CONTRACTURES AND ALLIED CONDITIONS:

THEIR CAUSE AND TREATMENT.

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THE deformities and disabilities that follow gunshot and other wounds form an interesting subject of investigation. Many of these are due to a contracted condition of the soft tissues, which obstructs the normal movement of the joints. Vague references to them as "cases of stiffened joints," or a general inclusion of all and sundry under the term "contracture" is a method of classification that is equally unscientific and unsatisfactory.

An attempt is made in this paper to elucidate some of the principles concerned in the production of these crippling conditions, and to outline the methods that may be adopted for their prevention and cure.

Passive resistance of a muscle to its normal elongation may be due to one or both of two causes: (1) The muscle may be in a state of contracture; (2) it may have undergone fibrotic changes. The two conditions are distinct, but a muscle may be the seat of both. Muscles are rarely affected singly, the distribution is generally synergic as regards definite movements—thus both pronators of the forearm are affected together and the involvement of the biceps generally determines that of the other flexors of the elbow also.

Restoration of normal passive movement to the joint is often rendered more difficult by the participation of the fibrous tissues controlling the joint in the morbid process, and there is evidence that in these cases relaxed ligaments tend to undergo definite contraction.

There seems to be ample ground for the opinion that the occurrence of contractures is relatively more common in military practice than was the case in the treatment of wounds and fractures in civil hospitals in peace time, and most surgeons in charge of military patients confess to finding it necessary to exercise the most constant care and supervision to prevent the development of these troublesome and deforming complications.

NATURE OF "CONTRACTURE."

It is necessary to make clear what is implied by the term contracture.

The word *Kontractur* was used by Hermann to describe the idiopathic state of contraction into which an excised muscle passes after it has been subjected to repeated stimulation. Under certain conditions a definite amount of residual contraction remains after each relaxation of the muscle, and if the muscle is made to contract several times in rapid succession the amount of this residual contraction is much greater and persists much longer. Finally, a condition of contraction can be produced which passes off very slowly indeed. A condition somewhat akin to this arises in muscles of the human body when under abnormal conditions they have been subjected to prolonged and excessive stimulation. As used at present, the word is of somewhat loose significance. It obviously should not be applied to muscles whose resistance to elongation is due to hypertonus; their state of contraction is in response to continuous stimulation, the result of increased innervation. It also should not be applied to muscles whose resistance to elongation is due to structural changes; such structural changes are essentially of a fibrotic character. Either the normal fibrous framework of the muscle has undergone contraction, or fibrous tissue has been deposited in the muscle substance.

There remains, however, a definite class of cases to which the term "contracture" may legitimately be applied. These are muscles that have been subjected to an excessive and prolonged degree of stimulation, and it is found that many of these offer a resistance to their normal elongation which is unaffected by deep chloroform anaesthesia. Two explanations of this resistance can be offered: (1) It is due to a state of contraction in the muscle fibres; (2) it is due to fibrotic changes in the muscle structure.

If fibrotic changes can be excluded, then the resistance arises from the state of the muscle fibres. They offer

resistance to normal elongation in virtue of the state of tension developed in them during the contractile process. Nothing short of section of the nerves to the muscle can exclude the possibility of stimuli reaching it and being the cause of the state of contraction in the muscle fibres; but if we take it that deep chloroform anaesthesia blocks all efferent stimuli, then the state of contraction of the muscle fibres must be of the residual type, and is closely allied to the condition of *Kontractur*.

The suggestion that has been offered that the muscle has undergone "structural shortening" in response to the prolonged state of contraction in which it has been maintained, must imply one or both of two things—either the fibrous framework of the muscle has adapted itself to the shortened condition of the muscle, and has undergone definite contraction, or the muscle fibres themselves are in a state of definite contraction. It will be seen that the first supposition comes under the head of fibrotic changes, and the second under residual contraction, or contracture.

Some reference to the contractile process is required in a consideration of these contracted conditions of muscles.

Various theories of the process of muscular contraction and relaxation have been advanced. The essential point in contraction is the development of a state of tension in the muscle fibre, and it has been shown that the energy developed is manifested as a surface phenomenon. During contraction lactic acid is formed, but there is no consumption of oxygen or evolution of CO₂. The restoration of this state of tension to the normal is accompanied by a process of oxidation, and the lactic acid disappears. There is considerable combustion of oxygen and production of CO₂. Fletcher and Hopkins¹ demonstrated in 1907, however, that the lactic acid did not disappear by oxidation, but that energy is restored to the system by the oxidation of carbohydrates. Hill expresses the matter by regarding the lactic acid as part of the machine but not of the fuel.

It will be seen that the lactic acid plays a very important part in the contractile process, but the nature of its action is not definitely understood.

Mines² considered the production of lactic acid as responsible for changes of surface energy, due possibly to its effect on the optimal hydrogen ion concentration for contractile response.

In the presence of oxygen the lactic acid tends to disappear, but its removal cannot be instantaneous; therefore, according to his view, a series of rapid stimuli may bring about a concentration of acid that is maximal, and so the muscle passes into "tetanus."

All authorities agree that during the process of contraction lactic acid is produced, and that during relaxation it disappears, and that its production is attended by an increase of tension in the muscle fibre, and its disappearance with restoration of the system to normal. In 1906 McDougall³ published a theory of muscular contraction in which he conceived the state of tension developed during contraction to be due to interchange of fluid between the muscle fibrils and the surrounding sarcoplasm, such interchange being determined by the relative acidity of the two media. He regards the muscle fibre as consisting of a sarcolemma enclosing contractile substance—sarcoplasm—in which fibrils are embedded. The muscle fibril is conceived to be divided into segments by transversely placed membranes, the lateral walls of the segments are inextensible, so that increase of fluid contents leads to shortening of the segment and of the fibril as a whole. A nerve impulse is followed by the production of lactic acid in the fibril, fluid passes in from the surrounding sarcoplasm, and the tension developed results in shortening of the fibril. The lactic acid tends to disappear in the presence of oxygen—he suggests that it is neutralized by an alkaline substance inherent in the sarcoplasm—and its disappearance is followed by return of the fluid absorbed and the restoration of the normal tension within the muscle fibril.

If the nerve impulses are continuous, a stage will be reached when the neutralizing substance will become exhausted and a concentration of lactic acid will result within the fibril, and consequently the absorbed fluid will be retained; the muscle will therefore remain in a state of prolonged contraction or *Kontractur*, and this will persist so long as the contents of the fibril remain acid.

Whatever explanation is advanced of the highly complicated changes that occur during the contractile process,

the part played by lactic acid in the production and maintenance of a state of tension is generally recognized, and therefore it is reasonable to assume that every factor that tends to maintain an acid condition of the sarcoplasm may be regarded as a factor in the maintenance of the state of contracture.

The production of rigor mortis appears to have some features in common with that of contracture. It is distinctly suggestive that in animals hunted to death, and in those persons who have undergone severe muscular exertion before death the onset of rigor mortis is very rapid.

The possible explanation of this fact is that the excessive oxidation going on in the system leads to a local deficiency in the supply of oxygen to the muscular tissues; therefore lactic acid tends to accumulate, and at the moment of death there is an excess of acid present.

The onset of somatic death and the failure of the general circulation stop any further supply of oxygen to the tissues. Molecular life, however, persists for some time after somatic death; and the formation of lactic acid in a dying muscle is a matter of common observation. This lactic acid would determine an increase of tension in the muscle fibre, and in the absence of a supply of oxygen this state of tension would persist. Rigor mortis would therefore be of more rapid onset in muscles exhausted by prolonged activity than in those not laden with lactic acid at the moment of death.

Some light may be thrown on the consideration of the state of contracture by a reference to the interesting phenomenon of the "catch" mechanism that is met with in some varieties of smooth muscles. Von Uexküll's⁴ description of a typical instance of its action may be quoted:

"If one takes a normal Pecten out of the water it gives two or three flaps with its shells before permanently closing them. While it is open, a piece of wood is pushed between the shells, which then close and hit upon the wood with so powerful a crash that their edges are splintered. The wood is then held as in a vice. One can, however, pull it out by twisting it about backwards and forwards, and then one is surprised to see that the shells remain motionless, just as would the jaws of a vice if an object clamped between them had been forced out.

"The shell movement shows not the least degree of elasticity. The muscular fibres seem to have been frozen solid. If one next tries to open the shell no effect can be produced, but even the pressure of a finger is sufficient to press them nearer together, and in this position they remain fixed again so that they cannot be brought back."

The action is analogous to a simple mechanical ratchet action.

The "catch" in the muscle has been shown to be put into action by one set of nerve impulses (excitatory), and removed by the intervention of another (inhibitory). A similar condition is met with in the urinary bladder of mammals, and possibly also in the muscular coat of the arterioles.

According to Bayliss⁵ the actual mechanism may possibly consist in the prevention of the spontaneous disappearance of the lactic acid produced by stimulation of the muscle.

These three conditions—contracture, rigor mortis, and "catch" mechanism—illustrate states of muscle contraction maintained without nervous stimulation, and, as has been demonstrated, it seems clear that the essential factor which they all three have in common is the accumulation of lactic acid within the muscle fibre, and this, as we have seen, is inseparably associated with the development of a state of tension therein.

PRODUCTION OF CONTRACTURE.

The production of contractures is favoured by several factors:

1. Immobilization of joints in a flexed position for continuous periods places the flexors of such joints in a position of prolonged contraction. This positional response is somewhat similar to the "plastic tonus" described by Sherrington.⁶ He has shown that in the decerebrate animal a limb will remain fixed in the position to which it is moved. This phenomenon is due to reflex tonicity from afferent impulses arising within the muscles themselves, and it would appear that each particular length of the muscle is able to set up afferent impulses of such a degree

that the resulting afferent response is sufficient to maintain the muscle at that level. Afferent impulses arise from the proprioceptors of a muscle, and in the reflex contraction of plastic tonus the muscle calls forth the necessary afferent impulse by the degree of stimulation it imparts to the proprioceptors. This illustration of plastic tonus applies to the condition we are considering, since the fixation of the joint renders the degree of contraction in the affected muscles almost a purely reflex phenomenon. The placing of a muscle in a position of contraction results in the muscle accommodating itself to this condition; an increased stream of afferent impulses calls forth corresponding afferent response, and the principle of "reciprocal innervation" leads to inhibition of its antagonists (McDougall). The consequence is that the flexors are subjected to a prolonged degree of stimulation, which maintains them in a state of contraction, and, as has been shown, it is this prolonged stimulation that leads to the production of contractures.

II. There is strong evidence that many of these cases of prolonged contraction are really cases of localized tetanus poisoning. It will be recalled that one of the earliest symptoms of the onset of acute tetanus is the increased irritability of the muscles in the neighbourhood of the wound, and, moreover, it has been found that 15 per cent. of septic wounds examined contain a virulent strain of the *Bacillus tetani*. The muscles which are the seat of the infection, and from which the virus travels up the nerve, would naturally be the first to experience the responsive efferent impulses from the anterior horn cells, and if the virus does not spread in the cord one can readily conceive a state of prolonged contraction confined to the muscles in the neighbourhood of the wound. Contractures and myofibrotic conditions, following prolonged tetanic contraction in cases of acute tetanus differ only in degree from those arising in cases not obviously the subject of tetanus poisoning. They are generally much more severe, and it is clear that, as in the case of immobilized joints, the excessive stimulation of the muscle is the essential cause of the condition.

III. The presence of local and general sepsis has probably an important effect in the production of contractures and myofibrotic conditions. Lymph streams leading from a septic focus will be charged with toxic products, and these cannot be without effect on the cells with which they come in contact. The nature of the cell membrane and the conditions that determine interchange between the cell and the surrounding lymph are still very obscure. It is known, however, that substances that render the membrane more permeable increase the excitability of the cell, and similarly, when a cell is in a condition of stimulation, it is more permeable to certain substances.⁷

The muscular tissue in the vicinity of a wound generally exhibits a somewhat more excitable condition than normal (defensive spasm), unless there is profound toxæmia present, when the reverse is the case. This increased excitability may not be wholly reflex, but may possibly be due to a permeable effect of the septic products on the cell membrane, and, if so, it is reasonable to suggest that we may here have a factor in the readiness to pass into a state of strong contraction, which muscles fixed in a position of contraction so frequently exhibit. Many muscles so affected are exposed to the effects of lymph streams which must be laden with toxic products. It is established, however, that if the lymph-borne products are highly toxic, the cell is permanently damaged, and fibrotic changes ensue. Under these conditions a definite myofibrosis takes place, with progressive shortening of the muscle as a whole.

STAGES OF CONTRACTURE.

Muscles that passively resist their normal elongation fall into three groups: (1) Muscles that are in a state of pure contracture; (2) muscles in a state of contracture, with myofibrosis supervening; (3) muscles that have undergone fibrotic changes without antecedent contracture.

Muscles in Pure Contracture.

The first group is typically represented in lesions of the upper motor neurone. In ordinary capsular lesions the flexors of the upper and the extensors of the lower limb show a condition of hypertonus. This hypertonus must obviously be due to an increased flow of efferent stimuli to these muscles.

Sherrington⁸ has shown the important part played by afferent impulses in the maintenance of muscle tone, and he regards the tonic contraction of the extensor muscles which enables a decerebrate animal to maintain a standing attitude, as an expression of reflex postural activity. He has demonstrated, moreover, that the essential afferent impulses that maintain tonic postural contraction in the extensors of the lower limb arise within the muscle itself, for the reflex tone is fully maintained even when all the skin nerves of both lower limbs and the nerves from all the other muscles of the limbs have been severed, and the tonus only vanishes when the afferent nerves from the muscle itself are divided.

These afferent impulses, on which the reflex tone of a muscle depends, pass into the cord via the posterior nerve roots and are conducted by various paths to different centres.

It may be assumed that the anterior horn cells are extremely sensitive and responsive to afferent impulses, and that they are protected from these afferent impulses by a series of synapses, part of whose function is to act as a resistance and to prevent the full force of the afferent impulse reaching them (McDougal). Moreover, there is evidence to show that in the reflex arc each afferent nerve fibre divides into two parts in the spinal cord; one division is excitatory and the other inhibitory in respect of motor neurones.

Certain poisons—strychnine and the toxin generated by the *Bacillus tetani*—have been shown by Sherrington to have a reversal effect on the inhibitory termination of the afferent fibre, and their action converts the process of inhibition into the one of excitation. It is probable also that these poisons lower the threshold of resistance at the synapses referred to above, and as a consequence a larger measure of the afferent impulse passes to the horn cells, and there is a correspondingly stronger efferent impulse transmitted to the muscle concerned. Hence the extremely powerful reflex contractions produced in these cases by very slight stimuli, such as moderate noises and movements of the bedclothes.

Normally, the afferent impulses are diverted along various paths, and only a portion of their influence is expended in the cells of the anterior horn. A considerable part of the sensory impulse passes up to the cerebral centres, where the response is to some extent under the control of the volition.

A series of experiments—Graham, Brown, and Sherrington⁹—have shown that inhibition is a more prominent reaction of the cortex than is excitation, and it would seem that one of the special functions of the cortex is to reverse the factors of purely spinal or decerebrate reflexes when necessary.

The demonstration of this fact serves to explain what is meant by "higher control" of the reflex response, and it would account for the hypertonicity of certain groups of muscles in lesions of the upper motor neurone.

In the latter conditions, the inhibitory influence of the cortex being removed, there is a correspondingly uncontrolled reflex response from the anterior cells, and the muscles concerned pass into a state of hypertonus.

In the upper limb the flexors naturally gain an early ascendancy over the extensors as they are more strongly developed, and, moreover, they have a postural advantage. They soon pass from a state of reflex tone to a state of reflex contraction—that is, they undergo shortening, and act on the joint concerned.

Once they assume the condition of definite contraction, the stream of afferent impulses from the contracted muscles is intensified, and there is a corresponding increased efferent response from the reflex centre. At the same time the afferent impulses from their antagonists have their efferent response inhibited, or most probably reversed to act on the flexors, and so what was at first a condition of increased tonus passes gradually into a condition of definite reflex contraction.

Reflex phenomena in lesions of the upper motor neurone vary according to the paths that are interrupted. Walshe¹⁰ has shown that there are two centres for reflex contraction—one, which is paracerebellar in situation, controls extensor groups only; the other, situated in the anterior horn, controls both flexor and extensor groups. The extensors are thus seen to have a double innervation.

In hemiplegia, contracture in extension in the lower limbs is the rule, and contracture in flexion is only pro-

duced when the extra-pyramidal path that connects the paracerebellar extensor centre with the extensor neurone in the anterior horn has been severed.

Then the paracerebellar extensor centre is cut off and the extensors are left dependent on the spinal reflex centre which is only partially responsible for maintaining the reflex tone of the extensor muscles. Thus, severe injuries of the cord are generally attended with flaccidity of the extensors, or with actual hypertonicity of the flexor groups.

This group of muscles in a state of pure contracture embraces, however, a much wider range of cases than those produced by lesions of the upper neurone. It includes all those flexor groups that, placed in a position of prolonged contraction by immobilization of a joint, tend to pass into a state of contracture. These have already been considered and need not be alluded to further. The muscles most frequently affected in this manner are the biceps, brachialis anticus, pronators of the forearm, and the pectoral muscles.

There is, however, an interesting condition that may be referred to here. Amputations below the knee are frequently followed by spasmodic contraction of the hamstrings and amputations through the thigh by contraction of the ilio-psoas muscles. This contraction is due to irritation of the nerve stumps, and is obviously a defensive reflex, the effect of irritation of the nerve stumps being equivalent to painful stimulation of the tissues they supplied, with the consequent reflex withdrawal of the limb.

Muscles with Commencing Fibrosis.

The second group of muscles includes those muscles in a state of contracture in which fibrotic changes have supervened. Practically all the muscles belonging to the first group tend to pass into this condition. There is no degeneration of the muscle fibres, but the fibrous framework of the muscle has adapted itself to the prolonged state of shortening of the muscle, and it has undergone definite contraction. Microscopic examination of small portions of the muscle in such cases reveals no abnormality.

Fibrosis without Preceding Contracture.

The third group includes all those muscles which have undergone fibrotic changes without antecedent contracture. It includes both flexors and extensors. Such muscles have been the seat of inflammatory disturbance affecting them in whole or in part. There may have been direct trauma of the muscle, or it may have been involved in the products from a neighbouring area of inflammation.

A diffuse scar is formed where the muscle tissue has undergone degeneration, and this scar tissue often extends into and fixes the muscle to surrounding structures, thereby limiting its range of action more effectively. The muscle as a whole may have undergone fibrotic changes following degeneration of the muscle fibres, due either to the action of toxins or to prolonged strangulation, as in ischaemic contraction.

Microscopic examination in these cases, in the earlier stages, reveals the presence of numerous fibroplastic cells infiltrating the muscle fibres, and in the later stages fully-formed fibrous tissue is seen replacing and strangulating the contractile tissue and the blood vessels.

In the normal muscle the fibrous framework is adapted to the degree of complete normal elongation of the muscle, to which it offers no resistance, but pathological fibrous tissue formed while the muscle is not fully extended will, since it is practically non-elastic, obstruct its normal elongation, and will therefore limit the degree of movement at the joint which the muscle controls.

Allied to the condition of contracture, also, is the tendency of ligaments under similar conditions to undergo definite contraction, thus offering further obstruction to the normal free movement of the joint. The anterior ligament of the elbow joint has frequently been seen to be involved, but the ligaments most commonly affected are the posterior ligaments of the metacarpo-phalangeal joints.

TREATMENT.

The discussion of the treatment of contractures and myofibrotic conditions falls under two heads—preventive and curative. The essence of preventive treatment is to deal with the cause. The principal factor in the production

of contractures has been shown to be prolonged and excessive reflex stimulation of the muscles concerned, and myofibrosis has been seen to arise as a result of degeneration or destruction of the muscular tissues. "Keep diseased parts at rest" is a doctrine enjoined both by Nature and by Abernethy, and Nature endeavours to secure this rest by immobilizing the neighbouring joints. She achieves this by establishing hypertonicity of certain muscle groups (defensive spasm) and in some cases by creating a functional paralysis of others. If a joint in the vicinity of an injury is artificially fixed in a position of flexion, she acquiesces in the arrangement by throwing the muscles thus placed in a position of contraction into a state of hypertonicity.

This employment of muscles as splints frequently results, as has been seen, in serious damage to their structure and function, but it is obvious that immobilization of the neighbouring joint is necessary, if rest for the injured tissues is to be secured, and it is not possible to circumvent the methods adopted to secure it without interfering with the process of repair. Direct treatment of the cause of contractures is therefore necessarily somewhat limited, and in many cases it is best directed along lines that aim at hastening repair, and so bring about the release of the contracted tissues at the earliest moment.

Passive and active movements should be undertaken as soon as is consistent with the state of the injured tissues, but the surgeon has to balance the question of repair against the preservation of the function of the other structures of the limb, and it is frequently very difficult to decide the rival claims.

As a general rule, however, it will be found that, as regards the condition of the soft tissues, the ultimate results will be much better if the limb is treated in a position of extension, rather than flexion, as it proves to be much easier to overcome resistance arising in the extensor than in the flexor groups.

Where hypertonicity of muscle groups is due to the toxins generated by the *Bacillus tetani*, the obvious line of preventive treatment would appear to be more effective administration of antitetanus serum, and it will be interesting to observe if the recent order from head quarters that every patient with unhealed wounds is to be injected with antitetanus serum weekly, will have any effect in reducing the percentage of contractures that has been so far experienced. Once a persistent state of hypertonicity due to *Bacillus tetani* toxin has been established, attempts to prevent the formation of contracture by moving or fixing the joint will only result in increased reflex contraction, and we must wait until the action of the toxin has largely declined before encouraging restoration of function to the muscle affected.

Where hypertonicity follows lesions of the upper motor neurone there is seldom any direct treatment of the cause possible beyond surgical relief of external pressure where that factor is concerned in the production of the lesion.

An attempt may be made, however, to prevent the hypertonic muscles passing into a condition of contracture, and subsequent fibrosis, by systematic massage and by gentle movements of the joints. The condition is amenable to preventive treatment in this respect—that the greater the degree of contraction that the muscles are allowed to assume the more marked in proportion will be the reflex efferent response.

The value of splints in controlling the action of hypertonic groups in certain cases is obvious. Thus, in hypertonicity of the tendo Achillis group, the ankle-joint should be fixed by suitable apparatus, and if the contraction of the flexors in the upper limb threatens to bring about a condition of passive resistance in these muscles, suitable means for maintaining extension of the joint should be devised.

The prevention, and control, of fibrotic changes in muscles depends on the origin of the toxin that gives rise to the degenerative changes in the muscle fibre.

If the degeneration appears to be due to faulty excretion of the products of metabolism, then the obvious line of treatment is to restore the function of the muscle as soon as possible, and in the meantime to promote the health of the muscle tissue by massage, and by movements where possible. If the degeneration of the muscle, however, is due to toxins of microbial origin, the surgeon will naturally be concerned at first with dealing with the

septic process, and will postpone any manipulation until he is satisfied that the danger of extending the field of sepsis is past. It is apparent that serious harm will be done to the muscle cells if artificial stimulation is used to promote interchange between these and toxic-laden lymph channels.

If it is considered probable that a muscle will be the seat of fibrotic deposit, it is advisable, if other considerations permit of it, to place the limb so that the affected muscle will be as fully stretched as possible while healing.

Similarly, if flexor groups are likely to be the seat of scar tissue formation, the limb should be treated in a position of rest until the cicatricial elements have been laid down. Then it should gradually be brought into a position of full extension, and kept in that position until the wound is fully healed and hyperæmia of the scar has disappeared. During the healing process excessive granulations should be pruned down, as they promote the formation of fibrous tissue elements. As a general rule, wounds of the palm of the hand and front of the wrist should be allowed to heal with the fingers and hand in hyperextension; wounds near the flexure of the forearm with the forearm in extension; wounds of the pectoral muscle with the arm abducted, and so on (Jones).¹¹

In view of the theory promoted that the condition of contracture is maintained by the persistence of lactic acid in the contractile substance, attempts to neutralize the acid by an alkaline agent were carried out.

The serious obstacle to testing the value of this line of treatment, however, was the difficulty of bringing the neutralizing agent into contact with the contractile substance. Attempts were made to flood the local capillary lymph system with solutions of sodium bicarbonate and sodium citrate, but they were not very successful. Moreover, it is very probable that the cell membrane becomes impermeable after prolonged contraction of the muscle fibre.

While experiments have shown that a short stage of excitation of the cell results in increased permeability of the cell membrane, the fact that continuation of a state of tension depends on the persistence of lactic acid within the cell would go to show that prolonged contraction brings about a state of impermeability of the membrane.

Crude attempts were made to introduce weak alkaline solutions by numerous injections into the belly of the muscle, and there is no doubt that the effect was so far favourable that a definite increase in elongation was obtained shortly afterwards. The introduction of hydroxyl ions was found to be limited in action by the readiness of these ions to combine before reaching the muscle cells. The method, however, offers a field for further experiment.

Curative Measures.

Curative measures may be divided into surgical and non-surgical. While the great majority of contracted conditions will yield to manipulation under appropriate conditions, there will remain a proportion of cases that obstinately resist every effort at extension. Indiscriminate tenotomy is, of course, to be condemned, but in some cases it is the only resource. This is especially the case where the powerful muscles of the calf are concerned; a Z-shaped tenotomy of the tendo Achillis will effect an artificial lengthening of the tendon and will enable the deformity of the foot to be corrected. A suitable fixation during healing is obtained by plaster-of-Paris, and at an early date active and passive movements of the joint are undertaken.

Non-surgical measures include (1) methods that aim at the restoration of metabolic activity in the affected tissues, and (2) movements of the joint designed to overcome the resistance to its range of action. Both active and passive movements of the joint should be employed for this purpose. The former are naturally restricted by the degree of contraction present, and success will most quickly be achieved by the exercise of the latter method.

Passive movements should be of a steady and prolonged character; spasmodic and violent efforts only irritate or rupture the tissues, and attempts at stretching under an anaesthetic fail, as a rule, to effect much improvement, because considerable force is apt to be employed, the tissues are ruptured rather than stretched, pain delays manipulation for several days following, and effusion promotes further fibrous changes. It is generally agreed that

some form of preparatory treatment prior to manipulation of the tissues is desirable, and experience has shown that heating the affected part is the most valuable method of preparation. In a fibrosed muscle the effect of the pathological fibrous tissue is constriction of the muscle fibres and strangulation of the blood vessels, with consequent exsanguination of the muscle.

A rise of temperature is followed by dilatation of the vessels and an increased flow of blood; the fibrous tissue elements are opened up and metabolism promoted. Methods of heating may be classed as wet and dry. Of wet methods there are the ordinary still water baths and the recently-introduced whirlpool baths.

The *cau courante* has been adopted in this country in view of the excellent reports made by the French regarding its efficiency. Its superiority over immersion in a stagnant bath is apparent. The temperature registered by thermometer in a bath of still water is much higher than that to which the limb immersed is actually subjected. The skin is protected in a bath by a thin gaseous film—either adherent air or CO₂ given off from the pores. The buffer effect of this film to the passage of heat, is further increased by the fact that the layer of water immediately surrounding the limb is of a temperature intermediate between that of the tissues and the water—heat passing through fluids by convection, not by conduction.

With the water of the bath in a state of constant motion, however, the protective layers surrounding the limb are swept away, and the limb is more approximately subjected to the actual temperature of the bath. It is claimed that a massage effect is obtained in these baths, and air under pressure is introduced in order to heighten the result. There is no doubt that the sensory nerves of the skin are stimulated by these means and that the superficial tissues are reflexly affected, but reflex action in muscles is mostly in response to afferent stimuli arising in the muscles themselves and the number of "skin reflexes" is comparatively small. It is the deep structures that are concerned in most of these disabilities, and they appear to benefit by the heat imparted to them; it is not apparent that they can be influenced materially by the massage action of the water. As many of the cases treated are complicated by a degree of functional paralysis, the spectacular effect produced by the introduction of compressed air into these baths must have a certain psychical effect.

Reports from centres in this country where the whirlpool baths have been established are all unanimous that a great economy is effected by their use, and that in a short period they more than repay their cost. Modifications of the method will come with further experience—for example, a rhythmically interrupted sinusoidal current passed through the bath whilst the water is in motion will be found to be much more effective both physically and psychically than the action of compressed air, but there is no reason why the beneficial effects of moving water, wave current, and rushing air should not all be combined in one application.

Baths of hot wax have been advocated by some authorities as a means of imparting high degrees of heat to a limb. Very high temperatures have been employed in this manner, but it is apparent that the tissues are not subjected to the temperature at which the wax stands. They are undoubtedly insulated by the protective layer of air which the limb carries into the bath—an explanation similar to that given of the fact that one can with impunity plunge one's arm into a mass of molten metal.

Of dry methods of imparting heat to the tissues there are the various forms of radiant heat, dry air, hot sand, and diathermy. Radiant heat has many advocates, and there is no doubt that it is an efficient form of treatment. Hot sand has been recommended as a useful method of imparting heat to the tissues. It is, however, rather painful, and the skin is found to have been rendered much too tender for subsequent massage. It has no advantages over other methods, and is but seldom employed.

Of all methods of heating the tissues, however, the most scientific and effective is by diathermy, and its advantages are not approached by any other method designed for the production and application of heat. As is well known, it is a modification of the high-frequency current (the ampérage is much higher and the voltage much lower). Heat is produced in the part solely by the amount of current which passes through it, the enormous frequency of the oscillations of the current making it possible to

transmit large amounts of current without injury to the tissues. The advantage of producing heat in the deep structures themselves is obvious. Heat applied to the skin brings about a dilatation of the peripheral vessels and a flow of blood to the surface. A great part of the heat so applied must therefore be carried away at once into the general circulation, and the condition of the superficial tissues after the treatment cannot give any reliable indication of the state of the underlying muscles and ligaments. With diathermy, however, the skin is not unduly heated, and experiments show that heat is produced uniformly in the path of the current. Moreover, the oscillations of the current are known to have a marked effect on lymphatic absorption, and pain and swelling are observed to disappear rapidly under its action.

One disadvantage of diathermy is that it is not so easy to treat so large an area of the limb as is possible with the whirlpool baths. On the other hand, many parts of the body are more accessible to treatment by diathermy than by baths—for example, the muscles of the neck, shoulder, arm, and thigh.

Whatever system of preliminary treatment is adopted, it is followed by some form of manipulation. Of massage it is sufficient to say that by direct stimulation of the muscle fibres it aims at re-establishing the normal interchange between the muscle plasma and the lymph stream. Direct stimulation of the muscle by this means is attended by various reflex phenomena; increased efferent impulses temporarily restore the muscle tone, and vasomotor dilatation is followed by a local fall in blood pressure.

Following massage, contracted tissues should be subjected to periods of prolonged and steady traction. In the intervals active movements of the joints should be encouraged if the condition of the limb permits.

Contracted conditions of the tissues are most commonly met with in the upper limb. When the flexors of the wrist and fingers are involved, the method described by Robert Jones¹¹ will be found most effective.

The wrist is flexed to permit extension of the fingers, each finger is then strapped to a gutter-shaped splint to maintain it in extension. A day or two later, according to the progress made, the metacarpo-phalangeal joint is extended and the palm and splinted fingers are bandaged to a flat metal splint. The wrist remains flexed for a day or two, and then by means of a splint it is each day gradually extended until finally it is brought into a position of hyperextension. The splints should be removed each day, and tone and nutrition maintained by a period of gentle stimulation.

A much more troublesome condition to treat is that in which passive flexion of the fingers is prevented by a contracted condition of the posterior ligament of the metacarpo-phalangeal joint. These cases have arisen by maintaining the hand and fingers in a position of extension for a prolonged period. Occasionally when there has been direct involvement of the extensor tendons as a result of trauma or sepsis, the nature of the resistance is clear, but in many cases it is probable that several structures are concerned in the fibrotic shortening. In severe cases not much is gained by attempting to overcome this condition by forcibly flexing the fingers under an anaesthetic; this generally results in effusion, pain, and a more intractable resistance to further flexion.

By the use of a metal splint similar to that introduced by Robert Jones for maintaining extension of the wrist in musculo-spiral paralysis, continuous traction can be applied, first at the interphalangeal joints and then at the metacarpo-phalangeal joints. This splint consists of a metal stem applied to the front of the forearm and hand, with cross-bars partially embracing the wrist and palm. When bandaged to the forearm, the splint holds the hand in a position of hyperextension.

Small loops of zinc oxide strapping, with a cord attached to each, are passed over the middle phalanx of each finger. The cords are brought round the cross-bar which has been left exposed in front of the wrist, the phalangeal joints are flexed as far as possible, and the cords made fast. A few hours generally suffice to overcome the resistance at these joints, and after treatment with heat, massage, etc., the loops are slipped over the first phalanges and the metacarpo-phalangeal joints flexed to the fullest possible extent and tied down as before. As a rule, it is not advisable to maintain this position for more than six hours at a time.

The splint should then be removed, the hand should be heated, and active and passive movements of the joints carried out. The actual gain from day to day may be very small, but excellent results can generally be achieved if the treatment is persisted in. For the treatment of contracted conditions of the flexors of the forearm several methods of applying continuous traction are available. Splints with springs or elastic accumulators applied to the posterior aspect of the limb are, on the whole, rather unsatisfactory. The plan of tying weights to the forearm may be of some effect, but it does not commend itself to the patient.

The best results are obtained by placing the patient on his back on an ordinary massage couch. His shoulder and chest are fixed to the couch by adjustable strappings. A firm pad is placed under the flexed elbow, and traction is applied in the line of the arm by attaching a strong cord to the wrist, passing it over a pulley at the bottom of the couch, and fastening it below. After five or ten minutes the cord becomes noticeably slack as the flexion yields, and it requires to be tightened up at intervals. Cases steadily improve if this treatment is carried out for periods of an hour twice a day. The pectoral muscles can be stretched in similar fashion by tying the extended arm back to some object in the room, the weight of the limb being sustained by a small table placed under the forearm.

The Zander system provides an excellent method for the exercise of both passive and active movements. The machines can be adjusted, either passively to stretch contracted tissues or to provide a resistance against which the muscles are encouraged to contract. The action is a rhythmical one, and its value lies in the fact that the force is evenly exerted without sudden jar or strain; this is effected by an adjustable system of counterpoise, the action of which resembles in some measure the steadying and controlling effect exercised by antagonistic muscles during the contraction of their opponents. The Zander machines are expensive, but where large numbers of cases are treated they very soon repay their cost.

Whatever line of treatment is adopted, restoration of function and voluntary exercise of the affected limb should be encouraged from the earliest possible moment; and interference with the function of the muscles concerned should be as limited as is consistent with the treatment being carried out.

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Lectures .

ON

DISEASES OF THE MALE URETHRA.

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LECTURE III.—COMMON METHODS OF EXAMINATION AND TREATMENT (continued).

MASSAGE OF THE PROSTATE.

INSERT a gloved finger into the rectum. The prostate may be felt to be swollen, hot, and tender, or its outline may be lost and nothing be felt but a large smooth projecting abscess. If it is too tender, no further examination should be made, but if not, make gentle pressure with the finger from the outer limits of the swelling forwards and inwards towards the urethra. After a certain number of such squeezings, it will be found that a drop or more of purulent or opalescent fluid has appeared at the meatus. This is prostatic fluid. If needed for examination, it is caught on a microscopic slide, spread out as a film, fixed

by gentle heat, stained with methylene blue, washed, dried, covered with cedar oil, and inspected with a $\frac{1}{2}$ in. oil immersion lens.

Healthy prostatic fluid consists of little else but droplets of fat (lecithin) suspended in a clear fluid. These are seen in the film as blue amorphous particles of varying sizes. Here and there an epithelial cell may be seen, but pus cells are remarkable by their absence. In prostatitis the film of prostatic fluid contains a large number of pus cells. This is the diagnostic feature. It is uncommon to find either gonococci or other bacteria in a stained film unless the examination be made as the acute stage is coming to an end, and it is usually only possible to isolate the bacteria by special stains or by culture on suitable media.

I cannot too emphatically warn you to use only the greatest gentleness in this procedure. The process is one of "peaceful persuasion." A heavy hand is not needed. If too great force is used the rectal mucous membrane may be torn, which will cause a fissure *in ano* and even ischio-rectal abscess. I have never seen this in my own practice, but cases have been brought to my notice with these sequelae in which too great force has been used, the operator not having realized that great force is not required. Again, there is the risk of setting up epididymitis if force is used. The process should only last one or two minutes, and the object has been obtained if a drop or two of fluid can be seen exuding from the meatus. Cure attends gentle methods.

By thus emptying the prostate not only do you remove some of the infected contents, but you open up also the blocked ducts, so that drainage is improved. You also ensure that fresh fluid from the blood vessels enters the prostatic tubules ("Nature's antiseptic fluid"), and probably you liberate a certain amount of gonococcal endotoxin, and produce an autovaccination of the patient with his own vaccine from his own germ as it lives in the tissues.

As a general rule prostatic massage should not be carried out more than every fourth or fifth day, and in many cases once a week is enough, or even once a fortnight. In chronic cases give a course of prostatic massage every fourth or fifth day for four weeks. Then give the parts a rest, and if possible get the patient away to the seaside. After a rest of two or three weeks test the fluid microscopically, and if not yet healthy institute another course of some weeks' duration. It is a great mistake to go on too long without a period of rest.

Indications for Prostatic Massage.

1. As a diagnostic measure in subacute or chronic cases, to obtain a specimen of fluid for microscopic examination.
2. In subacute cases every second or third day, to secure the subsidence of the swelling, and drainage of the glandular tissue.
3. In chronic cases every fourth or fifth day to secure drainage and autoinoculation.
4. In acute cases never except under two conditions—first, when there is retention of urine, to secure rupture of an abscess into the deep urethra; secondly, in joint cases, to empty the blocked vesiculae and prevent further absorption of gonococci into the circulation.

LUBRICANTS.

The ideal lubricant is one soluble in water that contains no oil or fat, that is strongly antiseptic, non-irritating, and always ready for use.

The objection to oily lubricants sterilized by heat is not that they are not sterile, but that they coat instruments and the urethra with a film of fat. A film of oil makes it more difficult to cleanse the surface of an instrument, and prevents formaline vapour from acting efficiently as a sterilizing agent on the surface of an instrument. Again, a urethra coated with oil cannot benefit from lavage by antiseptic fluids. I have abolished all oily lubricants from my clinic, as there is no need for them.

The ideal lubricant consists of sterilized glycerine 20 parts, tragacanth 2 parts, oxycyanide of mercury $\frac{1}{4}$ part, sterilized distilled water 100 parts. This formula we owe to Casper of Berlin, and it has been widely copied as the K.Y. lubricant, or as Lubrifax by Burroughs and Wellcome. It is put up in tin squeezer tubes with a screw top, and is thus portable and always ready for use. It is sterile and antiseptic, is a good lubricant, is transparent enough for cystoscopic use, and is soluble in water.