THE UTILIZATION OF THE MUSCLES OF A STUMP TO ACTUATE ARTIFICIAL LIMBS:

CINEMATIC AMPUTATIONS.*

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It affords me the greatest pleasure to place before the British medical profession the facts as to what has been called cinematic amputation. I feel this all the more because I am thoroughly convinced of the enormous advance which the conception of cinematization will bring about in the treatment of disabled men, and believe that all that concerns this new current of ideas, as well as the store of facts related to them, ought to be placed at the disposal of the world at large.

In briefly reviewing the fundamental theories of plastic motors, and pointing out the vast field thus thrown open to the activity of orthopaedic surgeons and mechanical engineers through the practical application of these theories, I venture to express the hope that our efforts may prove welcome to all those who have hitherto had no opportunity of studying this important scientific innovation.

Whilst in Italy the tireless work of propaganda undertaken by Dr. Giuliano Vanghetti, the original exponent of these theories, has led to their full discussion and close study and to many experiments, and whilst both German and Austrian scientists have been actively working to obtain the most practical application of these same theories, the medical literature of France, England, and America contains very few, if any, allusions to the subject.

In the space at my disposal I must content myself with outlining the fundamental principles upon which the theory is based, pointing out, as briefly as possible, the various ways it can be put into actual practice, and making a short statement as to the method of operation and the results.

The possibility of utilizing the functional resources of the stump so as to convey movement to the artificial limb was an idea that came to Dr. Vanghetti first in 1896, at the time of Italy's second expedition into Abyssinia, when soldiers that had been taken prisoners by the native forces under the Negus were cruelly tortured and mutilated.

From that time onwards Dr. Vanghetti wrote and published innumerable articles, wherein he developed his theory on what he had now named "cinematic amputation." In them he described very fully the origin of his idea and the various methods by which it could be practically applied. Unfortunately for the speedy acceptance of this most novel and useful idea, Dr. Vanghetti, though his originality, cleverness, and ability are indisputable, is not a surgeon, but a physician, and for this reason was unable to put his theory into practice. He was therefore forced to resign himself to endless delays before he succeeded in convincing surgeons of the great value and practical possibilities of his theory and obtaining their co-operation, which was indispensable to any adequate test. This was the principal reason why, prior to the war, the cases of cinematic amputations did not number more than twenty.

THE PRINCIPLES OF CINEMATIZATION AND OF "PLASTIC MOTORS."

Dr. Vanghetti has given the name of "cinematic plastics" or "cineplastics" to any kind of bloodless or operative plastics that tends to economize, restore, or substitute those muscular masses that can be employed to impart direct and voluntary movement to an artificial limb.

The word "cinematization" was formerly used to indicate the cineplastic operation; it was subsequently applied to every kind of cinematic artificial limb, and finally to the active and early mobilization of such muscles as are involved in cineplastic operation.

Every moving entity obtained cineplastically, whether bloodlessly or operatively, is called a "plastic motor."

* Professor Putti, Professor Pellegrini, and Captain Pieri (Italian Royal Army Medical Corps), delegates to the Inter-allied Conference on the after-care of discharged sailors and soldiers, read papers and gave demonstrations on cinematic amputation and cineplastics in the section of the Conference on surgical treatment. Subsequently, Professor Putti summarized the present position of the subject in an address to the Royal Society of Medicine, the substance of which is here reproduced.

Plastic motors are based on the following general principle: In an amputation or disarticulation, actual or antecedent, the tendon and muscle, provided they have the necessary physiological protection—skin, vessels, nerves, etc.—can generally be used in cinematic prosthesis, on condition that the formation of an artificial point of attachment, to be protected in a similar manner, is available. Cinematization can be effected, or prepared, at the time that the primary amputation is made; it can also be done on stumps that have already healed.

Plastic motors may vary as to their number, position, shape, and function.

Without entering into too detailed a description of the numerous varieties of plastic motors, I will limit myself to stating that, at the present day the most elementary, and, up to now, the most commonly used are, as regards shape, the *clava* (*clavus*, a peg) and *ansa* (a loop) motors, and those obtained by means of the canalizing, or tunnelling, of the muscular masses.

As regards number, the motor may be single, double, or multiple; in function it can be either *unimotor* or *plurimotor*.

When the motor is made to execute two opposite movements in succession, it is called *alternative*.

According to the position they occupy, motors are either *terminal*, when placed at the extremity of the stump, or *extraterminal*, should they be placed in the continuity of the stump.

Down to the present time the upper limb has been more frequently cinematized than the lower, but the number of successful cases of cinematization of the lower limbs is daily increasing.

APPLICATION OF THE PRINCIPLES.

From what I have said, it will be evident that the application of cinematization entails essentially a radical upheaval of all preconceived notions as to the ordinary methods of amputation.

Principles observed in the performance of amputations according to prosthetic criteria have already caused a revolution in modern surgery, but they must again be subjected to modifications in order to ensure the preservation of the greatest possible amount of the original bone and of the residual motor masses and integuments, for these must be used for the preparation of the plastic motor.

In cases where it is practically impossible to perform primary cinematic plastic operations, as, for instance, at the first-aid dressing stations in the full stress of battle, the surgeon can, at any rate, always so operate as to prepare the ground for a future cinematization of the stump. Skin flaps, muscular insertions, various bone and tendinous fragments and segments of limb, which would seem utterly superfluous under ordinary circumstances for the preparation of ordinary stumps, must be recognized to be of the greatest value in view of the future cineplastics.

In order to prevent the possible loss of these elements and of these materials whilst the stump is undergoing the process of healing, it is advisable to take certain special technical precautions to avoid the retraction of the softer tissues; this ought to be done, however, in such a way as not to hinder the ordinary dressing of the wound.

When the inflammation has decreased, and further complications are no longer to be feared, the time has come for the actual cinematization, that is to say, for the preparation of the plastic motor or motors. A plastic motor, in order to fulfil the purpose with which it is made, must conform to the following requirements:

1. It must possess every requisite for withstanding a firm, resisting, and painless grip, and also a traction force that, in not a few instances, may be high.
2. It must be provided with a sufficient amount of muscle masses capable of functional movement to guarantee the accomplishment of the task that will be demanded of them.

The primary conditions for obtaining the first requisites are:

1. That the motors be covered with skin in perfect condition, well nourished, and possessing a normal degree of sensibility.
2. That, with regard to its shape and dimensions, the motor be of a size suitable for the fastening of the hooks, rings, and rods, that are destined to transmit the functional movement to the artificial limb.

The "Clava" Motor.

The movement masses must be sought for, and obtained from amongst those which the stump still possesses. Such masses as from their anatomical structure and physiological disposition produce broad, strong, and dissociated contractions, are the best adapted to the task. In the choice and distribution of these masses the fundamental principles of the physiology of movement must be thoroughly observed and respected.

As the tendon is the element best adapted for the transmission of muscular contractions, it should be largely employed for the formation of plastic motors. Should the tendon be missing, the muscles must be utilized either by including muscular bundles within the terminal motors, or by tunnelling the muscular masses in order to obtain the extraterminal motors.

The antagonistic force, indispensable to all active movement, must be provided either by the stump itself through the formation of two motors with elements belonging to muscular groups of opposite action, or by the artificial limb by means of elastic resistance in the opposite sense to that given by the plastic motor.

With a view to gaining both space and integument it may be advantageous at times to shorten slightly the bone or bones of the stump, and to excise superfluous muscular masses. This, however, can only be done when the bone is sufficiently long to allow it.

In order to provide such materials as may be missing *in loco*, recourse may be had to the numerous methods that modern plastic surgery places at our disposal, as, for instance, skin, muscular, aponeurotic, or osseous transplantations. Arthroplasties, with the interposition of an aponeurotic flap, may be utilized so as to render mobile those stump segments which, through stiffness and ankylosis, have become unusable. By these same means a new joint can be created in the continuity of the stump, thus giving the plastic motor the power to develop a leverage action.

The cinematization of the thigh stump enables us to solve one of the most difficult prosthetic problems—that of gaining active power over the knee-joint. With the ordinary artificial limbs the knee extension is obtained either by means of springs or of elastics, quite independently of the will of the patient, or else through straps put on the stretch by auxiliary movements of the trunk and shoulder. In some cases we have carried out successful experiments by cinematization of the quadriceps femoris; then the stump itself can control the voluntary extensor movement of the knee, and restrain the flexor movement.

As a result of cinematic plastics we are now able to utilize certain stumps which hitherto have always been held as incapable of functional movement, such as, for instance, carpal stumps, very short stumps, and disarticulation stumps.

The surgeon who, in the case of shoulder disarticulation, succeeds in sparing the deltoid and pectoralis major, in covering these muscles with skin, and in finding means of creating a point of attachment, may be congratulated on having preserved for the benefit of the mutilated man a precious functional capital.

With regard to the difficult problem of utilizing short forearm or short leg stumps, the solution will be enormously facilitated through the preparation of points of attachment that correspond to the insertion of the biceps and patella tendons.

[In order to illustrate the fundamental principles of cineplasties, Professor Putti demonstrated a number of plaster casts of amputated stumps, in which he had prepared different kinds of plastic motors. The first cast was of the stump of a forearm with two terminal motors; one of these had been formed with the tendons of the flexor muscles, the other with the tendons of the extensor muscles. It was a case of disarticulated wrist, and the stump was already completely healed. After excising about an inch and a half of the radius and of the ulna, two cutaneous flaps were prepared, each of which served to cover the two principal groups of tendons in the forearm, that is to say, the flexor and extensor tendons. Professor Putti thus obtained two plastic motors like clumsy fingers, of which one was controlled by the flexor, the other by the extensor muscles.]

Two points of attachment must be provided in these two "fingers," in such a way as to ensure the transmission of

their contractions to the artificial limb, with a view to giving movement to the hand. This I obtained by means of metal rings covered with vulcanized rubber placed at the base of the fingers, and gradually tightened; to them the artificial motors of the hand were attached. The stump thus became capable of giving flexor or extensor movements to the artificial hand.

In cases in which it is not possible to obtain sufficient material for the construction of two motors, we must limit ourselves to the preparation of a single motor, the antagonistic movement being provided in the artificial limb by a spring or an elastic.

The "Ansa" Motor.

Another type of plastic motor is that known as the *ansa* motor. In the case from which the cast exhibited was taken, after shortening sufficiently the radius and the ulna, I prepared the tendons of the flexor and extensor muscles, and gathered them together in such a way as to form a ring or loop, which I afterwards covered with skin. Whenever the disabled man contracts either of the two muscular groups, this ring, or loop, displaces itself alternately either in a flexor or in an extensor sense, and the contractions are transmitted to the artificial limb.

The plastic motors so far described are formed of the soft parts of the stump. In order to give greater consistency to the motors they can be provided with a bony support.

ILLUSTRATIVE CASES.

The stump in the first case demonstrated is from a case of disarticulation at the wrist. I formed a para-epiphyseal pseudarthrosis, excising from a third to a fourth of an inch of bone from the shafts of the radius and of the ulna and then interposing a double flap of fascia and of muscle. I was thus able to obtain an artificial wrist having all the movements with which, normally, the wrist is provided, for the muscles and tendons that cause these movements had been, for the greater part, preserved.

I performed a similar operation on the stump of an arm. Having detached a fragment of bone from the extremity of the humerus at the height of about one inch, I interposed a muscular flap between the severed section of the bone. Thanks to the neo-arthritis, the stump is capable of flexor and extensor movements, for into the piece of severed bone the muscular bodies of the biceps and of the triceps are still inserted.

I believe that these cases sufficiently show the principal types of terminal motors. As regards their preparation, it is nearly always necessary, as I have said, to sacrifice a certain quantity of the stump's original bone. But plastic motors can be obtained without compromising the length of the bone. This is achieved by directly tunnelling the muscular bodies.

In the forearm stump I prepared the group of the flexor superficialis, preserving its normal cutaneous envelope. By a plastic operation I next covered with skin the space comprised between the superficial flexor and the deep flexor, thus creating a canal completely lined with skin. During the period that the wound was healing I maintained this canal open constantly by means of a rubber tube. Once the cutaneous wounds had healed, I inserted a metal rod covered with vulcanized rubber in place of the rubber tube. This little rod serves as point of attachment for the cords used to convey movement to the artificial hand. Following each contraction of the flexor muscles, this small rod displaces itself in a proximal sense, and thus actuates the fingers of the hand.

Arm and thigh stumps are better adapted to this style of cinematization than are those of the forearm. I show casts of two stumps of the lower third of the thigh in which I prepared a canal running horizontally and to the full depth of the quadriceps a little above its insertion into the patella. Into the canal I introduced a skin flap folded back over itself in such a way that the cutaneous surface was turned towards the lumen of the canal. The tunnel thus formed is entirely lined with skin, and can withstand, without risk of damage or pain, the presence of the metal rod that serves for the transmission of the extensor movement to the artificial leg.

At the first glance it may appear strange that these mechanical attachments can be so easily tolerated. Experience has proved, however, that if the plastic motor is well placed, if the skin that covers it is healthy, if the

wounds are absolutely healed, neither the rings nor the rods cause the slightest harm. When the *clava* motor is sufficiently long, and its head is large enough, the ring surrounding the neck of the *clava* need not be tightened to such an extent as to interfere with the blood supply of the motor. Moreover, each ring is provided with a screw by means of which the disabled man can himself regulate the pressure.

The disabled men get so accustomed to the metal rod that they leave it in place even at night. The rod must, however, be removed once every twenty-four hours, in order to clean it with alcohol and oil it with vaseline. I have observed that the skin within the canals gradually acquires the property of throwing off sebaceous substances in greater quantities than normal, thus providing for the oiling of the canal.

FUNCTIONAL RESULTS.

Another point deserving consideration is the sensibility of the plastic motors. Professor Amar has made some most interesting physiological researches, showing that the superficial and deep sensibility, and the muscular sense of the stumps, which at first—that is, shortly after the amputation—are greatly altered, not only recover in time, but eventually attain a degree of sensibility superior to the normal, provided the stump is put through the proper functional training. I have observed that the same thing happens with cinematized stumps. One of my patients, on whom I operated over a year ago, is now able to note with considerable exactitude the difference in the size and weight of the articles which he seizes with his artificial hand.

The functional results that can be obtained from a plastic motor depend upon numerous factors, but especially on the cinematic powers of the muscular masses of the stump, on the manner in which the surgeon has found it possible to utilize them, and upon the functional use the motor undergoes. To give a clear conception of the amount of work that a plastic motor can do I may state that amongst the cases operated upon by me the power of the motors ranges from 10 kilogram-centimetres at the lowest to 100 kilogram-centimetres at the highest. For a motor to be of practical use it must be contracted not less than one inch. In the case of a hip stump, I have obtained one motor that contracted to the extent of two and one-fifth inches, lifting a weight of forty-four pounds.

I have only described the principal types of plastic motors. The genius and the ability of the surgeons will find here a vast field of action. Naturally, it is not possible to treat all amputated stumps in this manner. Those that best lend themselves to it are those that include healthy muscular masses, that retain normal innervation, and that possess an ample contractility. Stumps with rigid or ankylosed joints, covered over by skin that does not glide easily, being adherent or creased by a scar, do not supply satisfactory plastic motors. The age, and moral and intellectual condition of the patient are also important. The best age is from twenty to thirty years. Disabled men of insufficient mental development, or those who are not likely to be willing to follow with patience and assiduity the necessary functional training of the stump muscles, ought not to be operated upon.

It is to be understood that cinematization does not invariably require operations with the knife. There are stumps already formed which are endowed spontaneously with cinematic resources that, wisely employed, can be utilized for transmitting movement to the artificial limb. I will content myself with mentioning the wrist and forearm stumps, in which rotary movements are preserved, and the arm and forearm stumps, that possess a terminal hood having a development and contractility sufficient to ensure a good grip.

CONSTRUCTION OF SUITABLE ARTIFICIAL LIMBS.

Whatever type of plastic motors may be chosen, it is an essential condition for their efficient utilization to their full value that the artificial limb be adapted in a manner suitable to their power, their number, and their shape. This question of cinematic prosthesis is so vast and still so new that it deserves a special study to itself. It is now undergoing gradual development and will bring about a substantial reform in ordinary constructive methods. The surgeon, the physiologist, and the mechanic must all

collaborate intimately in this work, as only by means of the perfect fusion of these three can we obtain new methods of a really scientific character that will answer modern requirements and replace the empirical systems that have been followed up to now in the manufacture of artificial limbs.

[Professor Putti demonstrated specimens of artificial limbs especially constructed for cinematized stumps. Among others three hands, of which two were made for stumps with a single plastic motor; in one the contraction of the motor is used for opening the hand, which was kept closed by means of a spring; in the other the motor closed the hand. The third hand was made for a stump with a double motor; the movement of closing and opening the fingers was wholly controlled by the two motors. He showed also appliances representing various types of artificial limbs for forearm stumps, and continued as follows:]

The construction of the artificial limb is greatly simplified by the possibility of utilizing the intrinsic powers of the stump. The mechanical contrivances hitherto used for moving the fingers are most elementary; the cords, the levers, and the springs used for conveying movement to the hand by utilizing the movements of the elbow and of the shoulder can now be completely done away with, and the disabled man rendered able to open or close the fingers in any position of the limb. Even workmen's tools can be used in a practical way by the cinematized stump, and a special pincer shaped like a parrot's beak has been devised for the use of workers in metal.

RESULTS.

As to the ultimate results of the cineplastic method, no final judgement is as yet possible, for though the idea was conceived over twenty years ago, cinematization has been applied on a larger scale only since the beginning of this war.

The very few cases of operations of this type performed prior to the war—almost exclusively by Italian surgeons—had afforded sufficient proof of the soundness of methods, but they had not provided enough material to enable us to judge with regard to their practical usefulness. Only since the beginning of the war, when the necessity of giving practical aid to the vast and tragic army of disabled men came to the fore, were our surgeons convinced of the expediency of testing the principles and methods of cinematic surgery. We are yet at the very beginning of this new scientific movement, and the surgeons of all allied nations have not as yet contributed to it.

The German surgeons have followed Sauerbruch's example, and, although they have created an admirable scientific organization, they have limited themselves to the repetition of a single type of plastic motor. Consequently, in analysing the results obtained by them, we can form but a partial judgement of the practical value of cinematization. The number of operations performed by Italian surgeons is probably inferior to those done in Germany, but the variety of the motors experimented upon by us is certainly greater.

It is easily understood that, for the moment, it would be impossible to make a synthesis of such a variety of facts. I therefore believe that it will prove of greater benefit, in discussing the results that have been obtained through cinematization, to consider the question solely and exclusively from the point of view of my own cases.

These number about fifty examples of cinematization of the upper and lower limbs, either primary or secondary; plastic motors of various types were formed, and in each case an artificial limb was applied. The functional value of the motors was studied by dynamographic and dynamometric methods, whilst their practical capacity was tested in the actual use of the artificial limb.

At the Instituto Rizzoli I have at my disposal a large workshop for the construction of artificial limbs, so that I have been enabled to study cinematic prosthesis as well; this, as I have already said, constitutes one of the most important sides of this complex question.

CONCLUSIONS.

The researches that have been made in the Institute have brought me to the following conclusions:

1. The practical results that have been obtained through cinematization have convinced me that the hopes aroused by the principles and methods of the modern theory of

plastic motors are thoroughly well grounded. Cinematic plastics are entitled to be placed amongst the most brilliant of the discoveries of orthopaedic surgery, deserve to be accepted with perfect confidence, and to be tested on a large scale by all those whose aim it is to restore to the disabled man his functional activity.

II. The preparation of plastic motors is a well-defined surgical act that must be performed in accordance with its own special methods, which have already stood the test of experience.

III. From a physiological point of view plastic motors have been proved capable of giving both the quality and quantity of action of which the muscular masses that stimulate the said motors are capable. Yet, practically considered, plastic motors will yield the full measure of their value only if the artificial limb is perfectly adapted to their shape and their strength.

IV. As the principal aim of cinematization is to attain the vitalization of the artificial limb, it is essential that the surgeon and the artificial limb maker should work in harmony, in order to solve satisfactorily this most interesting but difficult problem.

Demonstration of Moving Pictures.

Professor Putti exhibited a number of moving pictures to illustrate the results of cinematic amputations. They included arm and forearm stumps with plastic motors, and demonstrated very well the power the man had over single or double (flexor and extensor) plastic motors. In other cases terminal "ansa" motors of the forearm were shown, and the power of the patient to lift a weight demonstrated. The films showed both the bare stumps and the same men fitted with artificial arms and hands. Two other films showed cases of cinematization of thigh stumps, plastic motors being obtained by tunnelling the quadriceps femoris. The patients were also shown wearing artificial legs. The case with which they could raise the limb with the knee in extension, and the advantage the plastic motor gave in walking were clearly shown.

THE RELATION BETWEEN HEAT-STROKE AND MALIGNANT MALARIA.

(Preliminary Note.)

BY

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HAVING been intimately connected with the study of heat-stroke and malaria throughout the record heat in Mesopotamia during the summer of 1917, I feel bound to record certain conclusions to which I have been forced as a result of observation.

That there is a close relation between the two conditions is beyond question; and this paper is written (in full consciousness of its heterodoxy, and in confident anticipation of much adverse criticism) in order tentatively, and with all humility, to suggest that heat-stroke as a clinical entity is non-existent, and is nothing more than a symptom, on a hot day, of malignant tertian malaria.

One of the clinical pictures with which one soon became familiar was that of a thick-necked, middle-aged man, who would be admitted to hospital, in the cool of the evening, still unconscious, and with a temperature of about 108° F.

In his own camp, about middle day, this man would have been seized with sudden headache, vertigo, and unconsciousness—sometimes with violent maniacal delirium. He would have been treated locally by means of cold sponging, and perhaps an ice-pack—for this year (1917) there has been no shortage

CHART 1.—A. On admission.

of ice—and he would have been transferred to hospital as soon as ever the heat of the day were over. (It were certain death to attempt to transfer such a case before 4 in the afternoon at the earliest, with a maximum shade temperature of 125° F., such as we had

in July of this year.) Such a case would, on admission, be taken direct to the heat-stroke station and treated symptomatically in the usual routine manner—by means of venesection, infusion, rubbing with ice, and copious ice enemata.

Another common picture was that in which the heat-stroke "super-vened" upon another disease. And in this the characteristic thick-necked, middle-aged, rather alcoholic type was conspicuous by its absence. This time the patient would be already in hospital suffering from some quite other complaint—sandfly fever, dysentery, even malaria itself. And there was no type that one came to recognize as being especially associated with this form of heat-stroke. The patient would feel the heat a great deal in the early afternoon—might even beg one to give him "something to make me sweat, sir," and was almost

CHART 2.—A. On admission, 6 p.m., the temperature was 103.2°; it did not rise above normal after September 5th.

CHART 3.—q. Quinine gr. x, thrice daily.

CHART 4.—q. Quinine gr. xv, thrice daily.

invariably constipated. One afternoon he would become very restless in bed, and in a very short time unconscious, with a rectal temperature of 108° or 109° F.

This year there were two formidable heat waves—the one in July and the other in August (1917). It was not

CHART 5.—July, 1917.

CHART 6.—August, 1917.

until the second of these that it became the custom in this hospital to make an immediate routine examination of a blood film for the presence of malaria parasites. In view of the very high percentage of heat-stroke cases whose blood was found to contain the parasite of malignant