at Mansfield. Mr. R. Watson-Jones has stressed many times the importance of rehabilitation, and his endeavours have not been without result in the Royal Air Force.

General Organization

Having received the necessary surgical treatment in an orthopaedic hospital, casualties are transferred to one of

several rehabilitation centres as soon as they have recovered sufficiently to become ambulant. The rehabilitation department attached to this hospital is contained entirely within a very large gymnasium, so that, having entered, patients have no occasion to leave until the end of the morning. The keynote of treatment is activity, in the form of progressive remedial exercises and games. The onus of recovering the function of an injured part is thrown on to the patient. The nature of his lesion is explained to him simply, and he is told what to do in order to overcome it. Passive treatment in the form of massage and electricity is avoided unless definitely indicated. By recording daily the range of movement of a stiffened joint with an angle

FIG. 1.—Suggestion and Co-operation! (The notice on the wall reads: "We cannot cure your weak muscles and stiffened joints, but we can show you how to cure them yourselves—and it is up to you to pull your weight.")

measurer, or the strength of a wasted muscle group against the resistance of weights running over pulleys, the patient becomes interested in overcoming his disability and enthusiastic over his progress (Fig. 1). Having gained his co-operation, it remains only to supervise his progress and to ensure that his activities are graduated. The progress made by every patient is recorded weekly in a folder, which has followed him from the R.A.F. hospital in which he received his initial treatment and which contains prints of the pertinent radiographs. This folder is subsequently returned to the surgeon who performed the initial operation.

The rehabilitation department is in the charge of a medical officer, who is assisted by a physical training officer, a sergeant, and three masseuses. The department is run in close collaboration with the sports officer, who organizes all kinds of games of a competitive nature for those in

walking plasters as well as for those who are nearly fit. The gymnasium contains a small but adequate four-cubicked physiotherapy department, the medical officer's office, a milk-bar at which the patients obtain some compensation for their expenditure of energy, and cloak-rooms. The floor space, approximately ten square feet per patient, is divided into four parts: the two largest areas are used for the general remedial classes and for special remedial exercises, the third area is used for skittles and other games, and the fourth is opposite the milk-bar and contains chairs and tables at which the patients may rest.

Every orthopaedic patient performs at least two sessions of special remedial exercises, mostly of a non-weight-bearing character, under individual supervision by a masseuse. When muscular tone is regained he joins the "nearly fit" class, in which he performs general remedial exercises of a muscle-developing nature and swimming, in addition to his special exercises, which he is encouraged to perform at every opportune moment throughout the day. Finally he graduates to the "fit" class and participates in all organized activities. The general remedial classes are run concurrently and last for three-quarters of an hour. They are followed by a ten-minutes rest interval and then by competitive games such as skittles and volley-ball; both classes then adjourn to the swimming-bath.

During the afternoon golf, tennis, swimming, and volley-ball tournaments are arranged by the sports officer, who is advised as to what each patient should and should not do. It is not always appreciated that dancing has considerable remedial value.

Occupational therapy is not employed to any great extent, since it is considered that more improvement is made in the early stages of treatment by encouraging the patient to concentrate on overcoming his disability by working away at it all day long. In the later stages the patient's attention is diverted from his injured part by participation in competitive games. Patients do not undergo vocational training whilst at this hospital.

The Need for Individual Supervision

In the words of Dr. Moore: "A certain percentage of injured persons will work out their own salvation after receiving the necessary surgical treatment, with little or no help and without any special prolongation of incapacity. However, there will always be quite a fair percentage who will require something more if they are not to drift and greatly prolong their disabilities. This is due to many causes, of which the chief are failure to get over their earlier difficulties, all kinds of retarding psychological factors, apathy, a desire to escape return to their former duties, and so on. Consequently individual supervision of their progress is an essential part of their treatment."

A patient who is left to his own devices after receiving surgical treatment will quite naturally be fearful of exerting too much activity rather than too little. It is therefore most important that he should realize that the function of a plaster cast is not to prevent him from using an injured part but to enable him to use it to the greatest extent that is compatible with immobilization of the fracture. If the plaster is properly applied and remains intact it will immobilize the fracture whatever the patient may do. Supervision is necessary to ensure that the plaster does remain intact and comfortable and that the patient does make frequent use of every joint which is not necessarily immobilized.

Manipulation and arthrotomy are followed by effusion into the joint and surrounding tissues, and if the effusion is allowed to persist adhesions and wasting will develop rapidly. By means of teaching the patient to contract the

muscles which activate the affected joint before the operation, and by ensuring that he contracts them at frequent and regular intervals after the operation, the duration of incapacity is considerably shortened. Wasting and loss of tone of the quadriceps femoris muscle is of common occurrence and is apt to be associated with pain and effusion in the knee-joint if the patient performs too violent weight-bearing activity. This is because the lateral ligaments of the knee-joint were never intended to withstand strains in a mechanical sense but to evoke increased tone in the quadriceps muscle whenever they are subjected to tension. Should the quadriceps, "the guardian of the knee-joint," be weakened, the lateral ligaments may easily be stretched and cause effusion and pain, which is liable to keep the patient awake at night and is to be distinguished from stiffness on awakening, which wears off with exercise. Without supervision a patient with wasted thigh muscles may either be fearful of exerting sufficient activity to regain the strength and tone of the quadriceps or may exert too much weight-bearing activity, so that in either event the vicious circle of wasting and effusion will become chronic and incapacity is unnecessarily protracted. With supervision excessive muscular wasting is avoided and, by restricting activity to non-weight-bearing exercises until muscular tone is regained, the period of incapacity is minimal.

It is most important to treat the patient as well as his lesion and to ferret out any "fears" which he may hide in the back of his mind. A careless statement such as "he will never fly again," if overheard by the patient, may greatly retard his progress by destroying his will to recover. Daily observation of progress engenders optimism, and the progress made by others, in addition to suggestion by posters and by the staff, ensures co-operation from the patients. Compulsion is seldom necessary, and is avoided to the greatest possible extent because it tends to evoke an attitude of obstinate resistance. Before discharging a patient to flying duties it is important to ensure that he has regained confidence in his ability to perform all normal activities. A patient who has regained full movement and muscular tone after excision of the patella may yet be fearful of running. Encouragement and participation in competitive games will overcome this natural phobia.

Physiotherapy

Physiotherapy is of great value for selected cases. It is a form of passive treatment and as such is given sparingly, because some patients are only too happy to lie at their ease on a couch and receive treatment which, for remedial purposes, is a poor substitute for their own activities. Warmth facilitates the movement of any joint by inducing hyperaemia and relaxation, and the only problem is how to direct the heat where it will do most good. A hot bath, a radiant-heat cradle, and a diathermy set each have their particular uses, but in the rehabilitation department only radiant heat is used to loosen up stiffened joints before starting remedial exercises. Faradism is used only to assist a patient to acquire the knack of contracting muscles that are very much wasted, and once he has learnt to do this the faradism is discontinued, because it is considered better to avoid passive treatment and to encourage the patients to regain muscular strength and tone by their own exertions. Galvanism serves to reassure a patient with a peripheral nerve lesion that the paretic muscles will still contract, and is also of some value for the dispersal of static congestion. An experienced masseur is able to loosen muscular adhesions by deep massage, but this treatment is seldom necessary if the patient has contracted his muscles at regular and frequent intervals throughout any period of necessary immobilization.

Patients perform their remedial exercises under the supervision of a masseuse, and this arrangement is found to be more satisfactory than to use a specially trained physical training instructor for exercises and restrict the masseuses to physiotherapy, because otherwise certain patients will tend to evade the physical training instructor for more pleasurable treatment at the hands of the masseuse. It is probable that masseurs are more suitable for the treatment of non-commissioned ranks, but I believe that masseuses are better able to obtain the co-operation of young officers.

Fractures

For the purpose of rehabilitation, patients with fractures fall into two groups—those who are uniting and require immobilization, and those who have united and require remedial treatment to restore the strength and tone of their muscles and the movements of their joints. Obviously effective treatment of the first group will minimize the treatment required by the second group and will curtail the period of incapacity.

There is no really practical method of hastening the union of a fracture, and a month or a year may pass before union is sound, but this period can be minimized by completely immobilizing the fragments and stimulating their blood supply by muscular contraction. Incomplete immobilization must retard union by shearing across the developing callus which bridges the gap between the fragments. Repeated shearing of the callus will lead eventually to sclerosis of the bone ends, which is the cause of established non-union, and the pseudarthroses which reside on the shelves of our pathological museums.

To immobilize a fracture of the shaft of a long bone it is necessary to fix the joints at each end of the bone in a degree of flexion sufficient to prevent rotation occurring between the fragments. Complete immobilization of a fracture can only be ensured by internal fixation with a bone graft or a plate, and it is probable that a plaster cast alone seldom effects complete immobilization because of the interposition of soft tissues between the plaster and the bone. Union of a fractured tibial shaft may be slightly delayed when treated in an above-knee walking plaster; nevertheless if the patient walks properly, rocking from the

by muscles: the bones form only a frame, and our object is to restore function.

To adapt a leg plaster for walking purposes our practice is to use a wooden heel, which is laced on to the plaster by means of a canvas "spat," and a toe-cap (Fig. 2). The heel is hollowed out on its upper surface, to which is glued a layer of half-inch sorbo rubber. The heel and toe-cap are standardized so that they may be used on almost any plaster. They enable a patient in a below-knee plaster to walk so naturally that a casual observer would not notice

FIG. 3.—Activity!

FIG. 2.—Walking-heel and toe-cap used to adapt a leg plaster for walking purposes. This heel affords sufficient stability for the patient to be able to balance on his injured limb, and encourages heel-toe movement.

heel on to the forefoot and pushing off with his toes, there will be a minimal amount of muscular wasting and stiffness when the plaster is discarded. This is because venous drainage from the dependent limb is maintained by intermittent muscular contraction, and static congestion, which causes partial anoxaemia, rapid muscular wasting, and adhesion formation, is prevented. In the treatment of any fracture just as much attention should be paid to the soft tissues as to the fracture. For movement is effected

anything wrong with him; and if the heel of an above-knee plaster is raised with a three-quarter-inch plaster slab before applying the walking-heel, and the heel of the shoe on the sound leg is raised with a three-quarter-inch wooden block, the patient is able to walk without sticks or crutches with an almost natural gait (Fig. 3). Unlike the walking-iron, the wooden heel affords sufficient stability for the patient to be able to balance on his injured limb. This stability gives him confidence and encourages him to rock forwards on to the toes instead of pivoting his foot outwards on the stud of the iron as he steps forwards. Attention to the detailed construction of a walking plaster is well repaid, because if a patient actively contracts the flexor muscles of his toes while walking and is able to walk without limping muscular wasting and stiffness are minimal when the plaster is discarded and function is rapidly regained. Several weeks of incapacitation of a patient who is being treated in an above-knee walking plaster may be prevented by mobilizing the knee-joint two weeks before discarding the plaster. This is not done by replacing the above-knee by a below-knee plaster, but by reinforcing the anterior part and cutting away the posterior part of the above-knee portion of the plaster so that the patient is able to sit and swing his leg, thereby regaining flexion movement. For walking, the plaster is bound to the thigh with a crêpe bandage. So long as the knee-joint is splinted in the flexed position no rotation can occur at the fracture. After discarding the plaster full movement of the knee-joint is regained by non-weight-bearing exercises, flexion and extension, rowing and bicycling, until the strength and tone of the quadriceps muscle are regained. Full movement of the tarsal joints and ankle-joints is usually regained within a week as the result of walking and remedial exercises, and the patient is not discharged until his calf muscles are

powerful enough for him to be able to raise himself on to his forefoot without assistance.

After discarding a walking plaster the extremity of the limb will become swollen during the daytime unless the soft tissues are supported by an elastic or some other kind of bandage, and this tendency to swell will persist until sufficient tone is regained in the calf muscles to maintain the venous circulation of the limb. This is explained to the patients, and they are instructed to avoid standing and always to elevate the limb when sitting so that it drains by the action of gravity. Congestion is the prelude to adhesion formation, and while it persists muscular tone will not be regained. This is but one reason why it is important to maintain the tone of the calf muscles throughout any period of necessary immobilization.

Compression fracture of one or more vertebral bodies, as the result of hyperflexion of the spine, is a common injury among air crews who have crashed. Many of these cases are unassociated with injury to the spinal cord, and the patient is able to walk away from the site of the crash, although he complains of a constant aching pain in his back. Cases that require transportation should be rolled on to a stretcher and carried flat, because hyperextension of an injured cervical spine may cause dislocation, and hyperflexion of the lumbar spine may increase the compression. Compression fractures can usually be decompressed by the pull of the anterior longitudinal ligament which occurs with hyperextension of the spine by the two-table technique. Comminuted fractures can usually be realigned very satisfactorily by this method, but they unite slowly and extension should be maintained for at least five months in a Watson-Jones plaster jacket. Neurological examination often reveals symptoms referable to root compression in cases of compression fracture of the spine. These symptoms are relieved by extension of the spine but will recur if immobilization is discontinued too early. Premature mobilization of a fractured vertebral body may be followed by progressive wedging and absorption of bone. No harm is done by unnecessary immobilization of the spine provided that the tone of the musculature is maintained, but premature mobilization may produce chronic symptoms.

Activity is an essential part of the treatment of these patients throughout the period of immobilization. Extension exercises are performed daily and a progress chart is kept of the weight which each patient is able to raise over a pulley by extending his spine. If the fracture is firmly consolidated and the power and tone of the back muscles are maintained, these patients are able to return to flying two weeks after discarding their spinal jackets.

Manipulation

Manipulation is of value for increasing the range of a stiff joint that has become stationary and for relieving the symptoms in a joint that gives rise to pain at one extreme of its range of movement.

Manipulation of a stiff joint is indicated only when the surgeon is satisfied that as the result of his own unaided activities the patient is unable to gain any increase in the range of movement of the joint and that the joint has not been subjected to any form of passive stretching. The manipulation should be performed under full surgical anaesthesia, so that the muscles are completely relaxed and the surgeon is able to feel the resistance which he has to overcome. The operation should not be performed until the adhesions have become crisp and avascular so that they snap easily and are followed by a minimal amount of reaction, and manipulation should therefore not be repeated at intervals of less than two months. No matter how great the discomfort the patient should begin active

unaided movements of the joint as soon as he has recovered sufficiently from the anaesthetic, and should repeat these movements at hourly intervals. He should retain 75% of the increase gained under anaesthesia and recover the remainder subsequently.

Flexion of the knee-joint may be limited by adhesions between the patella and the femur, in which case manipulation of the joint will very probably fracture the patella; the latter should be mobilized before manipulation is attempted. Before manipulation a stiff joint should be radiographed to exclude bony block. Every effort is made to obtain at least 90 degrees of flexion of the knee-joint, and radio-ulnar movement is absolutely essential for the management of an aircraft.

Manipulation of a joint in order to relieve pain at one extreme of its range of movement should not be attempted unless the manipulator has an intimate knowledge of the normal movements, both voluntary and involuntary, of the affected and neighbouring joints. Adhesions resulting from prolonged stasis are usually broken down by the patient's own activities, but occasionally pain may persist which can be localized to one joint and one particular movement. Focal infection, if present, should be eradicated before manipulation is attempted.

Derangement of Joints

The stability of any joint is dependent upon two factors—the shape of the articular surfaces and the strength and tone of the muscles which activate the joint. Dislocation of the shoulder-joint is a not uncommon injury among air crews. This joint depends almost entirely for its stability upon the strength and tone of the muscles which surround it, and unless the tone of these muscles is fully restored dislocation is liable to recur. A surprisingly large proportion of these injuries are associated with nerve lesions, due presumably to the violence of the dislocating force. The knee-joint is sometimes dislocated. One patient who ruptured the internal lateral ligament and both cruciate ligaments regained 100 degrees of flexion movement and the joint was completely stable unless he was caught off his guard, so that he was able to run and to play games, and this was because he regained excellent tone and great power of the quadriceps femoris muscle. Rupture of the external lateral ligament is sometimes associated with injury to the common peroneal nerve.

Decrease in the range of movement of a joint by shortening of muscles or their tendons may arise from prolonged

FIG. 4.—Extension splint to overcome contracture of flexor tendons.

splinting. This may result in flexion of the fingers when the wrist-joint is extended. The wrist must be stabilized by a plaster splint, and the fingers can then be slowly extended by the pull of elastic which is stretched between a wire frame and stalls worn on the fingers (Fig. 4). The

patient is encouraged to flex the fingers at frequent intervals against the pull of the elastic, and as he relaxes the flexor tendons are stretched.

The After-treatment of Burnt Hands

The rehabilitation of patients with burnt hands requires much patience and perseverance. Provided that the tendons and joints of the fingers have not been destroyed, the degree of recovery that is possible may exceed all expectation. The first thing is to assure the patient of this, and the second is to see that he works away at his stiff joints all day long. Whatever the initial treatment has been after burning, the skin is usually very thin and tender and sweats profusely. The stiffness is due to general adhesion formation around the tendons and joints of the fingers, and is caused by the initial reactionary oedema. The fingers are usually straight as the result of splinting. Movement is regained by immersing the hand in olive oil or in paste made with fuller's earth, which is heated to a temperature of 110° F. for two sessions of fifteen minutes daily. The patient is encouraged to squeeze a piece of rubber sponge or a ball while his hand is being heated. For the rest of the day he wears a detachable splint which dorsiflexes his wrist, and a glove to the finger-tips of which are attached lengths of elastic that are tied around a hook in the splint (Fig. 5). The constant pull of the elastic tends

FIG. 5.—Flexion splint to overcome stiffness after burning.

to flex the fingers, and the patient is encouraged at all times to oppose this by extending them. Treatment may take many weeks, but to regain the use of a hand justifies any amount of trouble.

Summary and Conclusions

In this paper the principles underlying the rehabilitation of injured air crews are described. Orthopaedic casualties are transferred to a rehabilitation centre after having received necessary surgical treatment in an orthopaedic hospital. Some of these would probably work out their own salvation without further supervision, but others would certainly prolong their incapacity unnecessarily. These casualties are therefore kept under almost constant supervision in order to restore maximal function and make as many as possible fit for further flying duties, and also to curtail incapacity.

Each patient is studied individually, for with his co-operation graduated remedial activity will restore function more rapidly than any form of passive treatment. Muscular wasting and stiffness, associated with immobilization, are prevented to a great extent by active contraction. A fracture is no reason for neglect of the soft tissues.

The criteria by which successful rehabilitation is judged are: first, the category of the patient on returning to duty; and, secondly, the time that he takes to regain function. Figures are as yet inconclusive, but 16% more patients were discharged to flying duties during the first six months that this department was working than during the six months before it opened.

TREATMENT OF HAEMORRHAGIC DISEASE OF THE NEWBORN*

BY

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The recognition of extreme prothrombin deficiency as by far the most frequent cause of spontaneous haemorrhage in the newborn and the discovery that vitamin K is essential for the maintenance of the normal plasma prothrombin level have raised to the status of a specific deficiency disease what had perforce been accepted as a mishap which "occurs without apparent reason" (Tallerman, 1937). Previously the only positive findings had been the report of Whipple (1913) that he had seen no prothrombin in a specimen of blood obtained after death from a fatal case of neonatal haemorrhage, and the observation that the clotting time tended to be prolonged for the first five days of life, returning to normal about the tenth day (Rodda, 1920). The treatment of haemorrhagic disease was correspondingly vague, the earlier clinicians advising local application of styptics, and, in the case of bleeding from the cord, even encircling the umbilicus with a deep suture. Injections of gelatin solution and of whole blood intramuscularly were introduced about the same time. This latter measure, despite the early recognition that spontaneous recovery from the haemorrhagic state occurred often enough to make its therapeutic value doubtful (Schloss and Commiskey, 1911, 1912), is still widely used as a routine treatment.

In the severer cases there has been general agreement that blood transfusion is a more efficacious procedure. The introduction of vitamin K, and more especially of vitamin K analogues, into clinical practice, and the demonstration of the rapid elevation of the prothrombin index which follows the administration of these substances to the newborn (Macpherson *et al.*, 1940), suggested another and apparently specific line of treatment for haemorrhagic disease, the successful use of which has already been reported in Europe and America (Nygaard, 1939; Waddell and Guerry, 1939; and others).

Since profound hypoprothrombinaemia is now recognized as the characteristic abnormality of the blood in haemorrhagic disease of the newborn, it follows that the efficacy of any method of treatment can be measured by its capacity (1) to raise the prothrombin content of the plasma so rapidly that the haemorrhage stops in a short time; and (2) to maintain the prothrombin at so nearly a normal level that the haemorrhagic tendency does not recur.

This communication reports an attempt to evaluate by these standards the merits of intramuscular injection of whole blood, blood transfusion, and injection of vitamin K analogues as treatment for haemorrhagic disease of the newborn.

Method Used

All prothrombin estimations have been made upon capillary blood by a modification of the method evolved in this hospital (Innes and Davidson, 1941) and found to give results closely comparable to those obtained by methods requiring the use of venous blood (Quick *et al.*, 1935; Ziffren *et al.*, 1939). The test has been performed as originally described except that (1) the oxalated blood has always been diluted with four times its own volume of saline; (2) the solutions have been kept at a constant temperature; (3) the lecithin-venom solution described by Hobson and Witts (1940) has been preferred, as it was

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