able. Preliminary results are encouraging, and such a process has manifestly so many advantages that work to this end will be continued.

3. *Disinfestation of Furniture and Clothing.*—A van process of disinfestation, using heavy naphtha, has been developed which promises well. So far it has not had an extended trial, but the preliminary results are satisfactory. Further work is in hand.

4. *Reaction of Workmen using Naphtha in Disinfestation Work.*—Complaints by workmen have been almost negligible. One man developed a slight skin irritation on the hand, but this has been cured by the use of lanolin, and, generally speaking, the men have taken kindly to the use of naphtha as a fumigant.

The earliest experiments with heavy naphtha and much of the subsequent work described in this paper were made possible through the interest and co-operation of Dr. J. Macmillan, medical officer of health for the borough of Woolwich. We wish to express our indebtedness to him for the use of houses, equipment, and the services of members of his staff.

All the work on heavy naphtha has been carried out for the Medical Research Council under the auspices of its Bed-bug Infestation Committee.

THE RECOVERY PERIOD IN ANTERIOR POLIOMYELITIS

BY

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No big epidemics of anterior poliomyelitis have been recorded in England, yet on an average 640 cases occur annually, and the more severe of them present an important medical and economic problem.

It is well known that many patients improve greatly after the acute illness has subsided. However, observers disagree on the length of the period of recovery when adequate treatment is given. Some state that it is as short as nine months, others as long as four years. There is therefore some uncertainty regarding the proper duration of hospital treatment; and when spinal, abdominal, and lower limb muscles are involved it is even more difficult to decide when patients should be allowed to walk. In order to avoid the possibility of insufficient treatment it is best to err on the side of safety, and keep them in bed while there is any possible hope of improvement. This means that some patients are treated in hospital for a longer time than is afterwards found to be necessary. Economic considerations are involved, for the cost of keeping a patient in hospital is at least two pounds a week, and another person is for the time being deprived of the bed. More accurate information on the length of the recovery period is needed before this essential margin of safety can be reduced.

Although a huge American literature on poliomyelitis has accumulated during the last twenty-five years, most of it is devoted to descriptions of various forms of treatment and comparatively little to analysis of the results. In the Royal National Orthopaedic Hospital, since 1932, the progress of patients with infantile paralysis has been carefully recorded on muscle charts, which have provided the data for this study. The value of these charts in the prognosis and treatment of poliomyelitis has not been sufficiently appreciated in England, and it is to be hoped that they will be more generally used.

In the present investigation I have determined the progress of paretic and paralysed muscles in thirty-six patients all receiving the commonly accepted treatment from the time of the acute infection. The data so obtained are important in arriving at a prognosis regarding the degree of muscle recovery, and when the lower limbs are involved this affords a guide in deciding when to begin ambulatory treatment.

Treatment

During the acute phase of the disease a patient is given absolute rest in either a plaster shell or a complete plaster case. In this way the damaged anterior horn cells are shielded from stimuli on the sensory side and from the patient's desire to move the part. This period of rest during the stage of acute inflammation is in accordance with general pathological principles, and in practice is approved by competent observers who have dealt with many cases. When muscle tenderness has gone one infers that the acute inflammation in the cord is subsiding. Muscle re-education is then started in conjunction with radiant heat and massage, while joints are moved, passively if necessary, to prevent stiffness. Particular care must be taken to avoid fatigue of the recovering muscles, and when exercises are not being carried out, overstretching of the weak muscles is prevented by resting them in plaster shells or splints. Light tasks are imposed on muscles too weak to function against gravity. In many instances the exercises are carried out in warm-water baths, gravity being eliminated thereby, while the heat improves the circulation. In a few instances electrical stimulation is an additional therapeutic measure, valuable when there is one weak muscle in a group the other members of which have the same function but are not paralysed. For example, the biceps femoris, semimembranosus, and semitendinosus are flexors of the knee. When these muscles are involved it may be found that the semimembranosus and semitendinosus are strong enough to flex the leg against gravity, while the biceps shows scarcely a flicker of contraction. Under these circumstances active flexion is performed by the stronger muscles, and the biceps is not used; electrical stimulation of the latter is therefore indicated. But, wherever possible, reliance is placed on voluntary exercise, which is the only true form of muscle re-education.

The Muscle Charts

The progress of cases under treatment was recorded on muscle charts introduced into the hospital by Mr. H. J. Seddon, the resident surgeon. At first charting was done every two months, but is now carried out at intervals of six weeks. The chart here shown is used for the lower extremity. The skeletal muscles are classified into forty groups, and the voluntary power of each is tabulated as N; R+; R-; G-; F; or O. R+ signifies that the muscle will overcome gravity and additional resistance, but is less powerful than normal. R- indicates that it will overcome gravity but not additional resistance. G- is recorded if the muscle will carry out its action only when gravity is eliminated; while F means that there is a flicker of contraction insufficient to move the part. Since the only movement of use to the patient is that which he initiates voluntarily, the recording of voluntary power is a more direct measure of recovery than that obtained by electrical stimulation. Such a chart has the merit of showing improvement or retrogression accurately enough for clinical purposes, without the use of special apparatus such as that devised by Lovett. With a little practice the necessary observations can be made fairly quickly.

Although one may not be responsible for the management of many cases of poliomyelitis it is desirable that the results of each examination should be charted, for unless quantitative measurements are made ideas of progress are

ROYAL NATIONAL ORTHOPAEDIC HOSPITAL					
Name.....	Number.....	Trunk and.....	lower extremity		
Date					
*Type of Contraction.....					
Erector Spinae.....					
Abdominals					
Gluteus Maximus					
Abductors of Hip					
Tensor Fasciae Latae					
Adductors of Hip					
Quadriceps					
Sartorius					
Psoas.....					
Inner Hamstrings					
Outer Hamstrings					
Calf Muscle					
Tibialis Posterior.....					
Tibialis Anterior					
Peronei					
Extensor Longus Hallucis					
Extensor Longus Digitorum					
Flexor Longus Hallucis					
Flexor Longus Digitorum					
Small Muscles of Foot.....					
Gait	Trendelenburg				
Contractures, Deformities, Measurements					
Operations					
*V—Voluntary	F—Faradic	G—Galvanic			
Strength of Contraction	N	Normal contraction			
	R+	Contraction against gravity and resistance			
	R-	Contraction against gravity only			
	G-	Contraction but not against gravity			
	F	Flicker			
	O	No contraction			

Muscle chart of the lower extremity for recording progress of cases under treatment

apt to be affected by one's optimism or pessimism at the time, and the patient is easily deluded by trick movements so readily acquired and accounted as recovery. No one can remember for long the state of all the important muscles, and even when the patient is always seen by the same observer such notes as "extensors of the foot stronger" convey little more than a general impression, and are much less informative than a muscle chart. The keeping of a chart also eliminates the personal factor from the records, and is therefore invaluable if another clinician is called upon to treat the case.

The Patients

The patients studied were admitted to the Royal National Orthopaedic Hospital, Stanmore, Middlesex, between the years 1932 and 1936. Their ages ranged from 4 to 14 years, so that they were old enough to co-operate in both charting and treatment. The lesions were probably more severe than those of the average type seen in the London area during those years. Some cases admitted from orthopaedic clinics were of average severity, but others were transferred from general and fever hospitals because of extensive paralysis calling for prolonged treatment.

When admitted to hospital the distribution of muscular paresis or paralysis in fifty* cases was as follows:

	Per cent.
Both lower limbs ; abdominal and spinal muscles	34
Upper limbs ; lower limbs ; abdominal and spinal muscles ..	18
Lower limbs only	18
One lower limb	8
Upper limbs	6
One upper limb	6
Both lower limbs and one upper limb	6
One lower limb and one upper limb	4

It will be seen that in more than half the cases the lower limbs and the abdominal and spinal muscles were all affected.

The Muscle Re-education Period

There are few terms more generally misunderstood than "recovery period" in anterior poliomyelitis. Lovett defined it as the period during which spontaneous recovery of muscle function occurs. In most standard English textbooks the term is used without being defined, but the authors do not hesitate to state that its duration is from two to four years. As the discussion which follows usually concerns treatment it is not always clear whether reference is being made to a period of spontaneous recovery—that is, natural recovery without medical care—or the period of improvement under the treatment described. Since most cases are now diagnosed and treated early, the spontaneous "recovery period" is of little importance compared with the period of improvement under muscle re-education. Rather than alter the original definition of recovery period and thereby create confusion I would suggest that the term "muscle re-education period" be used to indicate the time during which the muscles will improve under treatment, assuming that it is started without delay. Although there is no real justification for the idea, many students and practitioners infer that since the "recovery period" is two years it would be useless to suggest muscle re-education for a patient who suffered from the acute disease two or more years ago and who has never been given adequate treatment. In such a case it is always worth while to give at least a few months' treatment, as the following case shows.

A girl of 10 suffered from infantile paralysis when she was 4 years of age. She had never been treated. On examination of the thenar muscles of one hand it was found that there was scarcely a flicker of contraction in the short abductor and opponens pollicis. In order to relax these muscles the thumb was splinted in opposition, and after four months' treatment they had so developed that she was able to abduct and oppose her thumb strongly against resistance. After the initial lesion many damaged anterior horn cells no doubt recovered, but the muscles they supplied were so overstretched that paralysis persisted. When they were placed at a mechanical advantage, and controlled voluntary movement was encouraged, recovery occurred in response to the functional demand. Other equally striking examples could be cited from a group of fourteen late cases. Because of this, operations for joint stabilization should not be considered until a thorough attempt has been made to obtain maximal improvement. If this is not done there is a grave risk that one will excise a joint and find later that the operation was unnecessary, the muscles having become stronger after the arthrodesis which gave them the relaxation necessary for their recovery. This point is well illustrated by the following cases:

* As fourteen of these had been treated for some months before admission they have not been included in the group considered under the heading of "Recovery Period."

In September, 1933, a boy aged 8 years suffered from anterior poliomyelitis. Both upper limbs were affected, and he was kept in bed for ten weeks. When seen by a surgeon in January, 1934, the left upper limb had completely recovered, but the right deltoid remained paralysed. A note made at this time read: "No hope for deltoid, will probably need arthrodesis." A splint was not applied, and the deltoid naturally remained paralysed. Thirteen months after the acute infection the patient attended another clinic, where it was found that in spite of the absence of treatment the muscle would contract against gravity but not additional resistance. An abduction splint was supplied, and after six weeks' treatment the deltoid was seen to be capable of contracting against both gravity and resistance. By November, 1935, the muscle had completely recovered, and re-examination in November, 1936, showed that it was normal.

Some years ago a patient upon whom an arthrodesis of the knee had been performed for quadriceps paralysis came under the care of Mr. Bankart. When examined by him the affected knee was soundly ankylosed, but the quadriceps had recovered.

Progress in the Muscle Re-education Period

The following table shows the number of times important muscles were involved together with the percentages of good and poor recoveries under adequate treatment. For the sake of clarity and simplicity I have not given a complete list of the recorded muscles.

Table showing the Result of Treatment in 36 Cases

	Number of Times Involved	After Treatment Completed. Percentage Capable of Contracting at least Against Gravity	After Treatment Completed. Percentage Capable of Moving Part with Gravity Eliminated	After Treatment Completed. Percentage showing no Useful Contraction
Lower limb		Per cent.	Per cent.	Per cent.
Gluteus maximus ..	44	80	9	11
Gluteus medius and minimus	48	57	26	17
Quadriceps femoris	52	54	16	30
Hamstrings ..	41	65	5	30
Calf muscle ..	44	69	9	22
Dorsiflexors of toes	46	67	8	25
Anterior and posterior tibials	51	38	6	56
Peronei	45	67	11	22
Upper limb				
Deltoid ..	15	79	14	7
Triceps ..	13	70	15	15
Biceps and brachialis	14	100	—	—
Short muscles of thumb	13	78	—	22

It will be seen that the chief muscle groups of the lower limb were involved with approximately equal frequency, but that some recovered more completely than others. In general the distribution of paralysis and the extent of recovery in individual muscles were not very different from those in certain series of cases recorded in America. The gluteus maximus fared best and the two tibials worst; over 80 per cent. of the former became strong, while over one-half of the latter remained useless. I could not find such a striking contrast in any other series of cases. Generally the gluteus maximus did not do so well and the tibials recovered more completely. Also, it is unusual for the peronei to recover so much more frequently than the tibials. It is possible that in the present series better results might have been obtained

in the tibials had the feet been more carefully splinted in inversion during the re-education period and the soles supported by accurately moulded plaster gutters.

Early Recovery

The most rapid improvement in voluntary power takes place during the first six months after the acute illness. Indeed, in those cases in which the ultimate function was good, surprising recovery was found after the initial six or eight weeks of complete rest. Under muscle re-education during the next four months there was a further marked increase in strength. However, no certain prognosis could be given during this period except in mild cases, and in the most severe where all the muscles of a limb remained completely paralysed after four months. In the ten instances where all muscles of a lower limb were charted as O or F at four months the extremity remained flail.

Recovery at Six Months

Interesting facts emerged when the condition of three hundred muscles at the end of the six-months period was compared with their ultimate state.

I. Those which contracted against gravity and resistance (R+) at the end of six months became more powerful, and many were eventually regarded as normal.

II. All muscles capable of contracting against gravity only (R-) became strong enough to move against additional resistance (R+).

III. Of the group that were able to move the part only when gravity was eliminated (G-), (a) 45 per cent. recovered sufficiently to contract against gravity and resistance (R+); these were initially the stronger muscles; (b) 45 per cent. were ultimately able to contract against gravity only (R-); (c) 10 per cent. did not improve.

IV. Of those showing only a flicker of contraction (F) 90 per cent. failed to improve, while 10 per cent. became powerful enough to contract against gravity (R-). Briefly expressed, the majority of muscles which after six months were capable of moving the part developed useful contractions, while most of those that could not do so failed to recover. Therefore, at six months from the onset of the acute infection it is possible to predict the ultimate extent of recovery with reasonable certainty.

Reading at Six Months	Ultimate State
R +	N or R +
R -	R +
G -	R + : 45 per cent.
	R - : 45 "
	G - : 10 "
F	R - : 10 "
	F : 90 "

In this series of cases improvement continued until nine to eighteen months from the acute infection, and in odd cases even longer, but in the vast majority no great change was seen after a year of muscle re-education. It may be true that the period of spontaneous recovery is from two to four years, but the period of notable improvement is much shorter when adequate treatment is given from the first.

Some cases progress differently from those considered here. Young children who cannot co-operate fully in the muscle re-education may show a relatively slower improvement over a longer period than those who are older. This is well illustrated in the case of a child aged 2 years at the time of the acute infection. After nine

months' treatment the anterior and posterior tibial muscles showed only a flicker of contraction, yet in three years they were able to invert the foot against gravity. Steady progress occurred during that time as the child gradually learned to co-operate. Acute illness or joint stiffness may also affect both the rate and duration of recovery. This was noticeable in a patient who developed scarlet fever during the re-education period. The toxæmia caused a definite decrease in muscular power, which was regained as the infection subsided. Later the child suffered from acute suppurative otitis media and a similar phenomenon was again observed.

The decision as to when ambulatory treatment may begin depends on the condition of the lower limb muscles and those of the abdomen and spine. The problem is relatively simple if only the former are affected, but when asymmetrical abdominal or spinal paralysis is present there are many difficulties. If the limbs alone are affected the patient should be kept in bed until three successive muscle charts, made at intervals of six weeks, show no further improvement. Patients with slight paralysis usually improve rapidly, and it is safe to allow them up as soon as the muscles will contract strongly against resistance. Six months after the acute infection those who are more severely paralysed may still have very weak muscles. As has already been shown, the ultimate prognosis in these cases can usually be given fairly accurately after one has studied the charts. If there is any prospect of obtaining useful recovery in key muscles extended treatment should be given, but in a small proportion of cases this expectation will not be realized and successive charting will show that progress has ceased. The patient should then be allowed to walk with suitable supports. The majority will be doing so within a year from the beginning of treatment.

The R+ curve shows the number of muscles that improved to R+ during each successive period of two months. The curves R- and G- show the number of muscles increasing in power to R- and G- respectively. It will be seen that a maximal number of muscles increase to R+ at the four-months period, that at six months only half the number did so, while after a year very few increased to R+.

It was previously stated that when abdominal and spinal muscles are involved there is difficulty in determining the optimum time for treatment in recumbency. In the first place there is no simple and very satisfactory way of recording the degree of recovery in the abdominal or the individual spinal muscles. Asymmetrical recovery, with or without the influence of gravity, frequently results in scoliosis, which may be slight when first noticed as the patient lies in bed but rapidly progressive when he walks about. Even if he is kept in bed until recovery of muscle power is maximal there is no guarantee that with asymmetrical paralysis the balance between muscles on each side of the spinal column will be improved. Indeed,

in many instances it is further upset, since the less damaged muscles recover more rapidly than the weaker ones. Once deformity is produced the less powerful muscles, being overstretched, become still weaker; thus a vicious circle is established. This helps to explain the development of scoliosis in certain cases two or three years after the acute illness. Usually when there is much paralysis of the spinal and abdominal muscles the lower limbs are also involved, so that if one could assume that the former recovered at the same rate as the latter the patients could be allowed out of bed when the legs showed maximal improvement. Probably such an assumption is not justified, since muscle re-education is more easily applied to the limbs and more rapid improvement would be expected in them. Because of this it is sometimes necessary to keep a patient in bed for two years or more if the trunk paralysis is at all extensive. From a purely theoretical point of view progressive scoliosis could be best controlled by preventing weight-bearing during the period of spinal growth. In most instances this is neither practicable nor desirable. It would mean keeping children in bed until they had reached the age of 16 years. A compromise has to be made, and it can be empirically stated that if patients can possibly walk they should not be kept in bed for more than two and one-half years. Spinal and abdominal supports must be given where necessary and methodical examinations made during the next few years. Sometimes a scoliosis progresses rapidly in spite of supports and remedial exercises, and leads ultimately to the vital capacity being diminished and to circulatory insufficiency. When this is found to be occurring, and the patient is over 8 or 10 years of age, he should be admitted to hospital again, and the deformity corrected as far as possible by head suspension. The Fisher frame used at the Royal National Orthopaedic Hospital is an excellent appliance for this treatment. At a later date one might consider the question of spinal fusion in those cases where external support will not prevent progressive deformity, with its unfortunate sequelae.

Summary

1. An account is given of the results of a study of thirty-six recent cases of anterior poliomyelitis, progress of which under treatment was recorded on muscle charts.
2. The muscle re-education period is usually found to be much less than the spontaneous recovery period. In the average case it is from nine to twelve months.
3. At from four to six months after the acute infection it is possible to determine the ultimate degree of recovery with fair accuracy.
4. The methods of treatment are briefly given, and the optimum time for treatment in recumbency is discussed.
5. A plea is made for the general adoption of graduated muscle charts as an aid both in treatment and in prognosis.

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BIBLIOGRAPHY

- Aycock, W. L. (1924). *Science*, N.Y., **60**, 85.
 Gaenslen, F. J. (1935). *J. Amer. med. Ass.*, **104**, 1002.
 International Committee (1932). Baltimore.
 Jones, Sir R., and Lovett, R. W. (1923). *Orthopaedic Surgery*.
 Legg, A. T. (1935). *New Engl. J. Med.*, **213**, 415.
 Lovett, R. W. (1916). *The Treatment of Infantile Paralysis*, Philadelphia.
 Lowman, A. L. (1927). *J. Bone Jt. Surg.*, **9**, 119.
 Ministry of Health (1936). Chief Medical Officer's Report for 1935.
 Rodgers, S. Perry (1934). *Amer. J. Surg.*, **26**, 326.
 Thompson, I. Maclaren (1927). *Canad. med. Ass. J.*, **17**, 317.