The response of hypertonic muscle groups to prolonged periods of stretch: a clinical study.

The polythene-polyurethane splint; its value in arthritic and neurological disease.

By

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PREFACE.

The original object of the research was to extend the scope of a new method of making polythene plastic splints whereby they could be moulded direct to the patient, thus avoiding the need for intermediate plaster casts. It appeared that such splints would be of great benefit in the management of patients with certain chronic diseases, especially rheumatoid arthritis. The stimulus for this work arose from a personal communication by Dr. John T. Scales of the Royal National Orthopaedic Hospital, who described the technique. At that time its scope was restricted to the manufacture of simple wrist slabs. I extended it to the making of eighteen types of limb splints and spinal supports and these were proved useful by clinical trial.

The progress of 163 patients supplied with these appliances was observed; their subjective reports and, where measurable, the objective results being recorded. Some benefit, either lessening of pain or improvement in function, was obtained by all. The results obtained in acute polyarthritis were especially rewarding.

A large proportion of the patients (66%) suffered from rheumatoid arthritis but appliances were also provided for some with neurological disease. One of these was a young man with residual hemiplegia who presented such intense tonic spasm of the flexor muscles of his knee that both medical and surgical treatments had been unable to overcome it during the course of one year. As fibrous contracture appeared likely to develop a plastic splint was made which held the knee fully extended with the object of preventing its occurrence. He was instructed to wear it as much as possible. Interpreting this literally, he did not remove it for one month. During examination of the limb at the end of that time it was observed that all evidence of hypertonus had disappeared from the flexor muscles and that full voluntary extension was obtainable. No other form of treatment had been given during that time and it appeared probable that hypertonus in the flexors had been abolished as a result of the prolonged and constant stretch of those muscles while the limb was extended in his splint.

In order to investigate this phenomenon more fully, a group of 17 hemiplegic patients was selected and 27 flexor muscle groups presenting clinical hypertonus were stretched in a similar manner to that described above. The period of study extended over two years and eleven months. In each case clinical evidence of excessive tonus was abolished in the stretched muscles; the duration of stretch required to achieve this appeared to vary directly with the degree of tonus originally presenting. Out of ten surviving patients six have retained complete abolition of hypertonus for an average time of 57 weeks since stretch was stopped. It appears therefore that a lasting abatement can, in certain circumstances, be achieved by that means. No previous work concerning the effect of prolonged stretch upon hypertonic muscle has been found. It is suggested that the results of this small series indicate that further study is desirable. If they are supported, the value of such a safe and long acting method of reducing tonic muscle spasm may be of service in the management of patients with hemiplegia, and perhaps also with other forms of upper motor neurone disease.

The research thus diverged by chance into three channels. It was thought that the work on muscle hypertonus might be of most interest and it is presented first. A brief account of that concerning the new type of appliance forms the second part. The third consists of a study of the value of these appliances as a means of obtaining rest and stabilisation of the joints in rheumatoid arthritis. Some other chronic diseases affecting the locomotor system were also treated and the results are given.

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PART 1.

THE RESPONSE OF HYPERTONIC MUSCLE GROUPS IN HEMIPLEGIC PATIENTS TO PROLONGED PERIODS OF STRETCH: A CLINICAL STUDY.

INTRODUCTION.

Reseatch concerning the functions of the pyramidal and extrapyramidal centres will be reviewed. The servo-loop theory of willed movement and its relationship to the central influences in normal and pathological states will then be examined.

It has been known since the time of Hippocrates that cerebral haemorrhage caused paralysis. Wepfer, in the seventeenth century was, however, the first to show that the paralysis affected the opposite side of the body to that of the haemorrhage. In 1691, Robert Boyle described a case of depressed fracture of the skull which had caused paralysis of the contralateral limbs. Removal of the bone fragment led to disappearance of the motor deficit. This observation offered evidence of a motor area in the cortex, but not until nearly two hundred years later was this demonstrated experimentally. Fritsch & Hitzig (1870) showed that stimulation of the precentral gyrus in dogs caused movement of the opposite side of the body. By selecting points of stimulation discreet movement could be produced. Earlier in that year Hughlings Jackson had postulated the existence of such a motor area on the basis of a study of focal epileptic seizures. He said that these must originate from irritation of "areas of the brain having specific motor function." Ferrier (1873, 1876) confirmed Fritsch & Hitzig's suggestion that the motor area occupied the precentral gyrus. He found too that if an area which, on stimulation, caused arm movement was removed the arm became paralysed. Soon after, the axons of the neurones of this area were found to constitute a tract descending to the levels of the motor outflows from the cord. This tract was variously named the pyramidal or cortico-spinal tract. Injury to it or to its parent cortical cells was found to cause paralysis, partial or complete.

Spasticity was a usual accompaniment. There was general agreement that both were the direct result of damage to the motor tract. J. Hughlings Jackson was however a notable exception. He wrote (1877, 1878 & 1899), that destruction of the motor tract could only result in loss of movement - the "negative element". The presence of spasticity - the "positive element" - he attributed to release from cortical control of more primitive mechanisms. These could then act without restraint upon the lower motor neurones producing the clinical picture of spasticity. His concept has since been proved to be correct.

Little more work was directed to this problem for many years. Then Fulton (1932, 1934), studying the effects of destruction of the motor cortex, and Tower (1940), in her classical paper on the effect of pure pyramidal section in monkeys, showed that injury confined to the motor cortex or its efferent fibres resulted in flaccid paralysis. Their work indicated that the pyramidal tract, besides conveying the impulses for voluntary movement, mediated a facilitatory influence on muscle tone, since its destruction produced loss of tone as well as loss of movement. Tower interpreted the dual function thus: "Together, the tonic function provides for smooth, continuous, efficient action, while the phasic function contributes outstandingly precision and lability to total performance. In the realm of somatic motor function both of these are unquestionably motor or excitor functions. Of inhibitory function as such there is no evidence."

It seems that these functions of the motor cortex obtain also in man. Bucy (1949) extirpating the motor cortex in human subjects found that residual spasticity was very mild in degree. That any spasticity at all developed was probably due to involvement of cortical tissue outside the true motor area. Bucy himself emphasised that point.

Hines (1936, 1937) was the first worker to show that there was an area of the cortex, situated just anterior to the motor area, which was concerned with control of muscle tonus. Extirpation confined to this part produced only increase of tonus in the muscles of the contralateral side of the body. This cortical area is usually called the suppressor strip and is designated area 4S in Von Bonin's cytoarchitectural map of the cortex (in Bucy, 1949). Dusser de Barenne & McCulloch (1938) found that stimulation of area 4S resulted in diminution of muscle tonus. They found, too, that the electrical activity of other parts of the cortex was depressed by stimulating this area.

In 1940, Verhaart & Kennard followed degenerated fibres from area 4S which had been destroyed some time previously, as far caudally as the pons, but not below it. They proposed that they had a relay station in that area. McCulloch et al, (1946), traced the efferent fibres of area 4S by using the strychnine spike technique. It was found that the fibres from the cortical supporessor strip ended in the reticular formation dorsal to the pyramid. Bodian, (1946), using an interesting technique, supplied evidence confirming this. He inoculated monkeys with poliomyelitis and those animals in which generalised spasticity developed were sacrificed immediately after its appearance. It was found that the neurones in the inhibitory area of the reticular formation were most severely damaged. In 1946 Magoun & Rhines produced direct evidence that a reticular inhibitory centre did exist. They found that stimulation of this area in decerebrate cats abolished muscle tonus. Further, movement produced by stimulating the motor cortex could be completely inhibited by similar means. The reticular formation can not however, in intact animals, inhibit in the absence of influence upon it from area 4S. The striatum too has been shown to play a part in inhibition, (Mettler, 1943, 1944) and injury to it causes signs of spasticity. In hemiplegic patients showing intense hypertonus it is possible that besides interruption of fibres from area 4S, damage to the striatum has occurred.

More recently another and more extensive area of the reticular formation, outside the inhibitory area, has been found to subserve facilitation of muscle tonus (Magoun & Rhines 1946, Niemer & Magoun 1947). The former workers, by stimulating this area, obtained very striking records of exaggerated response to muscle stretch. They concluded that reticular facilitation was a more potent factor in maintaining spasticity than was reduction of reticular inhibitory influence. The facilitatory area was found to be a relay station of impulses originating in the basal diencephalon, with contributions from the globus pallidus and other thalamic nuclei. This mechanism is held in check by cortical inhibitory influence (Magoun & Rhines 1947). In 1949 Lindsley et al and Schreiner et al, using electromyographic recordings of muscle potentials in spastic cats, confirmed that facilitatory and inhibitory influences were exerted by the reticular systems.

The cerebellum also produces both types of influence, (Bremer, 1922, Holmes 1937 & Snider et al 1947); the anterior lobe exerting inhibition and the middle lobe facilitation. The vestibular nuclei too have, for many years, been known to have an excitatory effect upon the lower motor neurone.

Even the cord itself appears to contain such centres, (Harrevald & Marmont 1939, Lloyd 1941, Kabat & Knapp 1944 and Scarff & Pool 1946), but in this study of the effect of cerebrovascular accident these need not be discussed.

The extrapyramidal mechanisms which influence the lower motor neurone are seen to be complex. Those which mediate facilitation have a wide distribution in the brain and cord and this may enable them to avoid destruction with more success that the more localised inhibitory mechanisms. Perhaps it is for that reason that injury or disease in the central nervous system, for example hemiplegia, is signalled by clinical signs of spasticity much more commonly than by flaccidity.

Magoun & Rhines (1947) reducing the concept of spasticity to its simplest terms say that it is a product of the reduction of inhibitory and the augmentation of facilitatory influences which play upon the spinal stretch reflex. It should be pointed out that the work upon which their concept is based was done with animals, but it is possible that the spasticity shown by the muscles of hemiplegic patients has a similar basis. In such patients there is, in addition to spasticity, a motor deficit which is generally believed to be related, though not directly related, (Lassek 1950), to the degree of destruction sustained by the pyramidal tract. It may be justifiable to presume that in the great majority of hemiplegic patients there is, playing upon the lower motor neurones, an excessive amount of extra-pyramidal excitation and a diminished amount of pyramidal influence. In order to determine by what peripheral pathways such influences may produce the clinical signs of spasticity and limitation of voluntary movement a review of work on the peripheral neuro-muscular mechanisms is required. In this field of research the concept of Merton (1951, 1953) that impulses mediating ordinary willed movement exert their influence by a "servo-loop mechanism" is perhaps the most significant since Liddell & Sherrington (1924) described the stretch reflex. I should like to review his work in some detail.

Since the muscle spindle plays an important part in his theory it may aid clarity to first give an account of its structure. Merton describes the spindle as being composed essentially of a sensory element which has muscular poles. The latter are made up of numerous muscle fibres - the "intrafusal fibres". These have been found (Leksell 1945) to play no part in main muscle activity, their sole function being to activate the sensory part of the spindle. They are innervated by the small efferent nerve fibres in the ventral roots.

For many years it was accepted that impulses mediating willed movement travelled down the pyramidal tract to the motor neurones in the anterior grey matter of the cord and thence along the large efferent nerve fibres to the motor end plates in the main muscle. In 1951 Merton, investigating the phenomenon of the "silent period" made certain observations which led him to the conclusion that this view was incorrect.

The subject of his experiment maintained a steady voluntary contraction of the adductor muscle of his thumb against the resistance of a spring. This tension was recorded. Leads were taken from the motor nerve (ulnar) supplying this muscle and the electrical activity recorded. When both records showed a constant level, a shock was applied to the nerve to cause a sudden twitch contraction of the muscle. It was observed that, during the time the record of muscle tension showed a rise, all electrical activity in the nerve was suspended. This response was found to be exceptionally delicate. Even a threshold shock, giving a twitch of only 3 - 4% of the background tension, was sufficient to obtain a clearly discernable "silent period". Sherrington had said that movement takes place against a background of posture. The steady muscle contraction maintained by the subject, created a state similar to that obtaining during a postural contraction. Merton argued that if, as had previously been thought, the pathway of voluntary movement was directly along the motor nerve to the main muscle, then the electrical stimulus applied to the ulnar nerve in his experiment simulated this neuromuscular action. How then was the phenomenon of the silent period avoided when willed movement was superimposed on a postural contraction? Avoided it must be, since otherwise the movement would be aborted as soon as it began.

Previous work on the silent period had shown that it was accompanied by a cessation of afferent discharge from the muscle spindles and that the absence of that discharge was responsible for its appearance. Merton argued that the only way in which afferent discharge could be maintained was through continued stimulation of the spindle by contraction of its intrafusal muscle fibres. It had been shown that these were innervated by the small efferent nerve fibres in the ventral roots. He therefore proposes that the pathway of willed movement is via the pyramidal tract to the small lower motor neurones. From these it is relayed in the small efferent nerve fibres to the intrafusal muscle fibres of the spindles. On contracting these stretch the sensory part of the spindle. This produces an afferent discharge which, on entering the cord, plays upon the large lower motor neurones and depolarises them. Impulses pass out in the large efferent nerve fibres to the main muscle and cause it to contract. In this way spindle afferent discharge is maintained, the silent period avoided and a smooth voluntary contraction of the main muscle is superimposed upon the postural state.

Merton went on to postulate that there is an inherent stable length relationship between the intrafusal muscle fibres of the spindle and the extrafusal muscle fibres. The function of the sensory part of the spindle, he said, is to detect any alteration of this relationship and act to correct it. How this applies to willed movement has been noted. As a further example, the stretch reflex excited by impulses from the spindle acts to keep the main muscle at the same length as the intrafusal.

Merton, in his experiments, did not record spindle afferent discharge and it may be questioned why he believed that the silent period response was due to cut off of impulses from these receptors and not due to inhibitory impulses from the tendon organs. It has been noted that the silent period could be obtained in the motor nerve of his subject by threshold stimuli. Merton deduced that the responsible end organ must be the spindle, since it had been shown by Matthews (1933) that the only other important sense organ involved, the tendon receptor, responded solely to high tension. In Matthews' words; "The B. endings" (his name for the tendon receptors), "have a high threshold and during contraction always behave as if they lie 'in series' with the contractile element. Their response depends only on the total tension in the muscle..." Fulton & Pi-Suner (1928) had already postulated this and it has recently been confirmed by Hunt & Kuffler (1951, b) who noted, in addition, that many tendon organs "gave no steady discharge with a maintained external tension." It seems clear, therefore, that the very weak tensions elicited by Merton's threshold stimuli would be insufficient to cause any discharge from these receptors. Furthermore previous work on the silent period offered confirmatory evidence that the muscle spindle was the active receptor. Sherrington (1900) had pointed out that the spindles lay between the main muscle fibres, parallel to them and having common fascial attachments. Denny Brown (1928) provided a further clue to their action when he observed that the silent period could be greatly curtailed by de-afferentation. He deduced that this phenomenon must be due to changes in the afferent discharge from the muscles. In the same year Fulton & Pi-Suner found that spindle afferent discharge was reduced during muscle contraction and they concluded that this must be due to the "in parallel" arrangement noted by Sherrington; muscle contraction relaxing them with consequent cut off of discharge. They concluded that these receptors recorded muscle length. Matthews (1931, b), using a small muscle of the frog's toe which contained only one spindle, investigated its response during electrical stimulation of the motor nerve. He concluded from his findings that "The pause, in the response of the muscle spindle to steady tension, when the muscle contracts is compared to the silent period in mammalian reflexes. It is suggested that the silent period is due to the pause in the response from the muscle spindles." Again in 1933 he said, "During active contraction the response of the A1 receptors" (spindles) "ceases." He commented "they behave as if they be "in parallel" with the contractile elements." A year later Hoffmann found that the silent period could be obtained in man against a background of either postural or voluntary contraction.

This background of research clearly supports Merton's views on the role of the muscle spindle in his experimental findings. It may have been noted that his concept rests also upon knowledge concerning the function of the small efferent nerve fibres. A survey of neurophysiological research in this field may therefore be desirable.

In 1894 Sherrington found ~~the~~ small nerve fibres in the ventral roots innervating the muscle spindles. Little attention was paid to this observation until 1945 when Leksell demonstrated the role of the small efferent nerve fibres in controlling the afferent discharge from these receptors. This stimulated a great deal of research and within a few years much important work was published. Hunt & Kuffler (1951,a) found that, of the total number of motor fibres in the lumbo-sacral outflow in the cat, one third were small nerve fibres and two thirds large nerve fibres. They found that stimulation of the large fibres caused contraction only of the extrafusal muscle fibres. The small fibres they found to be exclusively concerned with control of the afferent discharge from the muscle spindles. They produced evidence to show that there was "innervation of several spindles by single small nerve fibres" by means of terminal branching similar to that shwon in large efferent nerve fibres by Katz & Kuffler (1941). Kuffler et al (1951) found that "The excitatory effect of small nerve stimulation on the spindle discharges show a phenomemon of facilitation. The number of afferent discharges increases progressively during continued stimulation until a steady discharge rate is established." Hunt & Kuffler (1951, b.) deduced that the small nerve innervation of the spindle exerts its influence by stimulating the contractile elements forming its poles, which on contraction excites the sensory part lying between. Further investigation along these lines led them to say "the muscle spindle discharge is influenced by external stretch and the various modifications of stretch during contraction, as well as by the nervous mechanisms of the efferent small nerve fibres."

It appears that the servo-loop theory has been generally accepted since no work tending to discredit it has been found. It may be worth mentioning, however, that Hammond (1955) found the reflex element of the mechanism to be weak and of short duration before voluntary action took over in resisting sudden unexpected passive extension of the forearm. This work was done on normal human subjects and a mechanical contrivance was used to carry out the passive movements.

Of research concerning the connection between the extrapyramidal influence in spastic states and the servo-loop mechanism the most illuminating is probably that of Hunt (1951). Working with decerebrate cats he found a constant discharge in a high proportion of the small efferent nerve fibres and also some impulses in the large efferent nerve fibres with consequent motor unit activity. Discharge in both fibre systems continued even when the limbs were in the resting position. One interesting preparation exhibited spontaneous periodic fluctuations in the degree of extensor rigidity. When the limb was rigidly extended there was a considerable discharge in both the small and large efferent fibres to the extensor muscles. As rigidity decreased the activity in both types of fibre was reduced until only a single small nerve fibre showed a discharge. The limb gradually became rigid again and Hunt thought it significant that the resumption of small nerve activity preceded that in the large fibres.

Direct evidence of the influence of cerebral centres on the muscle spindle was produced by Granit & Kaada (1952) who first established the fact that the muscle spindle was under cerebral control. They showed that the background discharge in the small efferent nerve fibres could be selectively augmented or suppressed by stimulating several centres in the central nervous system. Eldred et al (1953) confirmed this work and found moreover that the increased small nerve discharge, caused by stimulating facilitatory centres in the brain, persisted unaltered after de-afferentation. By stimulating the facilitatory area of the reticular formation spindle afferent discharge was accelerated and this was followed by main muscle contraction. After section of the posterior roots, main muscle activity disappeared but the spindle response persisted unaltered. The reverse effect was obtained by stimulating an inhibitory area which in their experiments was the internal capsule in cat preparations, the inhibitory fibres from area 4S being thus influenced. From a series of such experiments they concluded that the central nervous system controls spindle activity throughout the whole range of normal movement.

It will have been noted that the research reviewed deals largely with animal experiments. To equate the results of this work to the mechanism of hypertonus in the human hemiplegic patient is scientifically unsound. On the other hand it is unlikely that similar direct experimental evidence can ever be obtained in man. Certain conjectures regarding the probable state of the human central and peripheral nervous systems resulting from a vascular lesion in the internal capsule may therefore be permissible. It is proposed that the destruction by such a lesion of inhibitory fibres from cortical area 4S and possibly also of part of the striatum, releases extrapyramidal facilitatory influence which creates a constant and excessive stimulation of the lower motor neurones. As a result a high level of "background" discharge is established in the small efferent nerve fibres to the muscle spindles. Through terminal branching of these fibres and through the facilitatory effect of continued small nerve activity a high proportion of the spindles may be kept constantly in a hyperexcited state. If excitement is sufficiently intense spontaneous activity in the extrafusal muscle fibres may ensue, leading to a state of postural contraction in certain muscle groups. The results of prolonged stretch upon a number of such groups will now be presented.

OBSERVATIONS.

(A). MATERIAL.

The effect of prolonged periods of stretch upon the spasticity shown by certain flexor muscle groups in hemiplegic patients was investigated. The period of observation extended over two years and eleven months. Twenty-seven muscle groups in a series of seventeen patients were studied. Table 1. shows an overall picture of the series.

TABLE 1.

Age, sex and muscle groups treated, duration of hemiplegia before muscle stretch was begun and the period of study.

Age	Sex	Muscle Groups stretched. Flexors of:-	Duration of Hemiplegia before stretch Begun. (months)	Period of Study. (months)
82	F.	Elbow	14	7
77	F.	Elbow	36	-
75	F.	Wrist	18	20.5
72	M.	Wrist	14	19.5
70	F.	Wrist & Fingers	18	6
68	F.	Knee & Wrist	2	6
65	M.	Elbow, Wrist & Fingers	17	35
64	M.	Fingers	14	19.5
62	F.	Wrist & Fingers	12	7
62	F.	Wrist & Fingers	72	19.5
52	F.	Elbow	16	20
51	F.	Wrist & Fingers	12	21
47	M.	Knee	12	13
45	F.	Wrist & Elbow	3	18
28	F.	Wrist	39	23
28	M.	Wrist & Fingers	6	26
13	F.	Wrist & Fingers	7	18.5
Aver. 56.5 yrs. Limits 13 -82	12 F 5 M	Elbow 5 Wrist 12 Knee 2 Fingers 8	Average 18.4 months. Limits 2 - 72 months.	Average 17.5 months. Limits 6 - 35 months.

(B) METHOD.

1. Selection of Patients.

The following were the criteria for selection:-

(a) The patient suffered from hemiplegia and the musculature on the affected side showed clinical signs of hypertonus.
(b) The hemiplegia had been sudden in onset and was presumably of cerebrovascular origin.
(c) The duration of the hemiplegia exceeded six months.
(d) No improvement in active movement or lessening in the degree of spasticity had been noted in the affected limbs for a minimum period of four weeks.
(e) The patient was thought to be sufficiently alert mentally to co-operate in his treatment.

The method of treatment under investigation was designed to obtain abatement of flexor muscle spasm and to increase the range of active antagonist (extensor muscle) movement in hemiplegic cases where spontaneous occurrence of such features could not be expected. A minimum duration of six months was selected as marking the end of such recovery. Authority for selecting this period was derived from the writing of Lowman (1948), Twitchel (1951) and Brain (1955). Lowman believes that three months duration signals the beginning of the residual phase. Twitchel in his study of patients recovering from hemiplegia found that postural abnormality disappeared within 43 - 60 days after onset in those cases who made a spontaneous recovery. Brain considers that such recovery occurs only during the three months after onset.

Two of the patients shown in table 1. had a hemiplegia of less than six months duration. They are not therefore included in the analysis of results which follows. It was thought however that their progress might be interesting to record and their case histories are included in the list of case reports in the appendix. (Cases 16 & 17. P.P. 191 - 196)

2. Controls.

Selection of a control group of hemiplegic patients was considered but rejected because of the difficulty in finding a group which would be comparable to the treatment group in duration of hemiplegia, degree of spasm and range of active movement. It was thought that a more reliable control could be exercised by comparing the progress of the muscle groups treated with other untreated groups on the affected side of the body. That method of control was therefore adopted.

3. Treatment.

In each patient one or more flexor muscle groups were subjected to prolonged stretch. This was achieved by keeping the appropriate joint extended in a P.P. plastic appliance. Stretch was constantly maintained for a certain period of time which varied somewhat with each patient, but was usually about three months. During that time the appliance was removed for only a few minutes each day while the limb was washed. In each case it was found that flexor spasm was abolished or greatly lessened by that means. In most cases abolition of flexor spasm was accompanied by an increased range of voluntary extension. Once these features were clearly demonstrable the stretching appliance was thereafter worn for progressively shorter daily periods until it was finally discarded. This second period of stretch was usually spread over 2 - 3 months. The patient was encouraged to make use of the gain in active extension during each daily period of freedom from the appliance, and also after it was finally discarded.

No other treatment was given to the patient or to his limb while the effects of stretch were being observed, nor since it was stopped.

4. Examination.

Experience with the above method showed that the decrease in flexor spasm made itself evident in two ways. First, the arc of passive movement from the position of full flexion towards the position of extension during which no increase in tonus could be detected was found to progressively increase. Secondly, the remainder of the arc which did offer resistance often showed a decrease in degree of resistance. It was interesting to find that Twitchel, (1951), while studying the natural course of hemiplegia in nineteen patients, observed changes the reverse of those described above in patients whose spasticity progressively increased.

It was necessary to have a method of clinical examination capable of accurately measuring changes in the range of normal tonus, changes in the degree of tonus and changes in the range and power of active movement. No exact clinical system of assessing these features was found in the literature. An attempt was therefore made to devise an acceptable method. The details of this examination technique are shown in the appendix (P.P. 83 - 89.) and only a brief summary is given here.

It was necessary to control or standardise certain external influences at each examination. These were:-
Temperature,
Emotion
Tonic neck and body-righting reflexes
Temporal relationship of examination to removal of the appliance.
Performance of active and passive movements between removal of the appliance and examination of the stretched muscles.

To avoid the influence of flexion and extension synergies during active movement the limb was held in such a way that movement was confined to the muscle groups under investigation. The range of movement of the joints controlled by these muscles was measured with a goniometer. Balboni et al (1946) gives 10° - 15° as the probable range of experimental error. It is agreed that that is a reasonable estimate.

The power of voluntary movement was recorded in the manner recommended by the Medical Research Council. Thus; 0 - no movement, 1 - flicker of movement, 2 - movement with the influence of gravity eliminated, 3 - movement against the counter force of gravity, 4 - movement against resistance, 5 - normal power. Intermediate values were indicated by plus signs.

In recording the degree of tonus found on passive movement of the joints a similar system was used.
A - normal, B - mild, C - moderate, D - marked, E - intense.
Intermediate values were given by coupling the letters, e.g. tonus which was thought to be between mild and moderate in degree was recorded as (B-C).

Clinical interpretation of the degree of power or tonus probably varies somewhat with different examiners. To avoid error arising in this way each examination was personally conducted.

An electromyograph was not available at the hospital in which this study was carried out. It was possible, however, to use this method of investigation in three patients, (Case Nos. 6, 7 &8), through the kindness of Dr. P. Bauwens, Consultant in charge of Physical Medicine and Electrodiagnosis, at St. Thomas's Hospital, London, who conducted the E.M.G. investigations in his department.

C. Results.

It is proposed to give the results in two sections:-
(1) An analysis of the findings recorded in the case reports.
(2) Individual case reports, followed in each case by a graph of the change produced in the range of active and passive movement.

The case reports are given in the appendix, (P.P. 90 - 196). A summary of one report, (Case Report No. 11, appendix P.P.154-166) will be given here to illustrate the sort of results obtained and, following this, an analysis of the results will be attempted.

SUMMARY OF ONE CASE HISTORY.

The patient selected was unusual in that the flexor muscles of the knee joint showed a degree of spasticity more usually seen in the knee extensors. However the response of this flexor muscle group to prolonged stretch was typical of that obtained in all other flexor muscle groups stretched and showed in addition a pattern of response more clear cut than in any other. *

A hypertensive male patient, aged forty-seven years, was admitted to hospital with a left sided hemiplegia the onset of which had been sudden. The musculature of the left side developed excessive tonus and this became especially marked in his knee flexors. He remained an In-patient for one year during which time both medical treatment and surgical proceddures failed to overcome the tonic flexion spasm of his hamstring muscles. These habitually held the knee flexed to approximately ninety degrees and so prevented him from walking.

A plastic knee splint was made which held the knee almost fully extended, thus stretching the spastic flexors. The appliance was put on and not removed for four weeks. At the end of that time flexion spasm was found to be abolished and voluntary extension of the knee was sufficently powerful to permit walking without theappliance. The splint was re-applied and, apart from removal for washing, was constantly worn for a further thirteen weeks. Thereafter he wore it for progressively shorter daily periods for a further seventeen weeks at the end of which time it was discarded completely. During this whole period he was able to walk, either in or out of the appliance. At the time it was discarded there was no spasticity in the hamstrings and voluntary extension of the knee could be performed with considerable power. Spasticity in the knee extensors, originally mild, was by that time quite marked.

Spasm in the hamstrings remained abolished, and voluntary knee extension showed no decrease in power or range of movement for six months after muscle stretch had been stopped. The period of observation was then terminated by the patient's death.

* NOTE.
The word spasticity is defined in the American Medical Dictionary as "marked hypertonus of muscles." In this work, when used to describe the tonus shown by a muscle group, it is employed as a synonym of the word hypertonus.

ANALYSIS OF RESULTS.

The response to muscle stretch of twenty-two spastic flexor muscle groups in sixteen patients is shown in table 2. One patient (Case report No. 17) was withdrawn from the series after two weeks observation. Insufficiently exact figures were obtained for four muscle groups and these are excluded from the table. The results obtained in two patients are included in the table but are excluded when determining average figures, since the duration of hemiplegia in those cases was less than six months, (Case Nos. 15 & 16.)

TABLE 2.

Increase in the range of normal flexor tonus and in the range of active extension at the end of the period of stretch. (.i.e. the increase in those ranges as compared to the findings before muscle stretch was begun.)

Case No.	Muscle groups stretched. Flexors of:-	Period of stertch. (weeks)	Increase in range of normal flexor tonus at end of stretch period. (degrees)	Increase in range of active extension at end of stretch period.(degrees)
1	Wrist	69	75	75
	Elbow	22	40	40
2	Wrist	25	85	85
	Fingers	13	60	60
3.	Wrist	18	55	50
4.	Fingers	18	70	60
5.	Elbow	29	70	60
6.	Wrist	19	65	60
	Fingers	19	60	10
7.	Wrist	16	60	65
8.	Wrist	21	30	30
	Fingers	21	70	10
9.	Wrist	23	35	30
	Fingers	7	65	10
10.	Wrist	14	35	40
11.	Knee	34	55	60
12.	Wrist	10	55	75
13	Wrist	19	45	10
14.	Elbow	13	50	45
	Wrist 10 Fingers 5 Elbow 3 Knee 1	Average 21.6 Limits 7 - 69	Average 56.8 Limits 30 - 85	Average 46.1 Limits 10 - 85
15.	Elbow	17	45	50
	Wrist	27	45	40
16.	Knee	16	-	85

It will be seen from table 2 that an appreciable gain in range of normal flexor tonus and in range of active antagonist (extensor) movement was obtained in most cases. It was perhaps of even more interest to find that quite a large proportion of the muscle groups in surviving patients have retained these gains during the period following cessation of stretch. Of the fourteen residual hemiplegic patients shown in table 2 four have since died. Of the ten surviving patients six have retained, until the time of writing, the gains obtained in all muscle groups treated and four have lost them. These two groups of patients will henceforth be referred to as Group 1 and Group 2 respectively. Tables 3 & 4 show the sex, age and muscle groups treated and lapse of time since stretched was stopped in each.

TABLE 3.

Surviving patients who have retained their increased ranges since muscle stretch was stopped. (Group 1.)

Case No.	Age (years)	Sex	Muscle groups stretched. Flexors of:-	Elapse of time since stretch stopped. (weeks)
1.	65	Male	Wrist	43
			Elbow	59
2.	28	Male	Wrist	53
			Fingers	53
3.	28	Female	Wrist	81
4.	64	Male	Fingers	63
5.	52	Female	Elbow	53
6.	13	Female	Wrist	57
			Fingers	57
	Aver. 41.7 Limits 13 - 65	Male 3 Female 3	Wrist flexors 4 Elbow " 2 Finger " 3	Average 57.7 Limits 43 - 81

TABLE 4.

Surviving patients who have lost their increased ranges since muscle stretch was stopped, (Group 2)

Case No.	Age (years)	Sex	Muscle groups stretched. Flexors of:-	Elapse of time since stretch stopped. (weeks)
7.	72	Male	Wrist	64
8.	62	Female	Wrist	59
			Fingers	59
9.	51	Female	Fingers	64
			Wrist	64
10.	75	Female	Wrist	65
	Aver. 65. Limits 51 - 75	Male 1 Female 3	Wrist flexors 4 Finger " 2	Average 62.5 Limits 59 - 69.

It was interesting to find that the muscle groups which have retained their increased ranges of passive and active movement since stretch was stopped (Group 1, table 3) have retained these increases intact. No change, either in the way of increase of range or loss of range, has since occurred which falls outside the range of experimental error. The muscles of those patients in Group 2 (table 4) who have not retained the increased ranges have lost approximately the entire range of improvement. No lasting intermediate stages of improvement have been observed.

The factors which were responsible for the patient losing or retaining his improvement are suggested by the findings shown in tables 5, 6 & 7. The two former show that the period of stretch to which the muscle groups were subjected in Group 1 patients (table 5) was considerably longer than that prescribed for the patients in Group 2, (table 6).

TABLE 5.
Duration of stretch in Group 1.

Case No.	Muscle groups. Flexors of:-	Period of constant stretch. (weeks)	Period of diminishing stretch. (weeks)	Total period of stretch. (weeks.)
1.	Wrist	30	39	69
	Elbow	14	8	22
2.	Wrist	18	7	25
	Fingers	9	4	13
3.	Wrist	4	14	18
4.	Fingers	10	8	18
5.	Elbow	21	8	29
6.	Wrist	8	11	19
		8	11	19
	Wrist 4 Fingers 3 Elbow 2	Aver. 13.6 Limits 4 - 30	Average 12.2 Limits 4 - 39	Average 25.8 Limits 13 - 69.

TABLE 6.
Duration of stretch in Group 2.

Case No.	Muscle groups. Flexors of:-	Period of constant stretch. (weeks)	Period of diminishing stretch. (weeks)	Total period of stretch. (weeks).
7.	Wrist	7	9	16
8.	Wrist	6	15	21
	Finger	6	15	21
9.	Wrist	18	5	23
	Finger	2	5	7
10.	Wrist	14	0	14
	Wrist 4 Fingers 2	Aver. 8.8 Limits 2 - 18	Aver. 8.2 Limits 5 - 15	Average 17.0 Limits 7 - 23

It will be seen from table 7 that the degree of spasm was usually less and the period of stretch usually longer in those patients retaining their increased ranges. That it was possible to abolish even intense degrees of spasm is shown by Case No. 1. It may be noted that his muscle groups were submitted to very long periods of stretch. It was my impression that the greater the initial degree of spasm the more prolonged must be the period of stretch before spasm was abolished. In retrospect it seem clear that the muscle groups of Cases 7 - 10, showing as they did considerable spasm, should have been stretched for longer periods.

TABLE 7.

Original degree of spasm and the length of stretch period.

		Group 1.		Group 2.	
Case No.	Muscle groups. Flexors of:-	Degree of spasm	Duration of stretch. (weeks)	Degree of spasm.	Duration of stretch. (weeks)
1.	Wrist	E	69		
	Elbow	C	22		
	Fingers	E	39		
2.	Wrist	(B-C)	25		
	Fingers	C	13		
3.	Wrist	(B-C)	18		
4.	Fingers	(B-c)	18		
5.	Elbow	D	29		
6.	Wrist	(B-C)	19		
	Fingers	(B-C)	19		
7.	Wrist			(D-E)	16
8.	Wrist			(C-D)	21
	Fingers			D	21
9.	Wrist			D	23
	Fingers			E	7
10.	Wrist			D	14
		Limits (B-C)-E. Most frequently occuring degree (B-C)	Average 27.1 weeks. Limits 13-- 69	Limits (C-D)-E Most frequently occuring degree D.	Average 17 weeks. Limits 7 - 23.

While these were probably important factors in determining the end results, active use of the improvements obtained appeared to be of even more importance. All patients who did not actively use the part lost their improved ranges.

All those patients who did retained them.

With regard to the response of different muscle groupstreated by stretch the number of groups shown in tables 3 & 4 is too few to be a reliable guide. It may be helpful therefore to give the clinical impression formed during observation of the response of all twenty-seven muscle groups in the series. Spasm was found to be most easily abolished in the wrist flexors. The flexors of the knee and elbow responded rather less quickly. The flexors of the fingers offered most resistance. It is probably significant that the three patients who obtained lasting abatement of spasm in their finger flexors - and in two of these an increased range of active finger extension - - showed only a slight to moderate degree of spasm before treatment began, (Case report Nos. 2, 4 & 6. P.P. 99, 112, 121)

Evidence has been adduced to show that by stretching spastic flexor muscle groups spasticity was abolished and that as this took place active extension was often permitted. It may be interesting to record any concomittant changes in the tonus of the antagonist (extensor) muscle groups and in the range and power of active flexion which occurred. In general a transferrence of excessive tonus from the flexor to the extensor muscles was readily appreciable in the groups governing movement at the knee and elbow joints. It was never observed in those of the wrist joint or of the finger joints. The muscles governing one joint in each of the Group 1. patients are examined to illustrate these features (table 8).

TABLE 8.

Change in the range of normal extensor muscle tonus and in the degree of tonus occurring as a result of maintaining those muscles in a shortened state. Change in range and power of active flexion is also shown.

Case No.	Muscle groups shortened. Extensors of:-	Change in range of normal extensor tonus.	Change in degree of extensor tonus in lost range.	Change in range of active flexion.	Change in power of active flexion.
1.	Elbow	-10°	(A)-(B-C)	Nil	Nil
2.	Wrist	-10°	Nil	$+5^{\circ}$	3+ - 4.
3.	Wrist	Nil	Nil	$+15^{\circ}$	3+ - 4.
4.	Fingers	Nil	Nil	Nil	Nil
5.	Elbow	-45°	(A)-(B-C)	Nil	Nil
6.	Wrist	Nil	Nil	-5°	Nil

Transference of spasm was appreciable in only two patients (1. & 5.) in this group and affected the muscles muscles controlling elbow movement in both cases. In neither was extensor spasm sufficiently marked to alter the range or power of active flexion. In only one patient did transference of spasticity to the extensor muscles have this effect. The knee flexors and extensors were those affected, (Case No. 11., P. 14 and appendix P.P. 154–166)

It was found that the range of active movement and the range of unresisted passive movement varied very little at the control joints throughout the period of observation. Clearly demonstrable changes did occur occasionally but in the final analysis of gain and loss in each individual movement the mean figures did not exceed the limits of experimental error. To illustrate this finding table 11. shows the mean change in active movement at the control joints in the patients forming Group 1.

TABLE 9.

Average change in active movement at the control joints over the period of observation.

Case No.	Control Joint.	Flexion	Extension.	Abduction.	Supination or external rotation.	Pronation or internal rotation.
1.	Shoulder	-10	+15	+10	+0	0
2.	Shoulder	+10	+5	+15	0	-10
	Elbow	0	-5			
3.	Shoulder	0	0	0	0	0
	Elbow	0	+15			
4.	Shoulder	0	0	+10	0	+15
	Elbow	-5	-10			
5.	Shoulder	0	0	0	0	0
	Wrist	0	0		0	0
	Fingers	0	0	0		
6.	Elbow	0	0			

The progress of the 4 residual hemiplegic cases who have died is recorded in their case reports, (Nos. 11, 12, 13 & 14). It may be helpful to state here that their response until the time of death supported the conclusions drawn from the above analysis in all respects. The results obtained by the 2 patients with hemiplegia of recent onset followed a very similar pattern.

SUMMARY OF RESULTS.

The results of prolonged stretch on the spasticity presented by certain muscle groups in a series of residual hemiplegic cases have been analysed. They tend to support the thesis that the hypertonus shown by flexor muscle groups in hemiplegia can be abolished or at least greatly diminished by subjecting them to judicious periods of stretch and that its reduction is not accompanied by loss of voluntary flexion. In addition, with abatement of flexor spasm, voluntary extension is permitted when such action has previously been aborted by hypersensitive stretch receptors in the flexor group. The amount of such recovery will of course depend upon the number of motor pathways to the extensors which have escaped destruction by the central lesion. Accompanying the return of extension some degree of spasm usually develops in the extensor groups but is seldom of such intensity that voluntary flexion is materially affected. Follow up of surviving cases suggests that flexor spasm does not reappear nor is voluntary extension lost provided the patient makes use of his gain in active movement after the stretching appliance has been discarded.

DISCUSSION.

As far as I am aware the effect of prolonged stretch upon hypertonic muscle has not previously been investigated in either animal preparations or in human subjects. In the treatment of hemiplegia a method by which long lasting abatement of hypertonus can be achieved would appear to be a therapeutic advance. The significance of the results may therefore best be discussed in two parts: as a neurological observation, and as an aid to the management of the hemiplegic patient.

The results of the rather small series of observations presented might be made more interesting if a theory of the mechanism through which they were obtained could be formulated. In so doing it is most strongly emphasised that this is a purely personal speculation which is open to criticism on several grounds. Not least is the equation of the results obtained in animal experiments to those observed in the hemiplegic patients studied. Nevertheless in the absence of experiments with human subjects such evidence must perforce be used.

In elaborating the theory those muscle groups controlling flexion and extension of the elbow joint will be used to illustrate the typical imbalance in degree of hypertonus shown by the flexor and extensor muscle groups in hemiplegia. As Brain (1955) has pointed out the elbow flexors are almost invariably held in a state of partial contraction and the extensors in a relatively lengthened state. How can passive extension of the elbow affect the abnormal neuro-muscular mechanisms responsible for this abnormal postural state? The question must be further divided: what is the effect of one unsustained passive extension?, and what is the effect of prolonged constant extension? There is some reason to think that the effect, and the mechanism involved in its production, may be different in each case.

Taking the first half of the question, if the elbow is forcibly extended from its resting position of flexion the phenomenon of clasp-knife rigidity usually presents. This comprises an initial strong reflex contraction of the flexors in opposition to the extending force, but when the force is maintained the resistance suddenly fades and further movmment of the limb to its fully extended position meets with little or no opposition. The initial strong refled contraction is most probably the result of a hypersensitive stretch reflex. Its sudden disappearance might be explained on the basis of an observation made by Hunt (1951). Recording the small efferent nerve discharge in decerebrate cat preparations he found that stretching a spastic muscle group reflexly inhibited discharge to it. In his words, "The activity of small nerve fibres to a muscle can be varied by the amount of external tension on the muscle. When the muscle is pulled upon the discharge in the efferent fibres to its spindles is reduced. On the other hand, allowing the muscle to shorten passively increases its small nerve activity." In hemiplegic muscle showing clasp-knife rigidity the disappearance of resistance may coincide with inhibition of small nerve discharge and consequent relaxation of the sensory part of the spindle. Further lengthening of the muscle would not then evoke the stretch reflex. Hunt's work also suggests that, when the elbow joint has attained the extended position, small nerve discharge to the shortened extensors becomes greater. In the present study, if the extending force was removed soon after the joint had been extended the flexor muscles again contracted. The rate at which they did so appeared to depend on the intensity of their tonus prior to extension. The lenghening reaction was never observed. This recurrence of flexion may depend on a reversal of small nerve influence from extensors to flexors when the inhibiting extensor force is removed.

The second half of the question may now be considered. What is the effect of prolonged constant extension upon a hypertonic flexor group of muscles? The answer seems likely to be related to another feature of clasp-knife rigidity; one that is seldom stressed. If one passive extension movement is followed immediately or shortly after by a second a decrease in resistance, as compared to the first, can sometimes be detected. On the other hand it may require many such movements before this becomes apparent but in my experience it does always appear eventually. Once it has been detected further passive extension, if repeated a sufficient number of times, results in an ever decreasing resistance until it becomes, very often, barely noticeable. This might be explained by a build-up of inhibitory influence on the motoneurones in accordance with the reflex effect of stretch which Hunt noted. However, this theory appears an unsatisfactory explanation of the observation that in some patients the abolition of reflex response to stretch has remained unchanged for many months after all stretch force has been suspended. It seems likely that in such a long period of time any effect which depended on the presence of an inhibitory chemical transmitter substance (Eccles, 1953) would be lost.

It may be possible to base a more acceptable explanation on the work of Adrian, Zotterman, Bronk & Matthews on the response to stretch of the sense organs in muscle. In 1926, Adrian & Zotterman recorded the afferent response to stretch of the frog's sterno-cutaneous muscle. This muscle contained only one spindle. A weight was attached to the muscle and it was found that a high initial response fell within a few seconds to a lower level from which the decrease was much more gradual. They called this the "adaption level". They concluded from their experiments that "The adaption which occurs when stimulation is continued is due in part at least to a fall of excitability". Bronk (1929) confirmed their findings. He then attempted to fatigue spindle response in various ways. First he tried repeated short term loading. From his results he concluded that, "If tension is applied to the muscle just long enough for this discharge to fall to its adaption level, then released and applied again within one or two seconds the stimuli may be repeated many thousands of times without causing any large decrease in response." By varying the applied tension he found that both the maximal impulse frequency and the adaption frequency were directly related to the degree of stretching force. He found however that the greater the stretching force the quicker the fall to adaption level, and the lower this level became. He concluded, " The obvious interpretation is that the greater the activity of the end organ in response to the greater stimulus induces more rapid and more complete fatigue." He next tried the effect of a series of heavy loadings with very short periods of rest between each. By the fourth loading an almost imperceptible response was obtained. But even after that by allowing progressively longer rest periods the spindle completely recovered its original ability to produce a high discharge on stretch. Bronk concluded from his experiments that "The gradual and complete recovery of normal activity makes it seem probable that we are here dealing with a true fatigue phenomenon." Matthews, (1931, a.), also confirmed Adrian & Zotterman's observations on the response of the spindle to stretch.

This work suggests that, in addition to the reflex inhibitory effect upon small nerve fibre discharge to the spindles which stretch of spastic muscle produces, (Hunt 1951), there may also be a decrease in afferent discharge from the spindles themselves when stretch is maintained. Bronk found that after a twelve minute stretch with a rather heavy loading the response to further stretch was negligible, and that considerable time was required for the spindle to regain its previous state of excitability. It may be reasonable to suppose therefore that a period of stretch reckoned in months rather than minutes might cause a "fatigue" of the spindle from which recovery, if it did occur, would be very slow indeed. Before relating Bronk's results to those of the present study some differences in the experimental material must be closely examined.

The muscles of the patients retained their nervous connections with the cord whereas Bronk experimented with excised nerve-muscle preparations. Nevertheless, it may be permissible to assume that whatever the reflex effects upon cord mechanisms, the effect of stretch upon the spindles themselves may possibly have been of a similar nature. Another difference is that whereas the spindles in Bronk's experiments were stretched absolutely the spindles in the patients' muscles were stretched only in relation to their usual resting length. Nevertheless it seems possible that the effect was qualitatively the same though no doubt quantitatively less.

The results of Bronk's experiments clearly pointed to the difficulty, if not the impossibility, of permanent fatigue of spindle response. It may be for that reason that little attention appears to have been paid to treatment of spastic muscles by passive stretch. Manipulation of spastic muscles is indeed quite often advised, but usually with the aim of preventing fibrous contractures rather than reducing spasm. Analysis of the results obtained in the present study suggests that, under certain conditions, the response of the muscle spindle to external stretch may, at least in hypertonic muscle, be "permanently" "fatigued". The first requirement is a very long period of constant stretch, the average in the successful cases being 14 weeks. The second is that once spasm is clinically abolished the patient must make use of his increased range of normal flexor tonus and in the resulting range of voluntary extension. If he does not, and particularly if the part is kept constantly in a flexed posture after removal of the extending appliance, then the spindle appears to slowly regain its ability to respond to all increments of muscle lengthening from the resting position; as evidenced by the reflex contraction evoked on passive extension from the postural flexed position, (see chart of Case 7, p. 133).

It is proposed that the mechanism involved where spasm does not return and voluntary extension is not lost might possibly be described in the following terms. If a muscle, usually held by spasm in a state of partial contraction, is kept constantly lengthened for a long period of time its spindles will also be constantly lengthened in accordance with the servo-loop theory. It may be that after a certain time they undergo some intimate change which prevents afferent discharge occurring at any length shorter than that maintained during the period of stretch. This change may possibly be a structural stretch of the sensory part which thereafter becomes incapable of shortening even when the main muscle is shortened. This may well be too simple a theory but it appears to be supported by a certain clinical finding. Where a joint was splinted in a position which was less than the fully extended position resistance in the flexor muscles to passive extension disappeared only up to the locus in the arc of full extension in which the joint was held. For example, where spasm of the wrist flexors was being treated the appliance was usually made to hold the joint extended only to some 30°, the functional position, even though 70° extension or more might be obtained by further passive movement. After a period of constant stretch hypertonus in the wrist flexors was abolished - but only up to the angle of 30° extension. At that point a sharp reflex flexor contraction was felt and further extension could be obtained only by employing a certain amount of extension force. A good example of this feature is Case 6, (p.121 appendix). In her case electromyographic recording of activity in the flexor muscles was also made and showed a complete absence of potentials up to the locus in the arc of extension in which the wrist joint was held by her appliance. But when that locus was reached a marked motor unit response was evoked and this continued as extension was forced to the limit obtainable. This phenomenon was presented by all muscle groups which were held stretched to a lesser degree than that which was obtainable by further passive movement.

These findings indicate that the spindle does not lose its ability to respond to stretch. Therefore the fact that the muscle could be passively shortened and then lengthened to its position when in the appliance without resistance offers evidence that during such a manoeuvre the sensory part of the spindle is not in fact stretched. This suggests that when the muscle shortens the spindle does not. In other words the sensory part of the spindle may become physically "set" at an extended length.

If that is so, how is voluntary flexion unaffected? It appears probable that when the elbow joint of a hemiplegic patient is held extended by a splint the length of the spindles in the flexors is not greater than those in a normal subject with his limb relaxed in extension. This would appear especially probable if the effect of stretch on the small nerve innervation of the spindles in the hypertonic muscle of decerebrate cats (Hunt 1951), applies also to hemiplegic man. In terms of the servo-loop theory the normal subject flexes his elbow joint from such a position by activating the intrafusal muscle fibres. This stretches the lengthened sensory part still further and the resulting afferent discharge leads to main muscle contraction. But as the muscle contracts the sensory part tends to relax. To avoid cut off of sensory discharge the spindle muscles must contract further and so "take up the slack" in the sensory part. This process is repeated at each increment of main muscle contraction. It would appear therefore that, during active flexion, even in normal subjects, the sensory element can never be allowed to shorten from its length when the joint was extended. If this assumption is correct, the flexor spindles of the patients, incapable of shortening but responsive to stretch, will be able to function during voluntary flexion since the movement is initiated and maintained by still further stretch produced by intrafusal muscle contraction.

Though no previous study of the effect of prolonged stretch on spastic muscle has been found it was most interesting to discover an observation recorded by Denny Brown & Liddell (1927) which appears to offer support for the thesis that muscle spasm can be abolished or greatly reduced by this means. During preparation of chronic spinal dogs for their work on the stretch reflex they noted that, though rigidity in the quadricep muscles appeared and became quite marked during the thirty days following transection of the cord, it did not remain so. They say, "Within another thirty days this rigidity at the knee became less well marked until eventually it was quite slight though plainly present. The gastrocnemius muscle, on the other hand showed most marked rigidity and an extreme resistance to the movement of flexion throughout the post-operative period." They discussed this finding at some length and offered one explanation in the following terms, "A reason for the relatively weak rigidity of the knee extensors may have been that during the post-operative period all the preparations maintained an extension of the ankle and an acute flexion of the knee as their ordinary resting posture. The chronic flexion of the knee may well have impaired the stretch organs in the knee extensors." The post-operative period referred to was usually some two months.

This effect of "chronic flexion" upon hypertonus in the knee extensors in their spinal dogs seems a close parallel to the effect of "chronic extension" upon that in the flexor muscles of the patients observed in this study. It may be noted that Denny Brown & Liddell also postulated an impairment of the stretch organs as the reason for reduced hypertonus. It must however be pointed out that here again the results of observations in a different species and of different types of lesion in the central nervous system are being compared.

At the present time the mechanism of human spasticity presents many unsolved problems and I should like to make it quite clear that the theory which has been advanced is presented only in the hope that it may help to indicate the line of future research on the problem. In this respect recourse to animal experiment appears necessary, though again the results could not be reliably equated to the human subject. A higher primate in which a chronic hemiplegia had been induced might be the best preparation. It would be interesting to record the affernt discharge from one of its flexor muscle groups before and after subjecting it to the method of stretch which has been described. A period of stretch lasting three months is suggested. If, after this time, when the part was passively flexed and then extended, no afferent discharge appeared until the locus in the arc of full extension was reached in which the limb had been splinted, but thereafter the record showed a sudden rise, this would suggest a peripheral rather than a central change.

Whatever the intimate mechanisms involved it may be agreed that the analysis of results presented offer some hope that the method may have a place in the management of hemiplegia. Other methods of treating the hemiplegic patient and in particular his muscle hypertonus will be discussed. In so doing it may be possible to determine the place of the muscle stretch method which has been described.

Modern methods of treating hemiplegia caused by cerebrovascular lesions appear to fall into three main categories. Immediately following onset, ipsilateral stellate ganglion block is sometimes advised. When the signs of hemiplegia are fully developed rehabilitation is almost universally accepted as the treatment of choice. In the residual phase where spasticity is hindering further progress several methods of reducing it have been tried. Apart from these three main lines of treatment there are few accepted methods. Bourguignon (1925) claimed good results from trans-cerebral ionisation and Martucci et al (1937) advised trans-cerebral diathermy. In the absence of statistical proof of their efficacy these methods have fallen into disrepute, as has the "almost athermic" short wave diathermy of Wolf (1941). Brunstrom (1956) has described a method whereby the flexor and extensor synergies of the upper limb may be put to useful purpose, but he did not provide clear evidence of their value. Sciaroni (1948) attempted operative treatment whereby the circulation was partially re-routed to the affected area. In three residual hemiplegic cases so treated one showed moderate improvement and the others died soon after operation.

Stellate ganglion block is not comparable in any way to the method of treatment advanced in this work, and will therefore be briefly commented upon only because of its wide use. It was first introduced by Leriche & Fontaine (1936) who described it as a method of increasing the cerebral blood supply by blocking, with local anaesthetic injection, the sympathetic fibres to the vessels of the brain. They believed that spasm of these vessels enhanced the ill-effects of the cerebrovascular lesion. Villaret & Cachera (1939) conducted experiments with dogs which appeared to support that opinion. Perhaps the most objective clinical study was that of Mackey & Scott (1938), who found a quick and marked improvement in nine out of nineteen cases of early hemiplegia; that resulting from embolus responded best and they advised injection immediately after onset. This assessment has been supported by the work of Risteen & Volpitto (1946), Gilbert & de Takats (1948), Walsh (1956) and Amyes & Perry (1950). The last named called attention to the danger of puncturing blood vessels or pleura and also to the short-lived effect - a few hours - of a successful block. Harmel et al (1948), in a study of its effect on the blood supply of the brain, found that "Neither cerebral blood flow or cerebral vascular resistance was significantly changed following stellate ganglion block." Brain (1956) has stressed the need for more controlled trials of the procedure.

Rehabilitation. This might be described as a method of training the hemiplegic patient to make the best use of all the mental and physical resources spared by his cerebral catastrophe. Warren, (1948, 1950 & 1953) in this country, and Rusk (1953 & 1954) in America, have played a prominent part in securing recognition for this method. The idea of rehabilitation has however been gaining ground since the beginning of the century. Graham (1902), advocated regular passive and active movement of the limbs as soon as the acute phase had passed. Shepherd et al (1915) reiterated this advice and claimed that functional improvement could be so obtained. In 1920, Thompson wrote, "Re-education of the patient in making new movements will often greatly improve the paralytic limbs." The first recorded use of the word rehabilitation was in a paper by Mann (1935). In that report the modern concept had begun to take shape. Passive methods were not recommended. The emphasis was on active movement. Mann selected a duration of six months or more as signifying residual hemiplegia from which spontaneous improvement could not be expected. Since his report there has been a great deal of published work on rehabilitation of the hemiplegic patient. Much of it is repetitive and to avoid confusion it may be best to outline the main features of the method as practiced by leading authorities. Of these Warren and Rusk have already been mentioned; other contributions have been made by Lowman (1948), Rusk & Marks (1953), Fields (1955), Droller & Thornley (1956) and Benton & Rusk (1956).

Rehabilitation is now generally begun as soon as the acute stage of the cerebral accident has passed. Simple measures are carried out ab initio to prevent contractures, such as a pillow in the axilla and a foot board. More general splinting is very rarely advised, but in view of the results obtained in this study it might be interesting to treat an early hemiplegic with an appliance which kept the shoulder in abduction and the elbow, wrist and fingers in extension. Development of spasm in the muscles opposing those positions might thus be prevented. On the other hand, if spasm did not appear it might be argued that this had been a spontaneous occurrence. Perhaps a more instructive time to apply such a splint would be when a marked degree of spasticity was clearly developing and then observe the subsequent effect.

Returning to treatment by rehabilitation, the usual procedure is to begin with passive and assisted movements; later free active or resisted exercises are given. When sufficient voluntary movement returns in the leg the patient is encouraged to stand and sit under supervision. With further improvement he graduates to walking between parallel bars or holding a rail. Next he is trained to walk with the help of a three or four legged stick. In this manner he is taught to get about independently. At the same time he is taught to make the best use he can of his upper limb in dressing, feeding and other personal activities. Many special instruments and alterations in standard equipment are used to help him these matters. In this way the patient can often be discharged home and able to look after himself.

The author had the good fortune to work for some time with Dr. Marjory Warren and so gained experience of the great value of rehabilitation. Nevertheless the impression was formed that it has one major defect; it rarely produces much useful movement in the upper limb. Muscle hypertonus is commonly the limiting factor. In the leg this usually produces constant extension at the knee and the ability to walk is thereby assisted. But in the upper limb its effect is to cause a constant flexion of fingers, wrist and elbow and so function, far from being assisted, is usually greatly curtailed. The ability to use what movement remains can of course be improved by occupational therapy but where hypertonus is marked it appears that little can be gained even in that way. A spastic upper limb is a great source of annoyance and frustration to the hemiplegic patient and it was surprising to see with what eagerness they agreed to try the muscle stretch method despite its apparent tediousness. They seemed to welcome it as a positive line of treatment.

Experience with this series of patients suggests that the technique is probably most worthy of trial in the residual phase of hemiplegia when it is clear that hypertonus is not resolving and that further functional improvement in the limb is unattainable by the usual methods of rehabilitation.

What other ways of reducing spasticity are available? Probably the most comparable method of approach to muscle stretch is that described by Psaki & Treanor (1956) who proposed that afferent impulses from muscle and skin played an important role in maintaining spasticity in hemiplegic patients. They stated that if such influence from the more spastic muscles could be reduced some movement of their less spastic antagonists would result. As a test they blocked the nerves to the spastic groups with 1% Zylocaine and if antagonist movement resulted nerve conduction block was carried out by surgical procedure. Disappointingly, they gave no information regarding the results obtained.

La Joie & Gersten (1952) carried out an interesting study of the effect on the excessive muscle tonus in hemiplegia of various procedures claimed to be of value in reducing it. These were hot packs, paraffin wax, infra-red radiation, the drug "Myanesin", tetanising current, constant current and ethyl chloride spray. The degree of tonus was estimated by a mechanical device which extended the elbow, the tension required to initiate movement being recorded before and after ~~the~~ use of the method which was being examined. Electromyographic records of activity in the elbow flexors were made at the same time. The corresponding muscle group on the unaffected side of the body was used as a control. They found that only two of the above methods had any effect in reducing tonus. Infra-red radiation at a distance of fourteen inches caused a slight reduction. This lasted about ten minutes after removing the heat source. The other was "Myanesin". The drug was slowly injected over a period of some fifty minutes and it significantly reduced resistance. The maximum decrease usually occurred during injection and after it was stopped spasm returned within twenty minutes.

La Joie & Gersten's results indicate that "Myanesin" (3-Ortho-Tolaxy-1, 2-Propanediol) was a potent reducer of spasm. Other workers have confirmed this opinion. Berger & Schwartz (1948) found that orally administered, in the form of a 3.3% solution, it caused abolition of spontaneous motor unit activity in the spastic muscles within five to twenty minutes. Electromyographic recordings were used. They found that when spasm was reduced active movement was increased. The subjects of their tests included patients suffering from chronic residual hemiplegia. They found that the drug was well tolerated over a period of many weeks. Regarding the last point, other clinicians while agreeing that "Myanesin" reduces tonus have not found it safe enought for prolonged administration. For example Schlesinger et al (1948) using the intravenous route of administration noted that, when given in concentrations sufficiently high to produce clinically effective results, side reactions such as nystagmus, blurred vision, drowsiness and paraesthenia were commonly experienced. They also found that its effect lasted a maximum of forty-five minutes after administration was stopped.

Some other drugs have been tried. Among them was Curare but it does not appear to have been well received, mainly perhaps because of the danger of respiratory paralysis. It was also found that effective doses were likely to produce unpleasant side effects such as weakness, giddiness and diplopia. Again, voluntary movement was abolished at the same time as spasm since Curare exerts its effects by blocking transmission at both the alpha and gamma end plates (Hunt 1952). Schlesinger (1946) reported good and sustained results by using a suspension of Curare in oil but even he admitted that its main value was in permitting physical therapy during the period of relaxation. Another which had a vogue was Neostigmine. Controlled studies by Schwab & Chapman (1947) and Teitelbaum & Vyner (1949) did not support previous reports claiming success.

Basmajian & Szatmari (1955) presneted an interesting account of the effect of Chlorpromazine on hypertonus. Thirteen patients presenting spasticity, including residual hemiplegic patients, were studied by clinical examination and by electromyography. The drug was injected intravenously and within three minutes a dramatic release of spasm was detectable clinically. Electromyographic recordings showed simultaneous disappearance of spontaneous motor unit activity. Two hours after injection spasticity was found to have returned to its previous state. Most of the patients were made drowsy by the drug. Given by mouth the effect was less obvious. Discussing its mode of action the said, "Judging by the clinical effects on psychotic and on hyperexcitable patients it can be said to affect higher centres. However the exact level of action is unknown. Does it stimulate descending inhibitory pathways or repress facilitatory ones?" They concluded that the latter seemed to them the more likely.

It is evident that all of the above-mentioned drugs have disadvantages which preclude their general use. The ideal drug would be safe in effective dose, reasonably prolonged in action, easily adminstered and would act selectively on the appropriate extrapyramidal centres. At present no such preparation is available.

Some modern methods of treating the hemiplegic patient and his spasticity have now been reviewed. It may be agreed that no really effective treatment has yet been found. Hemiplegia presents a great and increasing problem, the magnitude of which is shown by Howard Rusk's estimate that there are between one and one and a half million hemiplegic patients in the United States of America. It is therefore apparent that an advance in the treatment of hemiplegia is urgently required. The only really effective treatment would be to prevent its occurrence, but until that can be done the only course is to make the best use of the nerve elements which have escaped destruction. In that connection, Lassek (1950) has published some interesting work. After an extensive study of the relationship between clinical paralysis and destruction of the cortico-spinal pathways he said, "I have not been able to find any distinct correlation whatsoever between the degree of destruction in the motor bundle and paralysis." Some patients presenting an almost total hemiplegia were found at autopsy to have an intact pyramidal system. Lassek's findings offer hope that voluntary movement may be regained by such patients if the other factors restricting movement can be overcome. What are these factors? The most obvious one is hypertonus but it should be noted that at least one other has been suggested. Sherrington (1947), Walsh (1948) and Lassek (1950) have called attention the possible importance of the interruption of afferent influx to the sensori-motor cortex, particularly that from the distance receptors. It will however be difficult to asses this factor until a means of abolishing muscle spasm has been found. It seems therefore that the immediate problem in the treatment of hemiplegia is to find such a method.

There is little doubt that the most promising line of approach is through pharmacological research on spasm relieving drugs. If an effective preparation can be discovered it will of course reduce spasticity in all the muscles. Meanwhile there may be a place for the method introduced in this work, whereby tonus in the more spastic groups can be reduced with consequent release of active contraction in the less spastic. Its main disadvantage is that it usually requires several months of constant ~~or~~ part time immobilisation to obtain lasting results. Nevertheless, when it is anticipated that the patient will survive for a period of years and will be able to make use of the resulting improvement this may be justifiable. It can at least be said in favour of the method that it is perfectly safe. Polythene-polyurethane appliances were used in each case and skin abrasions never occurred despite long periods of constant wear. But apart from their comfort and durability there does not appear to be any special virtue inherent in that type of appliance and any comparably safe means of stretch would no doubt do equally well.

A point which might be worth stressing is the importance of actively using the limb as soon as the period of constant stretch is over. This helps prevent two minor troubles attendant upon immobilisation - oedema, and sometimes also stiffness of the part. Every encouragement should be given the patient to use his limb and occupational or diversional therapy freely prescribed.

The danger of generalising from the results obtained in a small series of experiments is stressed. Further study is clearly required and, in future trial, methods of measurement more exact than those of clinical examination would be desirable. For example, change in the power of active movement could be more accurately measured by a machine which records muscle tension. To record changes in the degree of tonus would be more difficult. The apparatus described by La Joie & Gersten recorded this measurement by the amount of tension required to initiate movement. The reliability of such a technique is open to question since the tension recorded will depend to a large extent upon the position of the limb before passive movement is begun. These workers did not consider that point, but it seems important since it was noted throughout the present study that if, for example, the elbow joint was fully flexed it could then be extended through an arc during which no resistance could be detected - commonly some $40^{\circ} - 50^{\circ}$. Resistance would then appear in the form of a sudden contraction of the flexor muscle groups. The locus in the arc at which this phenomenon presented remained more or less constant in the absence of treatment. It is proposed therefore that it would be more satisfactory to adapt their apparatus to measure this range of unresisted movement and to measure also the strength of the reflex contraction eventuallyelicited. Alteration in those features would, it is thought, give a better assessment of change in the degree of tonus.

It may be permissible to hope that further research will substantiate the results obtained in the present clinical study. If the method of muscle stretch is proven to be successful in overcoming hypertonus, patients with hemiplegia and perhaps also those with other upper motor neurone diseases such as paraplegia or cerebral palsy might benefit.

PART 2.

THE POLYTHENE-POLYURETHANE SPLINT.

INTRODUCTION.

The first plastic material, cellulose acetate ("Celluloid"), was discovered by Parkes in 1863. In orthopaedic practice it was the only plastic commonly used until 1943. In that year McGowan described the manufacture of Polymethyl Methacrylate ("Perspex") splints from positive plaster casts of the patients' limbs. A year later Kulowski et al described a method of splint making in which a loosely knitted bandage of cellulose acetate and cellulose rayon was used. This was wrapped round the limb and sprayed with acetone. On drying the materials became rigid. In 1945 Scales & Herschell described a method of making small Perspex splints from negative plaster casts. Cholmeley (1945) also reported favourably on Perspex as a splint material. Collinson (1946) published a short account of the use of urea-formaldehyde resins for making splints direct to patients. Bandages soaked in these resins were wrapped round the limb and heat applied. It was found however that the length of the period of heating which was required to harden the materials was rather too long for this to be a practical method. It was also found that skin reactions from the formalin were not uncommon.

Herschell & Scales (1948) reported further on the value of Perspex in the manufacture of small splints and spinal jackets. Negative plaster casts were used. They pointed out the necessity of have a specially equipped workshop and the assistance of technicians skilled in the use of plastics when making the large appliances. In 1950 Scales described the use of polyethylene (polythene) and resinated asbestos felt in splint making. Both were moulded over positive plaster casts. The procedure for making appliances from resinated felt required specially skilled work, though good examples of rigid appliances such as pylons could be made with that material. Polyester resins and Vinyl Polymers are also used for the manufacture of splints though positive plaster casts and skilled labour are also required for their use, (Scales, in Nangle, 1951).

In 1953 at the 8th. International Congress for Rheumatoid Diseases a new method of applying Perspex splint material direct to the patient was demonstrated by Dr. H. Van Swaay of Holland, (Van Swaay, personal communication.) The malleable temperature of Perspex is 140°Centigrade. The technique was as follows: a new plastic possessing marked heat resistant properties was interposed between the patient's skin and the hot perspex. Heat insulation was sufficient to exclude all but a comfortable warmth. The new plastic was elastic in consistence and therefore was itself malleable. The plastics were moulded to the part by bandaging and when the Perspex cooled and hardened a mould of the part was obtained. There was no adherence between the materials and if padding was required it was neccessary to glue them together. Further progress was made in this method by using polythene in place of Perspex (Scales, personal communication). The advantages of this combination were the lower malleable temperature of the polythene (120°C.) and the adherence obtained between these plastics during heating.

It may be well to remark at this point that I played no part in inventing the method of applying these materials to the patient. My contribution was to extend the scope of the technique from the stage of making cock-up wrist slabs, to which it had been brought by the above workers (Van Swaay 1954), to the manufacture of more elaborate splints and spinal appliances. These are described later, (Appendix, pp. 204 - 255). The evolution of suitable designs for making these appliances, and elaboration of the procedures required for moulding them, were the result of my own research. I was fortunate too in being able to conduct the first clinical trials of this type of splint, (Brennan, 1954, 1955 & 1956). Since these reports were published new appliances have been designed and improvements in the details of using the direct to patient method have been made. It was thought that this work might be of some interest. A full account is therefore given in preference to affixing reprints. In view of its technical nature it is enclosed in the appendix. A description of the materials used, the apparatus required and the method of manufacture is given before describing the appliances.

OBSERVATIONS.

Material.

A polythene-polyurethane appliance is formed of two adherent layers of plastic. The outer layer is polythene, a semi rigid material. The inner layer, which lines the polythene is a soft spongy plastic called polyurethane. The polythene provides the required strength and the polyurethane, besides insulating the skin from the heat during moulding, remains as an adherent padding in the finished splint.

During a two year period two hundred and forty-seven appliances were made with these plastics. A list of splints and spinal supports which were designed and found to be useful by clinical trial is given below. One example will be given in some detail to illustrate the sort of design and method of application used.

RANGE OF APPLIANCES DESIGNED.

(A). Upper Limb Splints.	See Appendix Pages Nos:-
1. Ventral (Cock-up) wrist splint.	209.
2. Lively wrist splint.	212.
3. Dorsal wrist splint.	215.
4. Ventral wrist splint with extension to prevent ulnar deviation of fingers.	217.
5. Hand splint to prevent ulnar deviation of fingers.	219.
6. Wrist and finger splint for use in spastic paralysis. (Type A).	221.
7. Elbow splint.	224.
(B). Lower Limb Splints.	
1. Knee splint.	204.
2. Long leg and foot splint.	226.
3. Short leg and foot splint.	230.
4. Heel-sore splint.	232.
(C). Spinal Appliances.	
1. Cervical collar.	235.
2. Lumbar-abdominal support.	242.
3. Lumbar spinal support.	245.
4. Spinal brace.	247.
5. Sacral bed-sore jacket.	249.
6. Plastic bed.	252.

Also.

Wrist and finger splint for use in spastic paralysis, (Type B.). - described overleaf.

WRIST AND FINGER SPLINT FOR USE IN SPASTIC PARESIS.

TYPE B.

This shows the first stage of putting on this splint. The forearm bands are fixed and the patient is about to passively extend (with his good hand) the fingers and wrist of his spastic hemiplegic side so that it comes into line with the hand section of the splint at which point it can be slipped into position in the splint.

Showing the hand in position in the splint. (As illustrated, the design of this appliance allows the procedure of fitting to be separated into two parts and it was found that patients with marked spasticity could put it on and remove it without assistance.)

MATERIALS.

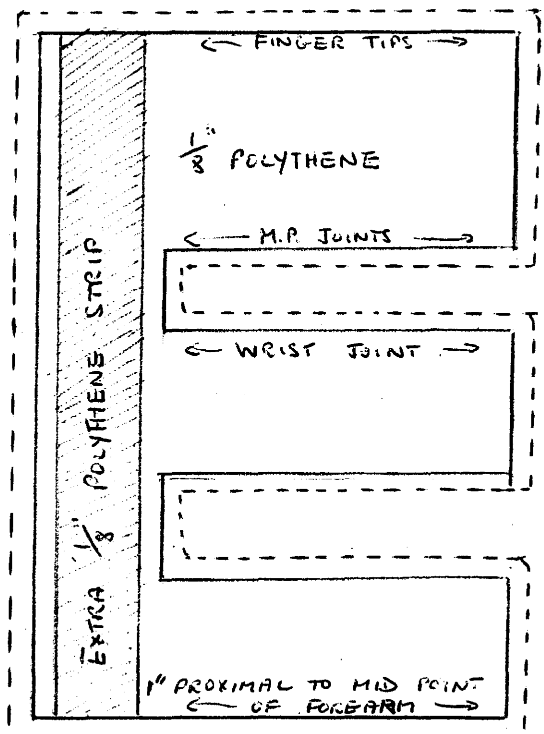
Polythene 1/8". Polyurethane 3/16".

MEASUREMENTS.

1. Distance between finger tips and 1" proximal to mid point of forearm.
2. Distance between finger tips and wrist joint.
3. Distance between finger tips and ½" proximal to M.P. joints.
4. Circumference of fingers at M.P. joints.
5. Circumference of wrist.
6. Circumference of forearm 1" proximal to its mid point.

PREPARING THE PLASTICS AND DIAGRAM OF DESIGN.

This splint is virtually a dorsal cock-up slab with bands round forearm, wrist and fingers. The design required to produce these results is shown opposite. The bands round the forearm and wrist are made 2" wide and the width of the band round the fingers is the distance between middle finger tip and ½" proximal to M.P. joints. The dorsal strip is 2" wide, and where there is more than mild spasticity a strengthening strip 1" wide and of 1/8" thickness is laid down the middle of the dorsal strip, (shaded strip in diagram).



In marking the patient's measurements on the polythene 2" is added to the circumference of each band so that they will overlap the dorsal strip in the moulded splint. This adds a little to the strength and also allows press-studs to be set into the plastics themselves and so avoids adding straps when finishing the splint.

MOULDING.

As described for moulding Type A. splint the spasticity is abated by passive manipulation of the patient's wrist and fingers for a few minutes. The heated plastics are then removed from the oven and, while an assistant holds the fingers and hand extended, the dorsal strip is laid along the dorsum of the limb and the bands are wrapped round the forearm, wrist and fingers - including the M.P. joints. They are then bandaged in place. The bandage is left on for some fifteen minutes to allow the dorsal strip (now ¼" thick) to cool and set adequately. During moulding, the finger band must cover the ventral surface of the M.P. joints. If it is moulded distal to these joints and covers only the phalanges flexion spasm at the wrist joint will, when the finished splint is worn, hyperextend the fingers.

FINISHING.

Four straps and press-studs are fitted in the position shown in the photographs and the splint is ready to wear.

Weight. 6ozs.   Cost 4/9d.

- - - - - - - - - - - - - - - - -

RESULTS.

I had the opportunity of making one hundred and forty-seven limb splints and spinal appliances by the direct to patient method described and of observing the results. The cutting, moulding and finishing of each was personally carried out. About one hundred others were made by non medical staff.

There was very little waste of material during manufacture. Odd pieces of polythene left over after cutting out certain designs were used as strengthening strips in other appliances. Odd pieces of polyurethane were used as extra layers of padding where this was indicated. Some examples turned out badly and had to be heated out flat for remoulding or, occasionally, thrown away. This only occurred during experiments with new designs and when these were satisfactory no such waste occurred.

Regarding safety, no burn was sustained nor was discomfort complained of by any patient during the manufacture of these appliances.

Malleability of the two adherent layers of plastic was found to be adequate for all but a very few patients. The limiting factor in each case was a sharp curve in two planes at right angles to each other, e.g. it was found that they would not mould satisfactorily to a knee which was flexed much more than 45°. In practice, splinting any joint at a greater angle of flexion than that was seldom indicated.

One of the most satisfactory reports from the patients was that these appliances were comfortable to wear. Only two patients refused to wear their appliances on the grounds of discomfort, (Appendix P.P. 99 & 195). In no case did even a small skin abrasion occur though in some patients with spastic muscles a rim of pressure made a tempprary appearance beneath the upper and lower borders, (Appendix P.P. 172-176)
No skin reaction was seen though in hot weather a few patients developed mild sweat rashes. Generally speaking, the warmth of the lining makes them more comfortable in cold weather than in hot.

The appliances were found to be extraordinarily durable. No appliance broke nor did any one lose its moulded shape. The polyurethane lining usually required renewal after about six months wear fer reasons of hygiene.

DISCUSSION.

Since invention of the method of applying these plastics was due entirely to the research of other workers it would, I feel, be inappropriate to include a lengthy discussion of its merits. On the other hand it may be permissable to give a brief account of the impressions formed during an extensive personal and clinical trial.

The polythene-polyurethane splint was found to have the following properties. It is light in weight, being some three to four times lighter than its Plaster of Paris counterpart, comfortable to wear, durable and inert. It can be washed. Temperatures tolerable to the patient have no effect upon it. It does not distort on prolonged use. It will burn slowly, like candlewax, if placed in a naked flame but will not otherwise catch fire. It is almost perfectly translucent to X-rays. The cost of material is small, a splint complete with buckles and straps is a little less than a similar removable plaster splint and a fixing crepe bandage. If a splint is no longer required by a patient it can be heated out till flat and remoulded to another.

The method of manufacture, avoiding as it does the use of plaster casts, holds a great advantage over other methods in which such intermediate models are required. Experience showed that equally well moulded limb splints could be made by either method while moulding on casts was found to be rather better for making spinal supports, especially large braces. Cervical supports could however be made very well by the direct to patient method.

It was found by personal experiment that the polyurethane layer between skin and polythene was indeed an efficient heat insulator and that there was no danger of burning occurring through it in the thickness and density used. This was supported by the testimony of every patient. Besides, if burning did occur it could only take the form of a "hot spot" under some point of undue pressure and would not compare in severity with the severe burns of the whole limb which have occasionally occurred with the "Glassona" type of splint. The latter type carries also the danger of acetone poisoning (Campbell, 1946).

One of the great advantages of the direct to patient method is that a physician or surgeon can devise original types of splint and immediately put his ideas into practice. No outside technical assistance is required. Some examples of appliances developed in this was are shown in the appendix. These include a splint for healing bed sores (P.232), a splint for preventing ulnar deviation of the fingers in patients with rheumatoid arthritis (P. 219) and an adjustable elbow splint for a boy with lower motor neurone paralysis of the arm (P.300).

Immediate conversion of one's ideas into practice in this way was found most stimulating.

Another advantage was the speed with which patients in urgent need of special appliances could be supplied with them. Two patients with severe root pain from carcinomatous secondary deposits in the cervical spine were supplied with cervical supports within two hours of request and derived lasting relief, (P.P. 286 - 292).

A disadvantage of making thermoplastic splints is that a certain amount of equipment is required. An electric heating oven and a machine for punching ventilation holes and riveting straps and buckles onto the splint are essential, and a power driven buff is desirable. On the other hand no large expenditure is needed. The oven is a simple thing to make (Appendix P.199) and could in most cases be made from the scrap available in the hosptial engineering department. The punching machine costs seventeen pounds and a buff costs about eight pounds. So that the total outlay need be no more than twenty-five pounds.

The method of making the splints is easy to learn and at the hospital in which this work was done approximately one hundred examples were made by physiotherapists and other non medical workers.

PART 3.

A STUDY OF THE VALUE OF STABILISING JOINTS IN THEIR FUNCTIONAL POSITION, BY MEANS OF POLYTHENE-POLYURETHANE PLASTIC APPLIANCES, IN THE MANAGEMENT OF RHEUMATOID ARTHRITIS AND NEUROLOGICAL DISEASE.

FOREWORD.

Polythene-Polyurethane (P.P.) appliances were used in the management of 163 patients in an attempt to relieve pain, prevent deformity and help restoration of function. Of this number, 107 patients suffered from rheumatoid arthritis. The remaining 56 included representatives of a wide range of chronic diseases, mostly neurological. It was however mainly in the hope of benefitting rheumatoid arthritic patients that work on the P.P. appliances was done. A much wider experience was therefore gained of their value in that condition than in any other single disease entity. The introduction and discussion of this series of patients will thus be confined to their use as a means of obtaining rest for the affected joints in the management of rheumatoid arthritis.

INTRODUCTION.

It is a fundamental principle in the treatment of disease that the affected tissues be rested. It has been found that the body's defence and repair mechanisms function best when the diseased part is at rest. This is perhaps of special importance in the treatment of inflammatory disease and many great teachers of medicine have laid emphasis upon it in that connection. Hilton (1860) advocated rest in the management of a wide range of disease processes. Hugh Owen Thomas (1878) applied it to the management of disease in the locomotor system with such outstanding success that his methods have been almost universally adopted. In 1909, one of his disciples Robert Jones, writing on the treatment of rheumatoid arthritis emphasised the importance of resting the joints in their functional positions as part of the management of that disease.

It is probably correct to say that rest is now generally acknowledged as an essential part of the treatment of acute arthritis. On the other hand the very small amount of published work devoted to study of its value suggests that this has not been widely investigated. It appears that attention has been almost exclusively directed towards the trial of a succession of treatments advanced as having a specific action upon the disease process. Simple rest must have seemed to many as a confession of defeat, as indeed it is, though a remedy the value of which has been so widely accepted appears to merit closer study. A few workers have however given it a high place in their scheme of treatment, and it appears significant that rest has been, and still is most strongly advocated by physicians with a very wide experience in rheumatology.

Coates (1933) insisted on prolonged rest of inflamed joints and forbade weight bearing when those of the lower limbs were acutely involved. After his death, Kindersley (1936) carried on his work and stated that he considered splinting to be the main feature of treatment and that other methods should be regarded as subsidiary to it. Bell (1940) was another advocate of rest. He wrote "immobilisation while the condition is acute, and splinting to prevent deformity will make the patient much more comfortable, allay the inflammation, aid in arresting the progress of the disease and definitely prevent deformity." In the same year Tippett advised the use of a plaster bed in cases where the disease was poly-articular, saying, "This will give generalised comfort and support to the painful limbs."

While the search for a specific anti-rheumatic remedy was persued with renewed vigour following the second World War the employment of rest continued to be advocated, Dunlop et al (1947), Copeman (1948), McMurray (1949) and Wiles (1951). One of its strongest supporters was Duthie (1951) who wrote "It would therefore appear that the best results will be obtained in respect of both constitutional and local symptoms if methods of treatment are used which will control the inflammatory process in the joints. Viewed from this standpoint, marked constitutional symptoms are a clear indication of the need for treatment of the primary lesion in the joints." He recommended strict immobilisation in encircling plaster casts for 1 - 3 weeks while inflammation subsided, and stated that ankylosis was prevented by this measure rather than encouraged as so many believed. Parry et al (1952) also advised both local and general rest for children with acute arthritis.

During the last few years, as the limitations and dangers of suppressive therapy became increasingly clear, many authorities reiterated their belief in the value of simple general measures including rest. These workers included Tegner (1952), Duthie et al (1955), Lawrence & Sladden (1955), Rae and Bender (1956), Kelly (1956) and Copeman (1956). The last named said that the prevention and treatment of deformity "rests largely on adequate and intelligent splinting of the affected joints before they become irrepairable." Like Duthie he decried the dangers of ankylosis and advised complete fixation of acutely affected joints for up to one week. Kelly (1954, 1956) also claimed that the benefits of immobilisation had been overlooked owing to fear of ankylosis. In his opinion it was during the acute phase that splinting was most desirable since its effect was to reduce inflammation and so lessen the chance of adhesions forming. He advised three to five weeks constant fixation in the functional position followed by progressive freedom from the splints. Duthie and his associates (1955) studied the effect of conservative method of treating 282 patients over the course of three years. They concluded that "The results which follow the conscientious application of conservative forms of treatment in hospital compare favourably with those claimed for other forms of treatment, such as the administration of gold or cortisone."

Against the above background of work the value of the polythene-polyurethane appliance as a means of obtaining rest in rheumatoid arthritis will be indicated. 107 patients were fitted with these appliances and the benefits obtained through their use were noted. It should however be pointed out that the primary object in this clinical trial was to find out if the patients would find this new type of appliance comfortable to wear and helpful in relieving pain during the long periods of use which were foreseen as being necessary for most of them. The great majority of the patients had advanced rheumatoid arthritis and it was not anticipated that objectively measureable improvements would result from the employment of these splints. From the clinical point of view the trial was therefore intended to be mainly on a subjective basis. It was only during the management of the few patients with early acute symptomatology that the value of prolonged stabilisation of the joints became objectively apparent. Thus in the absence of controlled observations only two illustrative cases will be presented. It is hoped that these have sufficient intrinsic interest to merit documentation. One feature of treating early acute arthritis by rest which they suggest is that, since nearly all the joints eventually become involved, it would probably be best to supply every patient with a plastic bed at the onset of the disease. In nearly all early cases a succession of limb splints became necessary with consequent difficulty and fatigue in fitting and removing them.

OBSERVATIONS.

MATERIAL.

Polythene-Polyurethane plastic appliances were used in the management of 163 patients with arthritic and neurological disease. The case histories of 36 patients are reported. The types of disease treated and the number of reported cases suffering from each is shown below.

		Pages No:
Early Rheumatoid Arthritis	7	(PP. 50 - 59 and) (Appendix 257 - 265.)
Advanced Rheumatoid Arthritis	7	(Appendix 266 - 280.)
Disease affecting the Vertebral Column		
(a) Spondylosis	3	(Appendix 281 - 285.)
(b) Malignant Disease	3	(Appendix 286 - 292.)
Decubitus Heel Ulcers	3	(Appendix 293 - 299.)
Neurological Disease.		
(a) Poliomyelitis	1	(Appendix 300 - 302.)
(b) Disseminated sclerosis	2	(Appendix 303 - 307.)
(c) Traumatic radial nerve palsy.	1	(Appendix 308 - 310.)
(d) Traumatic ulnar nerve palsy.	1	(Appendix 311.)
(e) Friedreich's ataxia	1	(Appendix 312 - 313.)
(f) Encephalitis	1	(Appendix 314 - 316½)
(g) Tuberculous meningitis	1	(Appendix 317 - 318.)
(h) Paraplegia	1	(Appendix 319.)
(i) Cerebral Diplegia	1	(Appendix 320 - 323.)
(j) Parkinson's diseas	1	(Appendix 324.)
Soft Tissue Lesions	2	(Appendix 325 - 326.)
Total	36	

METHOD.

The only criterion for the inclusion in the series was the decision arrived at by consultation with the physician in charge of the patient that he would benefit from local joint rest or correction by means of a plastic appliance. Thereupon one of the standard designs, or one specially devised, was used to meet the patient's needs. His subjective account and the objective observations were recorded at intervals during the period of wear. Apart from those patients with arthritis almost every one presented a different therapeutic problem and its response to the particular type of appliance used had to be individually assessed. Two cases of early rheumatoid arthritis are described in some detail to illustrate the method of treatment and observation.

RESULTS.

Rheumatoid Arthritis.

P.P. plastic appliances were used in the management of 88 advanced and 19 early cases of rheumatoid arthritis. Their purpose was to stabilise and rest painful joints in their functional positions. In all cases this resulted in some degree of abatement of pain and in many relief was complete within days or weeks. The average period during which the appliances were used, while the patients were under personal observation, was 0.91 years. No appliance was discarded on the grounds of discomfort. In no case did deformity occur while wearing a splint designed to prevent it. Although some patients kept inflamed joints immobilised almost constantly for weeks or months ankylosis was never seen as a result; in fact it was much more common to find that the range of movement increased when the signs of activity in the joint had responded to rest. It must however be pointed out that in no case was immobilisation absolutely constant as each patient removed his appliance at least once each day in order to wash the part. All were instructed to carry out a few active movements during that time of freedom.

In advanced rheumatoid arthritis one of the best results obtained by using these appliances was the increase in functional capacity. In almost all of the 88 cases the wrist joint was unstable to some extent and this prevented full use being made of the hand's capabilities. Stabilisation in a P.P. wrist splint increased the strength of the grip besides relieving pain in the wrist. Housewives were enabled to do rather heavy housework and cooking which had previously been outside their scope. Fixation of one knee joint was also of great help to many. Their comfort and light weight permitted wrist and knee splints to be used as almost permanent aids. Finally, the resilience of the splint materials and the employment of press-stud fixation enabled every patient, no matter how advanced his condition, to put on and remove his splints without assistance.

Neurological Disease.

The types of disease and the aims of treatment were so varied that the results can only be related to the particular therapeutic problem which each patient presented. The reader is therefore referred to the case records, (Appendix, P.P. 300 - 324). It may nevertheless be worth mentioning one or two features common to small groups.

Three patients whose hip movements were too weak to permit walking in metal callipers were able to do so while wearing P.P. plastic leg splints in virtue of their light weight, (Appendix P.P. 303, 312, 319).

The abolition of spasticity by prolonged stretch of the spastic muscles, already noted in the hemiplegic series, seems capable of attainment ~~of~~ by similar means in other upper motor neurone diseases. This is suggested by the results obtained in two cases of disseminated sclerosis, one case of cerebral palsy, one case of tuberculous meningitis and one case of Parkinson's disease. It may also be worth noting that the use of specially designed P.P. appliances achieved improvement in function in one case of poliomyelitis (Appendix P.P. 300 - 303).

Disease affecting the Vertebral Column.

Three patients with spondylosis found P.P. spinal supports light and comfortable to wearing during a period of observation lasting, on average, ten months, (Appendix P.P. 281 - 286).

The results obtained by useing P.P. neck supports in the management of 2 cases of secondary carcinomatous deposits in the cervical spine with severe root pain were very good. They were indeed the most rewarding of all in the whole series. Despite gross bony destruction the supports held the head in good position and relieved pain almost completely until the time of death, (Appendix P.P. 286 - 292)

Decubitus Heel Ulcers.

Three patients with ulcerated heels were provided with specially designed splints and the sores healed rapidly in two cases. In the third they resolved when other methods of treatment were used in addition, (Appendix P.P. 293 - 300).

Soft Tissue Lesions.

Two such lesions responded rapidly to rest, (Appendix P.P. 325 - 326).

CASE NO. 18.

Age 6½ years.

Sex. Female.

Condition. Juvenile rheumatoid arthritis.

Case History.

This little girl was admitted on the 3.7.54, with an effusion at the base of the left lung and signs of pericarditis. Her temperature was 104°F. A few small lymph nodes could be felt but the spleen was not palpable. On the 28.7.54 both wrists became swollen and painful, and the diagnosis of acute juvenile rheumatoid arthritis was made.

The wrist and carpal joints continued to be severely involved and flexion deformity appeared imminent. P.P. plastic cock-up wrist splints were therefore made. As the fingers showed less evidence of activity they were left free. Her elbows were also affected to a lesser degree, but it was thought best to let her use her arms so these joints were not splinted except for short periods.

The disease was kept under control by cortisone and ACTH therapy until December, 1954, when attempts to reduce the dosage produced a flare-up and other joints became affected, particularly the knees, ankles and cervical spine. Signs were also present in the shoulders, hips, finger-joints and tarsi, but were less acute. Radiography of the carpi at this time revealed advanced osteoporosis and cortical erosion. Of the newly involved joints the knees and ankles were most affected, the former being held flexed at an angle of 90° and the feet plantar-flexed. Attempts to correct their position caused pain and were resisted. Leg splints were made extending from thighs to toes. During application the warm plastics helped to overcome flexion spasm, and the splints could be made with the knees almost fully extended. Diagonal straps were provided to keep the feet dorsiflexed to 90°. A cervical support was moulded with the neck in neutral position.

The child wore her splints almost continuously, day and night, without complaint. The cervical support was worn only during the day. All were, of course, removed for bathing and for her daily physiotherapy periods. A careful watch was kept on the hip joints, but it was found that hip flexion was effectively prevented by splinting the knee in extension. Fracture boards were used under a firm mattress to prevent kyphosis. The dosage of cortisone and ACTH was very gradually reduced over many weeks, the former being stopped on the 22.4.55 and the latter on the 14.5.55. No rebound phenomena occurred.

By the middle of July, 1955, functional recovery of the joints was almost complete and splinting was discontinued. There was a completely normal range of movement, passive and active, at all the joints of the lower limbs. Muscle bulk was fair; about 75% of normal. The upper limbs showed a little restriction of movement at one or two joints. All movements at the left shoulder were normal. Flexion and abduction of the right shoulder was limited to 160° and rotation was a little restricted. The left elbow movement was normal but extension of the right elbow was restricted by a few degrees (10°). The wrist joints and carpi, which had been severely involved for over eight months, showed an excellent range:- right; flexion 90°, extension 60°, abduction, adduction, supination and pronation - normal.: left; flexion 70°, extension 45°, abduction, adduction, supination and pronation limited by a few degrees. Extension of the fingers was full but flexion was a little restricted. All movements of the cervical spine were normal with the exception of extension which was limited to some 30° - 40° from the neutral position. The other parts of the vertebral column showed a normal range, though there was a little dorso-lumbar kyphosis.

By this time the child was being allowed home, in a wheel-chair, at weekends. On return from one of these outings, on the 1.8.55, she was found to have bronchopneumonia. Her condition deteriorated rapidly and she died on the 4.8.55.

I saw this child every two or three days for just over a year. On no occasion did she complain of discomfort from the splints, and this despite being severely ill for most of the time - with some consequent irritability. Pain, which had caused considerable distress prior to immobilisation of the joints was seldom complained of after. Her death, when all seemed well, was a great tragedy.

The histological report on post mortem tissues is given. At autopsy the right knee joint was opened. No erosion of the cartilage was seen and there were no adhesions between the opposing surfaces of the joint. The soft tissues of the joint showed remarkably little macroscopic change.

<u>Histologist's Report on post mortem tissues.</u>

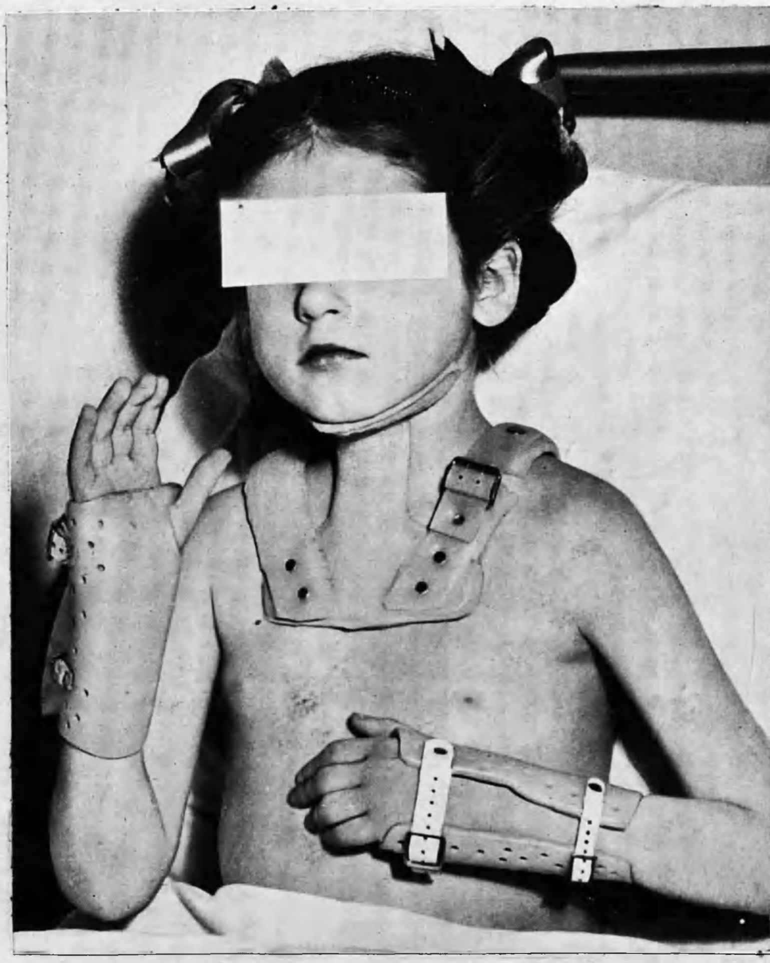
1. & 2. Bronchopneumonia with coccal masses and haemorrhage in lungs.

3. Severe chronic inflammation with ulceration of and slight amyloid change in mucosa and vessels of ileum.

4. Amyloid change in mucosa of colon.

5. Chronic inflammatory infiltration, fibrosis and superficial fibrinoid degeneration of synovia from right knee.

6. Cloudy swelling, peri-vascular and interstitial fibrosis and slight chronic inflammatory infiltration with trace of amyloid in vessels in myocardium of left ventricle; fibrous pericarditis.
7. Sago amyloid spleen.
8. & 9. Fatty change and trace of amyloid change in liver.
10. & 11. Fatty degeneration of tubular epithelium and trace of amyloid change in kidney.



The photograph shows the child wearing her wrist splints and cervical support. (The splints weighed 1½ ozs. each, and the collar weighed 5½ ozs.)

CASE NO. 19.

Age. 32 years.

Sex. Male.

Occupation. Secretary.

Condition. Rheumatoid arthritis.

Case History.

It was thought that it might be more interesting to report this patient's history by means of a photographic record rather than by a prose account. Only a summary will therefore be given.

He was admitted to hospital on the 11.8.54 with acute polyarthritis. The wrists, fingers and ankles were most severely affected. Treated with bed rest and aspirin he made some recovery and was discharged home. The wrist joints, however, remained troublesome and a pair of P.P. ventral wrist splints were made on the 1.9.54. During the succeeding nine months his condition slowly deteriorated and almost all the joints became severely involved. His wrist joints, stabilised and rested in his splints, gave comparatively little trouble. Ulnar deviation of the fingers was however beginning so "wrist and ulnar deviation splints" (Appendix, p. 217) were made.

In view of the large number of joints severely affected it was considered that several more appliances were required. But to fit and remove these would be tedious. It seemed that the most logical approach to his need for more general joint rest was to make a moulded plastic bed. By doing so all his joints would be rested in their functional positions for some ten hours per day.

A bed was therefore made and it was taken to his home on the 23.7.55. Boards were placed lengthwise down his side of a double bed which he shared with his wife. When the patient lay in the plastic bed his spinal curves were held in good position, as were the hip, knee and ankle joints. Upper limb supports had not been fitted, (a) to avoid encroaching on the other half of the bed and (b) because he already had wrist and finger splints. The bed had, however, been made in such a way that the shoulders were supported. He was able to get into and out of the appliance with a little assistance. He could sit up in it unaided by pulling on the sides.

He began sleeping in the plastic bed that night and has continued to do so until the time of writing, one year and ten months later. He has found it comfortable and it has afforded him considerable relief of pain. On some occasions he has tried to do without it but has always found that his joints, particularly those of his lower limbs, are stiffer and more painful in the morning. With the exception of one short course of cortisone he has been treated only with analgesics in the way of systemic therapy. Little physiotherapy has been required. He has remained in full-time employment.

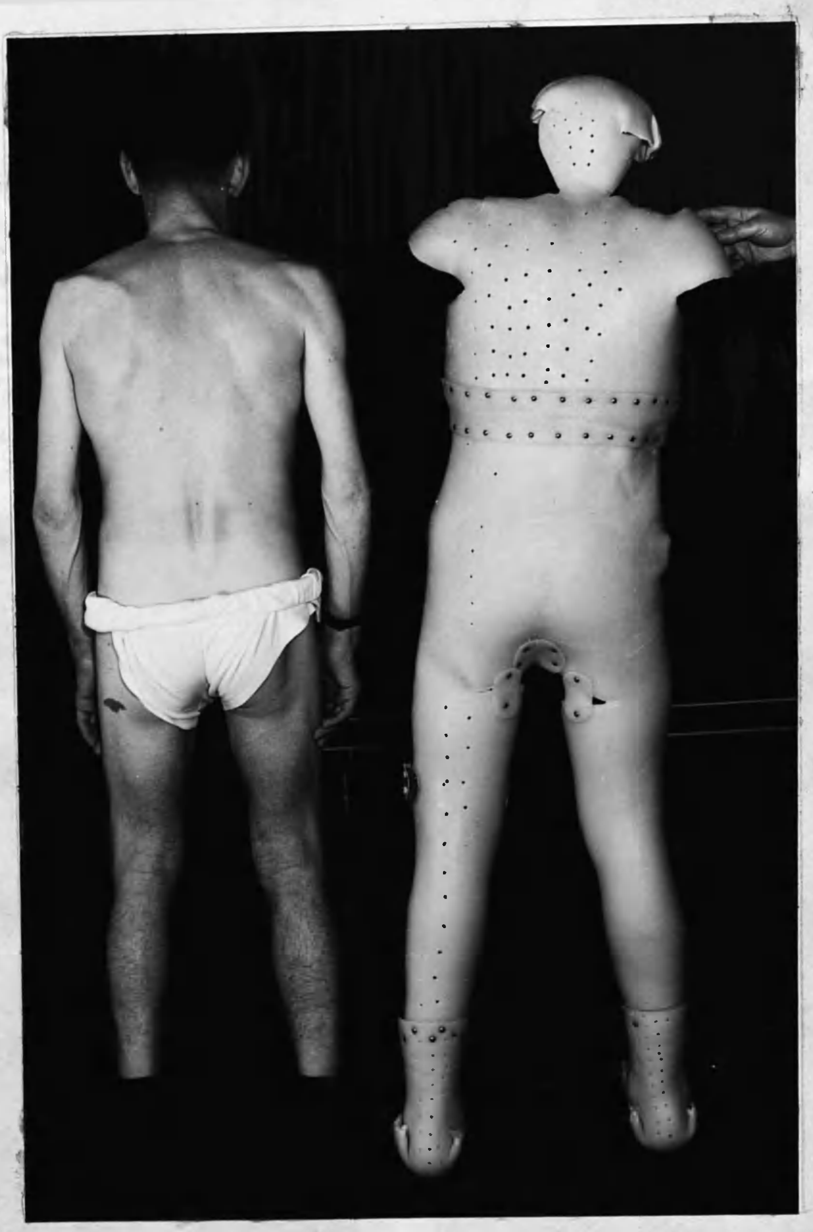
PHOTOGRAPHIC RECORD.

Photograph (taken on the 23.7.55) showing the patient lying in the appliance which has been laid on his own bed - at home. It may be observed that it does not occupy an excessive area of the double bed. The spinal curves are well maintained.

The large photograph was taken on the 23.7.55 and shows the patient attempting to stand as straight as possible. The bed is held up behind him. It may be noted that extension of the hip joints and knee joints in the appliance is more normal than that of the patient when he is standing erect. By moulding in the best possible position (Page 252) it was hoped that the patient's joints would be rested in a better position than that in which they were usually held.

The small photograph, taken on the 6.4.56, shows that hip and knee extension have improved and that his posture is appreciably better.

The curves of the bed have not altered during the nine months of use.



Large Photograph:- taken on the 23.7.55, shows posterior view of patient and of the appliance.

Small Photograph:- taken on the 6.11.56, shows similar views of the patient and the bed. It will been seen that there is some valgus deformity of the left foot - this was only present on weight bearing.

<u>Large Photographs.</u>
(Taken 23.7.55). Top left shows plastic bed. Bottom left shows patient lying in the bed. It may be noted that the contours of the bed are not altered by the patient's weight.

<u>Small Photograph.</u>
(Taken 6.4.56). Shows that ankle dorsiflexion, knee and hip extension and the spinal curves are unchanged.

1.

2.

3.

4.

5.

<u>Photographs</u> taken on the 6.4.56 after wearing wrist splints for 1 year, 7½ months. Splints designed to prevent ulnar deviation were worn for the last 11 months of this period - at night (shown in Photographs 4 & 5).

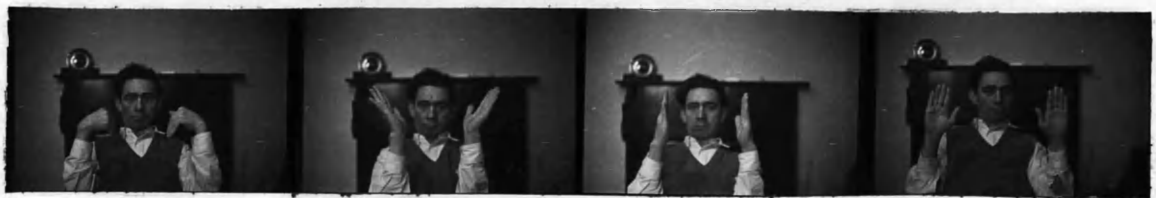
Photograph (1) shows degree of flexion;
(2) shows the degree of extension;
(3) shows that there is no tendency to ulnar deviation of the fingers.

Photographs (4) & (5) show the patient demonstrating how the resiliency of these appliances makes it easy for them to be put on without assistance. It may be seen that there is no lining in the splints. This had recently deteriorated (after10 months) and a new lining of polyurethane was put in later.

FINAL FOLLOW UP EXAMINATION (Photographic record only)

Date. 25.5.57.

By this time the patient had worn wrist splints for two years, nine months, and "wrist and ulnar deviation" splints for two years. He had slept in his plastic bed for one year and ten months.



1. 2. 3 4.

Photographs.

1. Shows degree of wrist flexion obtainable.
2. " " " " extension "
3. " " " finger extension "
4. " absence of ulnar deviation.

5.

5. Shows that almost normal extension is obtainable at both knee joints.

DISCUSSION.

In the management of rheumatoid arthritis provision of splints or a plastic bed to rest several or all of the joints might perhaps be regarded as a means of treating the patient and his disease process rather than as a local treatment of the joints. Support for this view is derived from an observation made by Duthie (1951) while treating a patient who had only one joint acutely inflamed. By resting it in a splint the signs of activity subsided and it was noted that as it did so the patient's general condition improved and his E.S.R. fell. On removing the splint and allowing the joint to be used the local signs returned and with their appearance the E.S.R. increased and his condition deteriorated. It may be desirable therefore when discussing the polythene-polyurethane appliance as a means of obtaining joint rest to review both the general and local forms of treatment in common use and compare their merits to simple rest. A great many remedies have been claimed to be of value in the treatment of rheumatoid arthritis. Only those which have been reported on by experienced workers within the last ten years will be discussed since it appears probable that the others have been found ineffective.

In the early part of the decade several reports appeared on the value of the sulphonamides and antibiotics. Coste and Galmiche (1947) treated 163 patients with penicillin and were favourably impressed with the results. On the other hand Hench (1946) and Coss et al (1948) found it to be valueless. Streptomycin was also found ineffective by Rice et al (1947). Virkunen (1947) and Parr and Shipton (1947) believed that the sulphonamides were of some value. From the lack of further reports on the above-mentioned drugs it may be presumed that most rheumatologists have found them to be of little importance.

Since its introduction in 1931 blood transfusion has been given a place in the treatment of rheumatoid arthritis. Appelqvist and Holsti (1947) used it in 24 cases and judged it to give good though rarely dramatic results. Simpson and Brooks (1948) noted an improvement in the general state of 24 patients when their plasmaprotein values returned to normal subsequent to transfusion. Its greatest value appears to be in those cases presenting anaemia and poor general health.

Paul et al (1954) used nitrogen mustard in the treatment of 17 patients. Good subjective results were quickly obtained by most and in two cases joint effusions were markedly reduced. Further work with this drug may be indicated though it seems likely that its action is suppressive rather than specific.

In 1952, Currie conducted the first clinical trial of the drug Butazolidine (Phenylbutazone). A ten day course of intramuscular injections was given to 81 patients with rheumatoid arthritis. Examined three weeks after the beginning of the course 77 patients showed subjective improvement and in 24 there was objective improvement. Joint effusions were moderately or markedly diminished in 10 of the latter group. Currie concluded that "as an anodyne in cases of rheumatoid arthritis butazolidine is quite exceptionally effective." Freeland et al (1953) supported this opinion after a controlled study of 57 rheumatoid arthritic patients treated with the drug. A daily dose of 600 mgs. was given by mouth for a period of one month. Statistical analysis showed a significant improvement in the group treated with butazolidine. Toxic effects were seen in only 3 patients but in another series of 164 patients, observed by the same authors, 40% showed such effects. Indigestion and skin eruptions were commonest. The incidence in ~~of~~ 109 patients treated with daily oral doses of 600 mgs. by Leonard (1953) was 42%. Nassim and Pilkington (1953) and Dilling (1953) also noted that toxicity was not uncommon, the latter describing a fatal case of agranulocytosis and gastric ulceration. Brodie et al (1954), using a daily dose of 800 mgs. found severe toxic manifestations in 17 out of 87 patients. de Sèze and Levernieux (1954) administering the drug by the parenteral route obtained inconstant results and they too found that the drug was liable to cause toxicity. Pemberton's (1954) findings in a trial with 210 patients was more encouraging, good results being obtained in rather more than half the patients. Nevertheless, using a daily dose of 600 mgs., side effects developed in 92 cases. Regarding the relationship between the clinically effective dosage of phenylbutazone and toxicity, Bruck et al (1954) found that subjective relief could be obtained with a level of 5 - 10 mgs. per 100 mls. of blood and that at that level few ill effects occurred. To reach this concentration they recommended that an initial daily dose of 200 mgs. be raised gradually to 400 mgs.

Many of the patients supplied with plastic appliances also received phenylbutazone in daily doses of 400 mgs. taken orally along with an aluminium hydroxide mixture. Even this minimal dosage was not found to be free from danger, especially when given over a long time. In a majority of cases the preparation had to be withdrawn, usually on account of gastro-intestinal disturbances. Skin rashes were only occasionally seen. On the other hand most patients obtained a definite relief while using it.

Since its introduction by Landé and Pick in 1927 gold has been accredited a valuable place in the treatment of rheumatoid arthritis and it is still used in many centres. Nystrom (1950) surveying a group of 620 of his patients, treated with gold between the years 1932 and 1946, found that 61.7% showed improvement after completing their courses. Complications arose in 40%, and he concluded that gold was "by no means harmless". This opinion has been supported by the work of many others. Browning et al (1947) reporting on six years experience with gold stated that though 23% of their patients had shown improvement 62% had suffered toxic manifestations, mainly skin rashes. Sundelin (1948) reviewing the case reports of 3,912 patients found a complication frequency of 50% including 0.25% deaths. Bille (1948) reported that 53% of 45 patients developed definite complications, mainly related to skin or blood. On the other hand despite the risk of toxic effects Duthie (1951) was able to state that gold was of undoubted value, and since then Batterman (1953), Schreiner and Stephntschitz (1954), Forestier and Thévenoz (1954) have reported favourably on its use. Perhaps Copeman (1956) sums up present day opinion when he says that gold salts remain the mainstay of the medical treatment of rheumatoit arthritis. He admits that there have been "no controlled series to support this", but adds that "most experienced rheumatologists agree."

In 1949 Hench and his associates at the Mayo Clinic introduced the adrenal cortical hormone (17-hydroxy-dehydrocorticosterone) as an anti-rheumatic agent. 14 rheumatoid patients were treated with it and another two patients were treated with the pituitary adrenocorticotrophic hormone. Excellent results were quickly obtained, though epigastric pain and transient oedema were occasional side-effects. They concluded that "Articular, muscular and other symptoms were lessened greatly, and sedimentation rates were reduced when either hormone was employed; when the use of them was discontinued symptoms and signs of rheumatoid arthritis usually, but not always, returned or increased promptly." This transient effect was soon confirmed by other workers. Boland (1951) wrote that "The favourable action of cortisone is suppressive only, not curative, and its administration probably does not alter the course of the disease." He reached this opinion after using the drug in the treatment of 60 patients with rheumatoid arthritis for periods which varied between six months and fifteen months. Signs of hormonal excess developed in 40% of the patients. He concluded that "it should not be considered as the treatment of choice for most cases and not as a cure for any case." Tegner (1952) also noted that relapse occurred soon after the preparation was withdrawn. He believed that the best method of using the steroids was to suppress symptomatology during acute episodes. Duthie (1954) agreed with that view as did Ishmael (1953). Side effects and rapid relapse on withdrawl were also reported by Clark et al (1953).

By that time it had become clear that the effect of these drugs was, as Boland had said, merely suppressive and that the course of the disease process was not affected by their use. Even their administration in short courses was not free from danger since withdrawal was not uncommonly followed by an exaccerbation. This feature could have been avoided by indefinitely prolonging administration but several reports indicated that the danger of side-effects was thereby increased, (West and Newns 1953, Holbrook 1953). These workers found, in addition, that the percentage of patients showing worthwhile improvement on a maintenance dose was small; too small in their opinion to warrant the risk. More recent studies (Duthie 1954, Toone and Irby 1955, Ridings 1956) have tended to support that view. Boland (1955) found orally administered hydrocortisone valuable in selected cases but not an ideal therapeutic agent because of the dangers of side effects. The two reports from the Medical Research Council and the Nuffield Foundation (1954, 1955) on a trial of cortisone and the adrenocorticotrophic hormones compared to aspirin has also thrown doubt on the value of long-term administration of the hormones. After two years they found very little difference indeed between the results obtained by aspirin and those by the steroids.

On the other hand some workers of wide experience believe that these hormones may be given with benefit. Ward et al (1953) found prolonged administration to be a useful and practical meausre. Copeman (1956) stated that long-term administration of the steroids was of great assistance "in the management of 20% of otherwise intractable cases." He claimed that side-effects were easily controllable.

The synthetic analogues of cortisone and hydrocortisone, delta-1-cortisone and delta-1-hydrocortisone respectively, have not on the whole been more favourably reported than their parent steroids. Fisher (1956) found that delta-1-hydrocortisone was more toxic than hydrocortisone, particularly in respect of gastro-intestinal disturbances. Boland (1956 (a) & (b),) found the delta group less liable to cause salt and water retention but, like Fisher, he found digestive disturbances more common. Hart et al (1955) found both delta preparations to be identical in effect. All appear to be in agreement that the analogues are more potent, weight for weight, than their parent preparations though it has been pointed out no therapeutic advantage is thereby gained.

Soon after the results of systemically administered steroids were made known the effect of introducing them into the joints was tried. Hollander et al (1951) found that cortisone had little effect but that hydrocortisone had a clearly marked beneficial influence. The duration of effect varied from two days to ten weeks but in most cases lasted six to eight days. Ziff et al (1952) in a carefully controlled study confirmed Hollander's finding that the intra-articular injection of hydrocortisone was much more effective than cortisone. The following year several other centres reported good results. Sez et al (1953, (a) & (b),) got excellent results with hydrocortisone and these lasted three to four weeks following injection. They pointed out that the dose of the orally administered preparations could be reduced when combined with local injections. De Pap and Teixera (1953) also found the method useful, the effect lasting about a week. They observed however that the underlying disease process was not affected and that symptoms invariably recurred. In 1954 Bornstein et al reported good results and stressed that side-effects were not encountered by using the intra-articular route of administration. Duthie (1954) agreed that it was a safe method and that good though temporary effects were obtained in the majority of cases. Copeman (1956) stated that joints which did not respond to general measures were vastly helped by intra-articular injections of 25 - 50 mgms. of hydrocortisone at judicious intervals.

Despite these good reports it must be confessed that experience with over a thousand injections of hydrocortisone into rheumatoid arthritic joints has left me in doubt as to their value in the treatment of acutely inflamed joints. Measurable objective improvement was rare when such joints were injected. Few patients volunteered the opinion that they had felt less pain though on direct questioning about half admitted that the joint was a little less troublesome. It must be pointed out however that all such cases treated by me were Out-patients and excessive use of their joints may well have counterbalanced any good effects produced by the hydrocortisone. Subjectively, the results of resting acutely involved joints in P.P. plastic splints were better than those obtained by hydrocortisone injections into similarly affected joints. Most patients supplied with splints also had such injections. Very few reported more relief from injection and even in those few it was short-lived.

Much better results were derived from injections of hydrocortisone in the advanced stage. When only one or two joints showed activity injection very often helped a great deal, the effect lasting two or three weeks. A measurable decrease in the size of a chronic synovial swelling was the rule rather than the exception. Non-articular rheumatic menifestations also responded very well. Nevertheless even in the chronic stage of the disease the splints were usually found more useful as a long-term measure. Using hydrocortisone, repeated injections were required, usually once every two to three weeks and sooner or later they had to be stopped. This was commonly on the grounds that the degree of subjective relief had become insufficient to warrant further trial. The splints, on the other hand, almost always relieved pain equally well and relief could be maintained as long as the patient cared to wear them. If pain returned after leaving them off a further period of wear alleviated it once again. Furthermore, stabilisation of the joints was obtained by the splints whereas hydrocortisone injection was of little use in that respect.

Having commented briefly on the value of splints as a local pain relieving measure and compared it with some personal experience of hydrocortisone injection I should like to discuss the value of rest in a wider sense. It may be well to preface this discussion with a note on the pathology of the disease process in relation to its effects upon the structures forming synovial joints. Boyd (1953) wrote that the joint cartilage is "attached both from above and below. The synovial membrane grows over it from the side, forming a thick vascular covering or 'pannus' which becomes adherent to the cartilage and eats it away." He says later, "The cartilage is also attached from below by granulation tissue which is formed in the superficial layers of the epiphysis as part of the inflammatory reaction." The commonly used anti-rheumatic preparations are aspirin, butazolidine, gold, the adrenal cortical hormones, cortisone and hydrocortisone, and the adrenocorticotrophic hormone. On examining these therapeutic agents from the standpoint of their effect upon the pathological process the findings are not reassuring. There appears to be general agreement that none has any effect upon its course. On the other hand most workers report that symptomatology is suppressed by all to some extent and most effectively by the steroids. Pain is relieved and so freer movement is permitted. This is advanced as the main virtue of these drugs. When the pathology of the joint is considered it may be questioned if these effects do in fact constitute a virtue. It might be argued that suppression of painful protective stimuli is not without danger. Free use of the joints, particularly the weight bearing joints, while the disease process is active seems almost certain to damage the diseased cartilages. Related to this danger is the observation of Wiles (1951) that cartilage once destroyed never regenerates.

When a patient presents with signs of early rheumatoid arthritis it is most probable that the disease will remain active for several years though it may settle down eventually to a relatively inactive state. Seen in the early stage the therapeutic problem is twofold. To relieve symptoms is the immediate one and to prevent destruction of the joint tissues is the long-term aim. How can both of these be best achieved? Pain can be relieved by aspirin or phenylbutazone but local signs are not often reduced by these drugs. Both pain and the signs of activity in the joints can be more certainly abated by the steroids or by immobilisation of the joints. The former method can achieve these results more quickly but it must surely be better to achieve them in a physiological manner ~~of~~ by allowing the body's defence and repair mechanisms to act naturally under the optimum conditions provided by rest. Polythene-Polyurethane appliances have been designed which will effect stabilisation and rest for any or all of the joints and which are comfortable for the patient to wear for prolonged periods of time. This feature of comfort is a vital one and it is probable that the prior absence of an easily available means of achieving comfortable rest has been responsible of the small amount of investigation in this field. I formerly found that attempts to immobilise the inflamed and tender joints in plaster of Paris were seldom successful. The patients usually reported that their discomfort was increased rather than decreased by such heavy and rigid splints.

Regarding the second primary aim of treatment, preservation of the joint tissues, there can be little doubt that rest is a more effective method of achieving it than analgesic or suppressive therapy. It may also be accepted that natural healing affords a much more reliable guide to the best time for permitting movement, particularly weight bearing. It seems quite clear that ambulation should not be permitted until the external signs of activity have disappeared from the lower limb joints. This is however a counsel of perfection since many patients are obliged to walk as soon as they are able because of social or economic circumstances. In such cases a course of compromise must be adopted. Kelly (1956) recommended putting one, or both knees in plaster and allowing weight bearing with the assistance of a stick or crutches. P.P. splints, because of their lightness and comfort, would probably achieve the same objectives more effectively. When the ankle joint is involved the P.P. ankle splint (Appendix P.P. 260 - 261) has been found useful and can be worn inside a shoe.

The ultimate aim is to preserve tissue and function until such time as remission may occur. Short & Bauer (1948) observed 250 patients over ten years. They found that 53.2% showed some improvement and 15.2% went into remission. These patients were treated with nothing but simple medical and orthopaedic measures. Ragan (1949) made a similar study of 374 patients and his results corresponded closely to Short's. It appears from these reports that in a fairly large proportion of patients the disease "burns out" spontaneously or at least settles down into a comparatively inactive stage. If the tissues and functions of the locomotor system could be preserved until that time the end results would be much better that those which are so commonly encountered in patients with long standing disease. It may appear unduly optimistic to propose that these could be preserved by simple splinting but the clinical findings in many patients, and the autopsy findings in the joints of the patient with juvenile rheumatoid arthritis already reported (P.50 - 52), indicates that it might be possible provided that sufficient care and supervision were exercised.

It is most rewarding to be able to say that all my patients reported some relief of pain and improvement in function through using P.P. appliances, but a controlled study with detailed objective clinical and laboratory observations is clearly indicated. Perhaps the most revealing study would be to compare the results obtained by two groups of 20 patients. One groups would be supplied with P.P. beds for use at night or during acute episodes, and with a range of limb splints for day wear. A simple analgesic such as buffered aspirin would be allowed. The second group would be treated by a combination of all other useful forms of treatment; blood transfusions to improve general condition, short courses of adrenocorticotrophic hormone during acute episodes, intra-articular hydrocortisone injections when indicated; aspirin or phenylbutazone as analgesics and all the physiotherapeutic methods which are thought to be of value such as wax baths, infra-red rays, passive and active movements. A period of study extending over five to ten years would be required. In the present series one patient (P. 53 – 59) with severe active polyarthritis has been under treatment with a P.P. plastic bed, limb splints and analgesics for almost three years. No deformity has developed and he is in full-time employment. It may be permissible to hope that if one such good result can be achieved other patients may benefit to equal extent from a similar method of treatment.

SUMMARY.

PART 1. The response of hypertonic muscle groups in hemiplegic patients to prolonged periods of stretch: a clinical study.

(1). The historical background of knowledge concerning the function of the motor cortex is given. This is followed by a survey of research on the extrapyramidal centres which exert inhibitory and facilitatory influences upon the lower motor neurone.

(2). The servo-loop theory of skeletal muscle action and the work upon which it is based are examined. It is concluded that the theory has a firm foundation. The influence of the pyramidal and extrapyramidal centres upon this peripheral neuromuscular mechanism is noted.

(3). From the results of the above work an attempt is made to conjecture the altered state of the central and peripheral nervous systems which results from a cerebrovascular lesion in the human internal capsule. Special reference is made to the muscle spindle.

(4). The effect of prolonged periods of stretch upon the hypertonus shown by 27 flexor muscle groups in 17 hemiplegic patients was studied. The numerical distribution of their muscle groups observed was: flexors of wrist 12, fingers 8, elbow 5 and knee 2. In each case the hemiplegia was sudden in onset and was believed to be the result of a cerebrovascular accident. In 15 patients the condition had been present for over 6 months. The period of study was two years and eleven months. No other treatment was employed during that time.

(5). Other untreated muscle groups on the affected side of the body were used as controls. All the treated groups were held by spasm in a state of postural flexion contracture. They were stretched by keeping the joints which they controlled in the extended position by means of plastic appliances. The duration of constant stretch in those patients whose results are analysed averaged 11.2 weeks, and thereafter they were stretched for progressively shorter daily periods for a

further average time of 10.2 weeks. The stretching appliance was then discarded.

(6). A method of clinical examination was elaborated which, it was hoped, would be sufficiently exact to detect minor changes in range of movement and in degree of tonus. External factors controlled at each examination were:- temperature, emotion, tonic neck and body-righting reflexes, flexion and extension synergies and two other factors peculiar to the method of treatment under investigation. Range of movement was measured by goniometer. Degree of muscle power was recorded by the system recommended by the Medical Research Council. Degree of tonus was recorded by a similar system. All clinical examinations were personally conducted. Some electromyographic investigations were made.

(7). It was possible to observe 16 patients for a sufficient length of time to record significant changes. In all of these hypertonus was abolished in the muscle groups stretched and this was accompanied by an increase in the range of voluntary extension. No concomittant loss of range or power of voluntary flexion was noted except in one case.

(8). At the time of writing there are 10 surviving patients. In 6 of these the abatement of spasm obtained by stretch has remained unchanged during an average time of 57.7 weeks since stretch was stopped. The increase in range of voluntary extension has also been fully retained in this group of patients, (Group 1.). The other 4 patients, (Group 2), have entirely lost their gains in range of normal flexor tonus and in range of active extension over the course of an average period of 62.5 weeks. Intermediate stages of recovery did not occur.

(9). Analysis of the results suggest that the requirements for a lasting abolition of hypertonus and gain in range of active extension are: an adequate period of stretch related directly to the initial degree of hypertonus; after constant stretch has achieved the desired results frequent voluntary use of the part is essential.

(10). Hypertonus in the flexor muscles of the wrist joint was found to be most easily abated. In the flexors of the knee and elbow it was rather less easily reduced and in those of the fingers it was most difficult. Transference of hypertonus from the flexor to the extensor muscles, following stretch, could usually be detected in the muscles controlling the knee and elbow joints but was not observed in those controlling the wrist and finger joints. In only one case did such transference restrict voluntary flexion - of the knee in that instance.

(11). No previous study concerning the effect of prolonged stretch upon hypertonic muscle, either in human or in animal sujects has been found.

(12). The results in the small group presented might be more readily accepted if a theory could be formulated in supprt of the thesis that muscle spasm can be abated by stretch. An attempt is made to formulate such a theory. It is mainly based upon: research concerning the response of the muscle spindle to stretch; an observation by Denny-Brown & Liddell (1927); and on the clinical and electromyographic records in the present series. It is most strongly emphasised that the theory is a personal speculation which is open to criticism in many respects and is presented solely as an interesting possibility. It is proposed that prolonged stretch of spastic muscle produces a physical lengthening of the sensory part of the spindle, and that thereafter an afferent discharge can be produced only by further lengthening as a result of mechanical stretch or of impulses mediating voluntary movement through the servo-loop pathway. The latter mechanism is thus capable of producing voluntary flexion even after the spindle is lengthened. Under certain conditions this spindle lengthening may remain permanent. On the other hand hypertonus may be reduced by a central change. To determine whether it is the spindle or the neural mechanisms of the cord that is affected by muscle stretch animal experiment is required and a suitable preparation and method is suggested.

(13). Other methods of treating the hemiplegic patient are discussed, with particular reference to rehabilitation. It is thought that the method of muscle stretch may have a place in the rehabilitation programme. Other means of reducing muscle hypertonus are reviewed and compared to the method presented. It is suggested that the latter compares favourably because of its safety and the long lasting results obtainable. It would appear that its main disadvantage is the long period of treatment required. Another minor disadvantage is the not infrequent appearance of mild local oedema but this can be controlled and is temporary, as is the joint stiffness which sometimes accompanies it.

(14). Further study is needed. The use of methods of measurement more exact than clinical observation is desirable; the type of apparatus required is described. If the results obtained in the present study are supported by future research the method of muscle stretch may have a place in the management of both hemiplegia and other upper motor neurone diseases where spasticity presents a therapeutic problem. Paraplegia and cerebral palsy are mentioned as two such diseases in which further research might be especially rewarding.

PART 2. The polythene-polyurethane splint.

(15). A historical survey is made of the use of plastics in orthopaedic practice. The evolution of a technique whereby thermoplastic polythene splint material may be moulded direct to the patient by interposing a heat insulating plastic (polyurethane) between the skin and the hot polythene is described.

(16). 18 types of splint and spinal support were designed to be made by the above method. These were found to be useful by clinical trial. One example is described.

(17). 247 appliances were moulded direct to 163 patients. 147 were made personally and 100 by non medical staff. Very little waste of material occurred during manufacture. The same splint can be used for several patients by reheating until soft and moulding again. The appliances are resilient, inert, washable, radiolucent and do not lose their moulded shape. The cost of a finished splint is usually a little less than a similar removable plaster splint plus a retaining bandage. The main disadvantage of the method is that special equipment is required, but the cost of that need not exceed £25.

(18). No case of burning, or even discomfort, occurred during moulding. The patients found their splints to be light, comfortable, effective and durable. For some patients special appliances were designed which may be original.

<u>PART 3</u>. A study of the value of stabilising joints in their functional position by means of polythene-polyurethane plastic appliances, in the management of rheumatoid arthritis and neurological disease.

(19). Polythene-polyurethane appliances were used in the management of 163 patients in an attempt to relieve pain, prevent deformity and help in the restoration of function. Of these, 107 patients suffered from rheumatoid arthritis. The remaining 56 presented a wide range of chronic diseases, mostly neurological. Since a much wider experience was gained of the value of local rest and correction in rheumatoid arthritis than in any other single entity the introduction and discussion are confined to that disease.

(20). The historical background of rest in the treatment of rheumatoid arthritis is given. Despite wide acceptance of its value little study has been devoted to it. The present study is itself at fault in being mainly subjective.

(21). 88 advanced and 19 early cases of rheumatoid arthritis were observed. The average period of splint wear while under personal care was 0.91 years. No appliance was discarded on the grounds of discomfort or for any other reason. All the appliances could be fitted and removed without assistance. In no case did deformity occur while wearing a splint designed to prevent it. Some patients wore appliances almost constantly for several months but in none did ankylosis occur. Rather, increased range of movement was the rule. The case histories of two patients with acute polyarthritis are given.

(22). Some results of treating other types of chronic disease are given. Most rewarding results were obtained in the management of two patients with carcinomatous secondary deposits in the cervical spine. Root pain was completely relieved by immobilising their necks in cervical collars. Decubitus heel ulcers in 3 patients were healed by the use of special appliances. A variety of upper motor neurone diseases, presenting muscle hypertonus, were treated with muscle stretch and the results appear to warrant further trial in those conditions.

(23). A survey of the anti-rheumatic preparations which have been used during the past decade and their reported effects is made. Special note is made of work with gold, butazolidine, the corticosteroids and their anologues. The high percentage of toxic effects resulting from their use is noted. The reported results of intra-articular injection of hydrocortisone and personal experience with 1,000 such injections are discussed and related to the results obtained by local joint rest.

(24). The pathology of synovial joints in rheumatoid arthritis is noted. The absence of effect upon it by the drugs in common use is pointed out. The danger of analgesics and suppressive therapy in relieving symptomatology while the disease process remains active is emphasised. This is compared to the safe and physiological resolution of signs which can often be effected by simple local or general rest. The results obtained by rest are thought to be more reliable when assessing the amount of activity, especially weight-bearing, which may be safely permitted. It is admitted that, in practice, weight bearing may be necessary while the lower limb joints show activity and a compromise course is suggested.

(25). The dual aim of treatment is to relieve symptoms and to conserve tissue and function. It is considered that this may be better and more safely achieved by judicious use of joint rest and stabilisation combined with simple analgesic therapy than by any other method of treatment available. An objective study extending over a period of 5 - 10 years is required to substantiate that opinion.

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APPENDIX.

HEMIPLEGIC PATIENT SERIES.

An analysis of the results of treating spastic muscles by prolonged stretch has been given. Before describing the individual case records an account is given of the way in which each will be presented and this will be followed by a description of the method of clinical examination which was used.

METHOD OF PRESENTATION.

Age.
Sex.
Complaint.
History.
Other forms of treatment employed prior to muscle stretch.
Muscle groups stretched, and type of appliance used.
Muscle groups observed as controls.
Initial examination.
Progress examinations.
Graph of progress.

Age.

The age given is that at the beginning of treatment.

Complaint.

When the duration of the complaint exceeds six months it is described as residual hemiparesis. Some patients are designated "chronic residual hemiparesis" to signify that their condition has shown no improvement over a prolonged period.

The word "hemiparesis" is used in the case reports in preference to "hemiplegia" since in each case some active movement was present and the former term is perhaps more accurate. (In the body of the thesis the condition has been referred to as "hemiplegia" in deference to common usage.)

Associated complaints are not mentioned under this heading

History.

The history is largely confined to the hemiparetic element of the patient's condition and attempts to give the reader a clear picture of the type, duration and severity of the condition. A brief history only is given of other disease processes present such as valvular disease of the heart or hypertension since these were not directly related to the condition being treated - spasticity of certain muscle groups.

Other forms of treatment employed prior to Splinting.

The type of treatment, its duration and its results are given. It was usually possible to obtain this information from the persons who had given the treatment.

Joints treated and type of appliance used.

In the interests of brevity the word "joints" is used to mean the muscle groups controlling movement at that joint.

Different types of polythene-polyurethane appliances were used in each case.

Joints observed as controls.

Here again "joints" indicates the controlling muscles. By preference one or more joints in the same limb as that under treatment was selected. It was thought that these would provide the best control. For example, when the wrist flexors alone were being stretched in a cock-up wrist splint any lessening of this spasm could very probably be attributed to stretch when neither the elbow flexors or finger flexors showed any change. Passive and active movements at the control joints were examined at the same times as those at the joint whose controlling muscle groups were being observed. At some of these examinations measurable variations in the range of normal tonus or active movement were found at the control joints but in the final analysis of gain and loss the mean change in no case exceeded $10^{\circ} - 15^{\circ}$. To avoid irrelevant documentation the range of movement observed at the control joints is therefore seldom recorded in detail after the "initial examination".

Initial Examination.

The word "initial" is used to signify the first examination recorded in the reports. This was in only one case (Case 11.) the first examination of the patient, since before a patient was admitted to the series he was personally examined two or three times during the month preceding admittance to ensure that recovery, either spontaneous or from other forms of treatment was not occurring.

Progress Examinations.

These record the changes in tonus and movement found at the succeeding examinations. The condition of the appliance and the state of the underlying skin and joints is also briefly described.

Graph.

The aim of treatment in each case was to abolish spasticity in flexor muscle groups and so allow voluntary contraction of their antagonists. These salient features have been plotted against time at the end of each case record. Their relation to the duration of stretch and their behaviour after stretch was discontinued is also shown.

METHOD OF EXAMINATION.

Treatises such as that by Kendal & Kendal (1949) on the examination of muscular contraction are excellent for examining individual muscles showing flaccid paralysis from lower motor neurone disease. They are of little help in the examination of spastic muscle groups. Only two publications were found describing examination techniques for that purpose (Brunnstrom 1941, and Rinzler et al 1951) but neither was thought to be sufficiently detailed nor to control external influences with sufficient care to be of service. The following system of clinical examination was therefore elaborated. It can, perhaps, be best described in two sections:-

A. Control of external factors influencing spasticity.
B. Examination procedure.

(A). Control of External Factors Influencing Spasticity.

(1). Temperature.

It is thought that external heat facilitates and that cold depresses voluntary muscle activity, (Schneider & Karpovich 1948). In hemiplegic patients with spastic muscles La Joie & Gerstein (1956) found that spasm was slightly and temporarily reduced by warming at close range. To avoid variations in active movement or in the degree of spasm arising in this way all examinations were conducted in an atmosphere of comfortable warmth.

(2). Emotion.

Bucy(1949) records that one of his hemiplegic patients found his spasticity increased during emotional strain. When examining my patients I noted that this occurred very frequently and that the effect was quite marked. Measures were therefore taken to avoid such strain. These included (A) no relatives during examinations, (B) the patient was settled comfortably before examination began and (C) examination was conducted quietly and with a minimum of conversation.

(3). Temporal relationship of examination to Removal of Stretching Force.

If the resistance of a spastic muscle group is overcome by passive stretch and the muscle held thus for a few seconds and then released, a second passive stretch, immediately after, will often meet with less resistance than the first, (see P.125). Therefore if the spastic muscles of a hemiparetic patient are being kept stretched by means of a splint and examinations of the degree of spasticity are estimated immediately after the removal of the splint it may well appear that little spasticity is present in those muscles. If they are re-examined after a further period of time an increase in spasticity may be noted. This phenomenon was observed during the first "progress examination" of Case No. 11. (P.159) By experimenting with the time lapse after removal of the splint it became apparent that a fairly reliable estimate of true reduction in spasm could be made at the end of thirty minutes. It was decided therefore to examine all patients one half hour after removal of their splint. In support of this decision it may be noted that by examining at this time on each occasion an accurate comparison with the findings of preceding examinations could be made even though absolute values were not obtainable.

It was, in fact, almost essential to adopt this thirty minute period. It might be thought that a longer interval would have been more revealing but in practice this would have presented a difficult problem. If, for instance, a lapse of four hours had been selected, a patient whose appointment was for 10.0.a.m. would require to have had the splint removed at 6.0.a.m.

(4). Active & Passive Movement before Examination.

It was noted when examining patients at the end of the half hour period described above that the degree of spasticity in the flexors might appear to be slight. Re-examination after asking the patient to perform voluntary movement quite often showed a perceptible increase in spasticity. For that reason the patient was asked to voluntarily flex and extend the part before spasticity was assessed.

To summarise the sequence of events before examination - the patient wore his splint until arrival, it was then removed. Half and hour later a few actige movements of the joint were made. Examination was then conducted in a warm room, the emotional atmosphere of which was tranquil.

(5). Tonic neck reflexes and Body righting reflexes.

The effect of these reflexes on spasticity and active movement in hemiplegic patients has been noted by Yamshon et al (1949), Twitchell (1951) and La Joie & Gerstein (1956). Twitchell found their influence on spasticity and voluntary movement relatively constant in both upper and lower limbs. La Joie & Gerstein found that rotation of the head away from the hemiparetic side effected the degree of spasm but that rotation towards the hemiparetic side did not. Neck extention and neck flexion both influenced spasticity, the former increasing and the later decreasing it. Yamshon et al (1949) in a study of the effect of tonic neck reflexes in twenty-two patients with residual hemiplegia following cerebrovascular accident found that rotation of the head towards the hemiparetic side produced a 25% increase in the range of active extension at the elbow joint and 324% increase in the power of elbow extension

The influence of these reflexes was controlled in my series in the following way. When the upper limb was being examined the patient sat upright looking straight ahead with the cervical spine neither flexed nor extended. By so doing it is unlikely that the tonic neck reflexes materially influenced the findings. When examining the lower limb the patient lay on the unaffected side. This position was adopted at each examination so that a comparable set of findings were obtained even though the effect of the body righting reflexes could not be excluded in this position, (Twitchell, 1951).

B. EXAMINATION PROCEDURE.

The change produced by stretch in the degree of spasm shown by flexor muscle groups was judged by the change in the range of passive movement and the range and power of active movement taking place at the joint controlled by those muscles.

Range of Movement

1. Passive.

Before the flexor muscle group was stretched it was found in each case that if the joint flexed by this group was placed in the fully flexed position there was a free unresisted arc of movement through which it could be extended before the stretch reflex was elicited. This has been termed the "range of normal flexor tonus". It was noted that as spasticity lessened in response to muscle stretch this arc of movement became increased and the amount of this increase (in degrees of range) was taken as a measure of the decreased spasticity. It has been termed the "gain in range of normal flexor tonus". Clinically appreciable decrease in flexor tonus was shown also in another way: the remaining arc of extension which still resisted passive movement often showed a decrease in degree of resistance. In regard to degree of spasm it may be worth noting that in many patients the phenomenon of clasp-knife rigidity was not seen, the whole arc of movement showing an even degree of resistance. However, in order to have a standard method of recording which would include those patients who did present clasp-knife rigidity the degree of spasm was taken as being that amount of resistance which was felt as soon as the stretch reflex was elicited. The method of recording degrees of spasm by symbols has already been given, (P. 13).

It was also noted that the speed with which passive extension was carried out affected the degree of resistance felt by the examiner, more resistance being experienced the more quickly the joint was extended. To avoid variations arising in this way all passive movements were carried out in the space of one second from the position of full flexion to the position of full extension. One way in which decrease in flexor tonus revealed itself was the posture of the limb under the influence of gravity. For example the elbow joint of many patients was held habitually in a position of flexion, say 90°, but as spasm of the elbow flexors was abated the joint adopted a progressively more extended position. This was termed the "settling position" and was recorded in the case histories at each examination. (The term "resting position" was avoided as the flexor muscles are not in fact at rest when the influence of gravity is exciting their stretch reflex. The word "settling" was thought to better describe the state of balance between the stretch reflex and gravity.)

Range of movement was measured with a goniometer. The joint was moved until the stretch reflex came into evidence and it was held at that angle by the attendant nurse while the range of normal tonus was measured. 10°/15° was estimated to be the range of experimental error. When recording the total range of passive movement through which it was possible to move the joint the finding of a fibrous contracture which limited the range is not documented so that tedious repetition of this common finding is avoided. If the last figure in the arc is less than that of the full arc a fibrous contracture is implied.

2. Active.

(a) <u>Range.</u> A goniometer was used in the manner described above. Movement was limited to the joint under observation by holding still the proximal part of the limb.

(b) <u>Power.</u> This was recorded by the system of symbols and their interpretation reccommended by the Medical Research Council (P. 13.). It was not uncommonly found that the power varied in different sections of the total arc through which active movement could be carried. For example, a patient might be able to extend his elbow quite strongly from the position of full flexion to say 90° but further extension past that locus might be much weaker. In most cases this sudden weakening was clearly the result of opposition from the stretch reflex. In those patients where this feature could be measured a record of it is made in the case report.

Examination Technique for Individual Muscle Groups.

An attempt was made to apply these methods of examination in the form of a standard procedure for individual joint movement

<u>Upper Limb.</u>

<u>Shoulder Movement.</u>

(1) The "Settling" position was noted.

(2) Position of 0°.
The position of 0° from which flexion, adduction, extension were measured was that of full adduction against the side of the body. External rotation and internal rotation were measured from a 0° position where the palm of the hand was placed over the epigastrium, the elbow being flexed to 90°.

(3) <u>Active.</u> From the settling position the range and power of active flexion, adduction, extension, internal and external rotation was measured, the head and trunk being held still.

(4) <u>Passive.</u> The limb was moved through these planes by the examiner the range of normal flexor tonus and the degree of resistance in the remainder of the arc being noted.

Elbow Movement.

(1) The settling position was noted.

(2) Position of 0° . Full extension at the joint was taken as 0°. Since all other positions are positions of relative flexion the word "flexion" is omitted after recording the number of degrees.

(3) Active. The range and power of flexion from the settling position was followed by the range and power of extension from the position of flexion.

(4) Passive. From the settling position the joint was passively flexed and any resistance noted. From that position of flexion it was extended the range of normal flexor tonus and the degree of resistance which followed it was noted. From the position of full extension the joint was again fully flexed and any resistance from the extensors was noted.

Wrist Movement.

The technique for examining movement at this joint was rather complicated because movement was possible on either side of the 0° position.

(1) Settling position. (a) with the forearm and hand held in full pronation, (b) held in full supination.

(2) Position of 0°. Where the metacarpals were in line with the forearm was taken as 0°. From this position flexion and extension are possible and so the number of degrees is qualified by the appropriate word. When pronation and supination were being examined the position of full pronation was taken as 0°.

(3) Active.
(a) The range of extension was estimated from the settling position with the hand pronated. If power was insufficient to extend the hand against the counter-force of gravity (3) the forearm and hand were held in mid pronation and any active extension (2) was noted. If power increased on treatment from 2. to 3. the former position was then adopted.
(b) The range of flexion was estimated from the settling position when the hand was supinated, or in mid pronation if power was less than 3.

(4) Passive. The ranges of normal flexor and extensor tonus and degree of spasticity were measured in the usual way.

Finger Movement.

The settling position and the ranges of active and passive movement were assessed with the wrist joint held by the examiner in the functional position of 30° extension.

(1). The settling position was taken as the distance of the finger tips from the proximal palmar crease and was measured with a ruler held between the fingers. The position of the thumb in relation to the forefinger was also noted.

(2) Position of 0°. When the phalanges of the fingers and thumb were in line with their metacarpals this position was selected as 0°.

(3). Active.
(a) Extension was judged in most cases by the distance from the proximal palmar crease to which the fingers could be extended. This could be more accurately measured than the range of movement at each M.P. and I.P. joint. Moreover with the wrist in the gripping position of 30° extension this measurement indicated better the functional potential of the fingers. Extension of the thumb was recorded as the distance from the forefinger to which it could be separated. For the purpose of the analysis (P.15-21) the range of extension is taken as 90° when the phalanges could be fully extended to a position of alignment with the metacarpals, halfway between touching the palm and full extension was taken as 45° and touching the palm as 0°.
(b) Flexion - the power of the grip was recorded.

(4) Passive.
(a) Extension. To estimate the range of normal flexor tonus the M.P. joints were flexed to 90° and the I.P. joints were extended fully. (Any resistance offered to either movement was recorded.) This position was taken as 90°. The phalanges, held extended at the I.P. joints, were then passively extended at the M.P. joints the range of normal tonus and the degree of spasm encountered were noted. This method of judging tonus in the finger flexors was selected because it allowed accurate measurement and, it was thought, indicated progress towards improved function better than any other.
(b) Flexion. Movement in the reverse direction to the above was carried out and any resistance noted.

LOWER LIMBS.
Hip Movement.
(1) Settling position. In the case of the hip joint this term is a misnomer but is used to indicate the angle at which the stretch reflex was elicited on passive extension of the thigh.
(2) Position of 0°. Where the thigh was in line with the trunk from both antero-posterior and lateral aspects.
(3) Active. Flexion, abduction and extension were measured with the patient lying on the unaffected side. Adduction, internal and external rotation were measured with the patient lying supine. Flexing of the knee to 90° or full extension to 0° was permitted. during these movements whichever was found most practical at the "initial examination". Whichever position was adopted it was used at all subsequent examinations of that patient.
(4) Passive. The above mevements were carried out by the examiner.

Knee Movement.
(1) Settling position. As at the hip joint this term was used to indicate the angle at which resistance was first felt during passive extension.

(2) Position of 0^o. Full extension at the joint was taken as the position of 0^o. Since all other positions were positions of relative flexion the word 'flexion' is omitted when writing the number of degrees.

(3). Active. Flexion and extension were examined with the patient lying on his unaffected side. If power seemed less than (4) and greater than (2) movement against gravity was examined by sitting the patient in a chair for extensor movement and lying prone for flexor movement.

(4) Passive. Flexion and extension movements were carried out by the examiner and tonus noted in the usual way.

N.B. The details of examining active and passive movement were as described for the elbow joint.

Ankle Movement.

(1) Settling position. The angle of the foot with the leg when the patient lay on his unaffected side.

(2) Position of 0^o. The hypothetical position of the foot in line with the leg was taken as 0^o. The foot at a right angle to the leg was therefore recorded as being at 90^o.

(3) Active. From the settling position the patient was asked to dorsiflex his foot the range and power being noted. From this dorsiflexed position (if obtained) the range and power of plantarflexion was noted. Inversion and eversion were measured from the neutral position - passively obtained where necessary.

(4) Passive. The above movements were carried out by the examiner.

Toes. Active movement of the toes was noted when present.

Electromyographic Examination.

It was possible to have the activity in certain flexor muscle groups examined electromyographically just before stretch was begun and five weeks after. Three patients were so examined (Case reports, Nos. 6, 7 & 8.). It was not possible to have the records photographed but a verbal account of the findings is given in each of the case records. This account has very kindly been read by Dr. P. Bauwens, Physician in Charge of Physical Medicine and Electrodiagnosis, who personally conducted all the tests. He finds that it is an accurate record of the findings.

CASE No. 1.

Age. 65 years.

Sex. Male.

Complaint. Chronic residual hemiparesis of the right side. (Duration, one year and five months.)

History.

On the 9.2.53 he developed a headache in the right tempero-parietal region and difficulty in speaking. Over the next few hours the right arm and leg became increasingly weak and his vision became blurred. He was admitted to hospital on the 13.2.53, where he was found to have a complete right hemiplegia, some aphasia and a right homonymous hemianopia. There was also some loss of proprioceptive sensation and two point discrimination on the right side.

He was given a course of hemiplegic rehabilitation and, as the right leg extensors became spastic and hip movement returned, he was able, within six weeks, to walk with a toe raising spring and a stick. Very little movement returned in the upper limb. He was discharged home on the 2.4.53.

He was seen at Medical Out-Patients in May, June, August and November 1953, ad in April 1954. The clinical records of these attendances showed that his walking had improved sufficiently by April 1954 for him to walk a mile each day. No useful movement had returned in hand or arm, and he had, by the 23.4.54, developed a spastic flexion deformity of the right wrist. During all this time, and up until I first saw him, he had been attending the Physical Medicine Department twice weekly for walking training, and for heat, massage and passive movements to his arm and hand. A Plaster of Paris cock-up wrist slab for wear at night had been made in May 1954, but this had been discarded by the patient after a few weeks because of discomfort. It was for that reason that a P.P. plastic splint was considered.

Joints treated and type of appliance used.

(1) The wrist joint was treated from 22.7.54 to 23.2.55. (He was the first patient to be supplied by me with a P.P. plastic splint.)

(2) The fingers. These were held extended in a wrist and finger splint from 2.11.55 to 27.7.56. The fingers were held extended as far as possible - usually to some 20° at M.P. and I.P. joints.

(3) The elbow. This joint was fitted with a splint from the 2.11.55 to the 12.3.56. The elbow was held at 15°.

Joints observed as Controls.

The shoulder, elbow and finger joints served as controls on the wrist joint. Later the shoulder was the only unsplinted joint and it was examined at each visit as a check on the others.

INITIAL EXAMINATION. 22.7.54.

Unfortunately, at the time this examination was conducted I was unaware of the good results which were later found to be obtainable. I therefore made only a brief examination the findings of which are recorded below.

Shoulder.
There was 60° - 70° of active abduction and flexion.

Elbow.
The elbow was held in flexion at about 50° - 60°.

Wrist.
The wrist was held in 45° flexion by very powerful spasm which required considerable force to overcome in order to obtain the 30° extension required to make a satisfactory splint.

Fingers.
The fingers were curled in the palm of the hand, and with the wrist held extended it was impossible to straighten them.

A cock-up wrist splint was made and fitted. It kept the wrist extended to 30°. It was explained to him that the purpose of the splint was to prevent his wrist from becoming fixed in flexion, and that in view of the severe flexion spasm he must wear it as much as possible if this object was to be achieved.

PROGRESS EXAMINATIONS.

H e was seen at the Out-Patient Clinic at monthly intervals. At the end of the first month he gave the history that he had worn the splint almost constantly as it had helped him to get a good grip of his gardening implements. Gardening was, apparently, his main hobby and he was pleased that the sp splint helped. On removal of the splint the wrist could be passively flexed and extended (to some 20°) fairly freely. He was told to continue wearing it as before.

Examination at the end of the second month showed a further release of flexion spasm and I made a note that he could extend his wrist voluntarily through a small range.

By the end of the fourth month of more or less constant wear there was a marked improvement in his active wrist extension (45°F. - 20°E.). There was also a release of flexor spasm (to splint angle) which persisted throughout the three hours he spent in the Department. He was told to wear the splint only at night. After a further three months, of night wear, he was told to discard it completely. The splint was retained in the Department in the hope that it might be of use to some other patient as it was still in good condition.

At this time (23.2.55), seven months after first supplying him with a splint, there was no detectable spasm on extending the wrist to the angle at which it had been held (30°E.). Past that angle there was marked resistence. He could also actively extend his wrist to this level. I must confess that I still did not attach much significance to this improvement, possibly because the function of the hand had not materially improved. Flexion spasm of his fingers was still very marked and this nullified, to a large extent, the improvement in his wrist.

It was not until two months later, in April 1955, that the improvement shown by Case 1 roused interest in this patient. He became then an important case. His flexors had been stretched constantly for four months, and each night for a further three months. The question was, had the flexion spasm remained abated during the past two months of freedom from stretch? I saw him at the O.P.D. a few days later and it was found that, in fact, the flexion spasm had remained in abeyance and he was still able to dorsiflex his wrist to 30° with considerable strength (4). There was no change in his finger, elbow or shoulder movement from the findings recorded at his first examination.

On the 6.5.55 he was presented at the Annual General Meeting of the "Medical Society for the Care of the Elderly", held that year at the Whittington Hospital. His return of voluntary wrist extension was described and the lack of flexion spasm at the wrist joint compared to the severe spasm in the flexors of the fingers and to the moderate spasm in the elbow flexors was demonstrated.

A fortnight later the patient went to stay with relatives in Wales and I did not see him again until the 2.11.55. Examination on that date was as follows:-

<u>Right Shoulder</u>. Settled in adduction. Only active movement was examined.
Abduction 80° (4). Flex: 60° (4).
Ext: 40° (4+). Adduction - full (4+).
Rotation:- ext: 90°(3+), Int. 90°(3+).

<u>Right elbow.</u> Settled at 55°.
<u>Active.</u> Flex: 55° - full flexion (4+).
Ext: Full flexion - 80°(4), 80° - 50°(3+).

Passive. Ext: full flexion - 70° (A), 70° - 10°(C).
Flex: 10° - 90° (A), 90° - full flexion (B).

Right wrist. Settled at 50°F. when pronated and at 0° when supinated.

Active. Ext: 50°F. - 30°E. (4). Flex: 0° - 60°F. (4+).
Supination 10°- 120° (3+).
Pronation 120°- 10°(4+).
Abduction and adduction 5°- 10°(3+).

Passive. Ext: 50°F. - 25°E. (A), 25 E.° - 60°E. (C-D).
Flex: 60°E. - 60°F. (A).
Supination past 120° was markedly spastic.
Pronation to 10° met with no resistance.
Full abduction and dduction were slightly resisted.

Fingers. Settled ½" - 1" (5th - 2nd) from palm, with thumb touching the side of the forefinger.

Active. Extension. There was only a flicker of active extension.
Flexion. Two examining fingers slipped into the palm were gripped with considerable force.

Passive. Extension. There was intense resistance (E) to extension. It was, in fact, impossible to completely extend them while the wrist was held at 30° extension.
Flexion. From the extended position there was no resistance to full flexion.

Reflexes.

All myotatic reflexes were markedly exaggerated on the right side. The Babinski test was positive on the right. The right abdominal reflexes were absent.

Sensation.

There was a definite loss to light touch and pin prick in tbe right hand and foot. This was less evident over the proximal parts of the limbs. Muscle and joint sensation seemed moderately reduced in the distal limb joints, and loss of vibration sense was easily demonstrated over the malleoli and over the heads of the metacarpals.

Mental State.

He was a very pleasant and co-operative patient and took a keen interest in any treatment designed to improve his condition. His cerebration was rather slow and his memory was not very good. His speech was slow, deliberate and carefully enunciated. He could express himself well and did not make mistakes in the use of words. His understanding of the spoken and written word was normal.

He agreed to try a wrist and finger splint in an attempt to obtain more active extension of the fingers, and an elbow splint to improve extension at that joint. These were made and fitted on the 2.11.55. It was found very difficult to keep both fingers and wrist extended during moulding because of the extreme spasticity of the former. Thus when finished the splint (Type a) was found to hold the wrist at 0° and the fingers in 25° flexion at the M.P. and I.P. joints. This was considered good enough for a start. The elbow splint was easily made and when fitted was found to hold the elbow at 15°.

PROGRESS EXAMINATIONS.

Throughout the course of treatment directed towards release of spasm in the elbow and finger flexors the range of active and passive movement at the wrist joint did not change. No further notes will, therefore, be made about it.

FOURTH WEEK.

He had been wearing the splints constantly.

Elbow. Settled at 40°.

Active. Flex: 40° - full flexion (4+).
Ext: full flexion - 40° (4), 40° - 20° (3) Gain 30°.

Passive. Flex: 40° - 80° (A), 80° - fullflexion (B).
Ext: full flexion - 50° (A), 50° - 10° (B-C)

Fingers. Settled 1" - 2" from the palm with the thumb lightly touching the side of the forefinger.

Active. Flex: - strong grip. Ext: - after gripping strongly he could relax quickly but no improvement in active extension was detected.

Passive. There was an appreciable lessening of the flexor spasm, but passive extension still met with moderate to marked resistance:- 90° - 0° (C-D).

The splints were in good condition and the skin was clear. There was no oedema of the hand. He was instructed to continue wearing both splints constantly.

NINTH WEEK.

Elbow. Settled at 30°.

Active. Flex: 30° - full flexion (4+).
Ext: full flexion - 30° (4), 30° - 10° (3). Gain 40°.
The final 20° - 30° of the movement was laboriously executed.

Passive. Flex: 30° - 70° (A), 70° - full flexion (B).
Ext: full flexion - 50° (A), 50° - 10° (B).

The splints were in good condition, the skin was clear and there was no oedema.

TWELFTH WEEK.

He said that he had worn the elbow splint constantly but had left off the finger splint for 8 hours per day - on an average.

Elbow. Settled at 15°.
Active. Flex: 15° - full flexion (4+).
Ext: full flexion - 20° (4), though the last 20° - 30° was still rather slow.
Passive. Flex: 15° - 80°(A), 80°- full flexion (B).
Ext: full flexion - 40°(A), 40°- 10°(B).

Fingers. Settled 1" - 2" (5th - 2nd) from the palm and the thumb lay lightly against the forefinger. The only change in active or passive movement was a slight lessening of flexor spasm:- 90° - 0° (C-D). Only a few degrees of active extension were seen - as before.

FOURTEENTH WEEK.

No change. A new wrist and finger splint (type b) was made and fitted (Photograph P.98). He could, with an effort, put it on unaided. He was instructed to try and wear the new splint constantly and to leave off his elbow splint during the night.

SEVENTEENTH WEEK.

He had worn the wrist and finger splint constantly and the elbow splint during the day. The skin was clear but there was a very slight amount of oedema of the dorsum of the hand - just detectable. The elbow movement was a little freer, both active and passive, but there was no material change.

Fingers. Settled ½" - 2" from the palm with the thumb ½" from the forefinger.
Active. Flex: strong grip. Ext: to 1" - 2½" from palm - i.e. there was only a slight improvement.
Passive. Ext: 90° - 45° (A), 45° - 0° (C). This represented a marked release of spasm.

He was instructed to wear the elbow splint 8 hours and the finger splint for 18 hours per day.

TWENTY-SECOND WEEK.

He had carried out instructions. Skin was clear. No oedema seen. Splints in good condition.

Elbow. Settled at 15.°
Active. Flex: 15° - full flexion (4).
Ext: full flexion - 10° (4) though the last 25° of extension was still slowly performed.
Passive. Flex: 15° - 80° (A), 80°- full flexion (C).
Ext: full flexion - 30°(A), 30° - 10° (B).

Fingers. Settled ½" - 2" from palm with thumb touching the forefinger.
Active. Flex: - firm grip.
Ext: 3" - 3½" (5th - 2nd). (see photograph on P.98)

Passive. Ext: 90° - 50°(A), 50° - 0° (C).
Flex: 0° - 90° - no resistance.

He was instructed to discard the elbow splint entirely (it was kept in the Department) and to leave off the other appliance for 8 hours during the day.

TWENTY-SIXTH WEEK. (2.5.56)

He had worn the wrist and finger splint as ordered. Skin clear. No oedema. Splint required no attention.

Elbow — Settled at 15°.
Active. No change since last examination.
Passive. Flex: 15° - 80° (A), 80° - full flexion (C).
Ext: full flexion - 30°(A), 30° - 10° (B).

Fingers.
Active. Flex: firm grip.
Ext: As at last examination.
Passive. 90° - 60° (A),, 60° - 0°(C).

Knowing that I would be unable to see this patient again for a considerable time, I instructed him to progressively reduce the number of hours per day during which he wore the splint by one hour each week until he was wearing it only at night. This would occupy eight weeks. He was to wear it at night only for a further month and then discard it completely.

I did not see this patient again until the:-

FIFTY-THIRD WEEK. (7.11.56.)

The patient was seen at home and gave the history that he had carried out my instructions. He had worn no splint since the beginning of August 1956.

His general health was good. He was walking up to a mile per day, still using a toe spring and a walking stick. His main recreation was his garden.

Examination. Only the right upper limb was examined and the examination was carried out in a warm room.

Shoulder. Settled in adduction.
Active. Abduction 90°(4). Flexion 50° (4).
Extension 40° (4+).
Rotation:- ext. 90° (3+), int. 90°(3+).
Passive. There appeared to be a fibrous contracture at about 120 of abduction.

Elbow. Settled at 20°.
Active. Flex: 20° - full flexion (4+).
Ext: full flexion - 15°(4). The last 30° of extension was still a little slow.
Passive. Ext: full flexion - 40°(A), 40°- 10° (B).
Flex: 10° - 80° (A), 80°- full flexion (B-C).

Wrist. Settled at 60° F. when pronated and 0° when supinated.

Active. Ext: 60°F. - 25°E. (4).
He repeated the extension movement forty times. After the twenty fifth repetition he could not extend it past 0° but at the fourtieth repetition this range of movement was still very strong (4) and showed no sign of tiring.
Flex: 0° - 60°F. (4+).
Supination. 10° - 130° (3+).
Pronation. 130° - 10° (4+).
Adduction & Abduction. 5°- 10° (3+).

Passive. Ext: 60°F. - 30°E. (A), 30°E. - 60°E. (C-D).
Flex: 60°E. - 60°F. (A).
Other movements showed moderate spasticity outside the active ranges.

Fingers. Settled ½" - 1" from palm with the thumb resting against the forefinger.

Active. Ext: Disappointingly, there was some loss in active finger extension. After gripping two fingers firmly he could relax quickly, but he could then extend them only 2" - 3" (5th - 2nd) from the palm. The thumb could also be extended about ¾" from the forefinger.
Flex: His grip remained very strong.

Passive. 90° - 50° (A), 50° - 0° (C-D).

EIGHTY-FIRST WEEK. (25.5.57)

He had worn no appliance since the last examination. He had been using his hand as much as possible. His general health was good and he was able to walk about one mile each day.

FINAL EXAMINATION (on the above date.)

The gain in elbow and wrist extension had been retained unaltered. Finger extension was a little better, 2½" - 3½" (5th - 2nd) from the palm. He could extend the thumb 1¼" from the side of the index finger. Shoulder movement showed no material change since the previous examination.

SUMMARY.

This patient had his wrist flexors stretched for a period of seven months. He thereafter retained a gain in attive extension to the functional angle (30° extension) for two years and three months after stretch was discontinued. His elbow flexors were stretched for a period of five months and he retained a gain in active extension to 15° (compared to 50° before stretch) for one year and one month after stretch was suspended. The finger flexors were extended for nine months but despite the prolonged stretch gain in active extension was

was less good that that at the proximal joints. Nevertheless a useful gain (2" - 3") was maintained for ten months after stretch was stopped.

GRAPHS. (Next Page).

Graphs of changes in the active and passive range of movement at the elbow and wrist joints are appended. No exact figures were obtained during the first four months of treating the wrist joint; thereafter the gain of 75° in active and passive range remained constant at each examination.

PHOTOGRAPHS.

1.

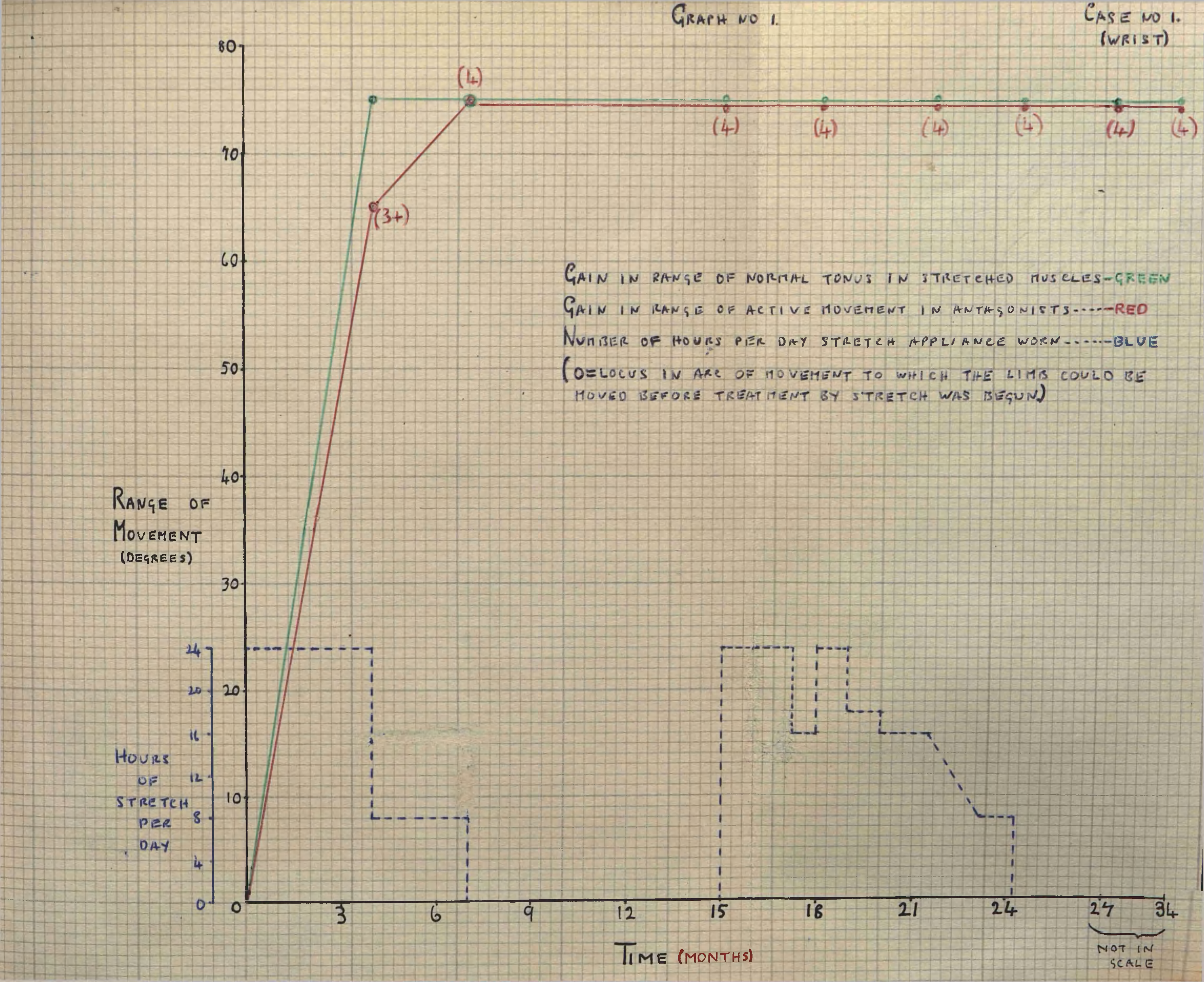
2.

Photographs 1. & 2. show the patient wearing a type (b) splint. (Text. p. 95.)

3.

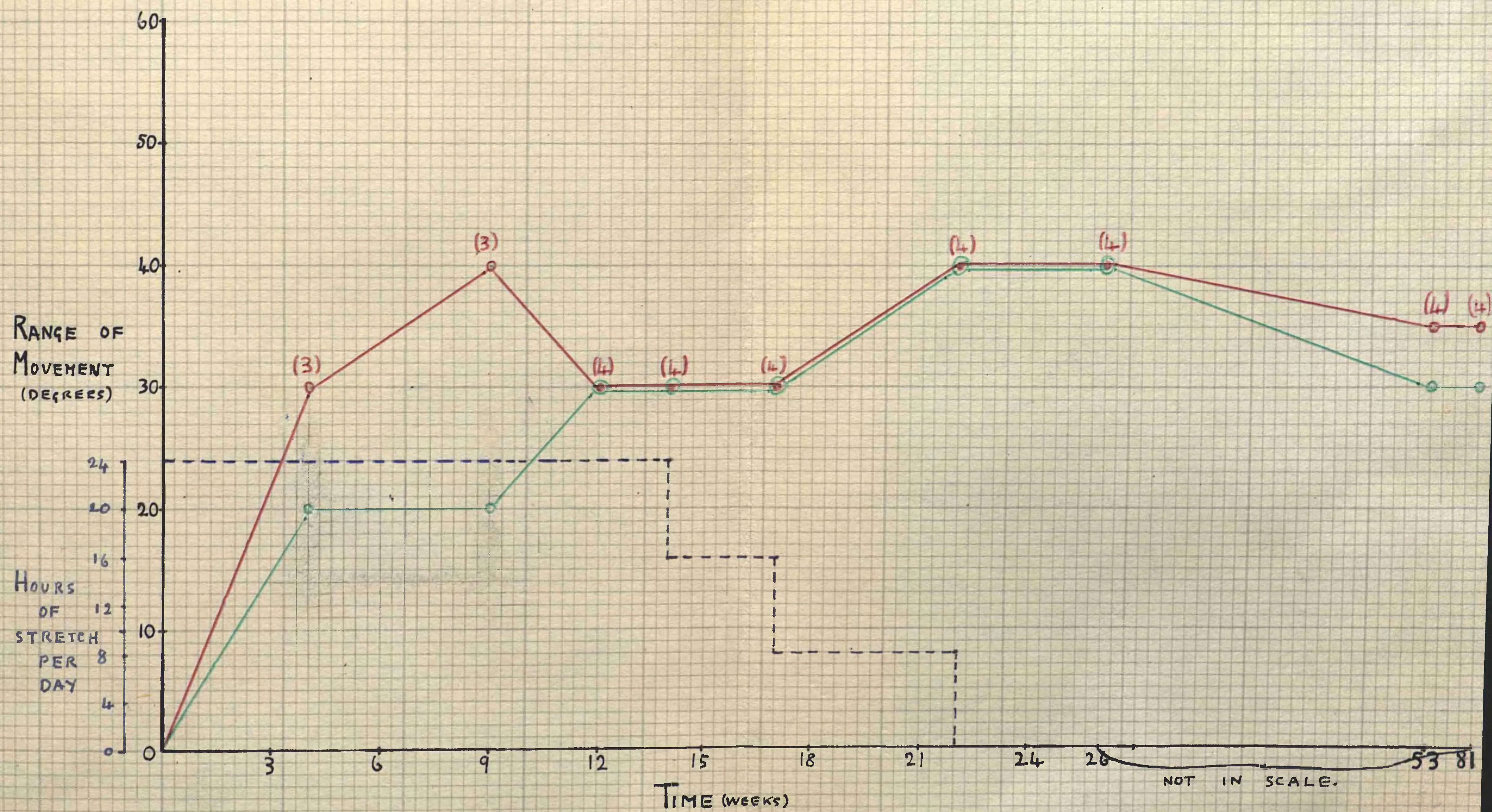
4.

Photographs 3. & 4., (taken on the 25.5.57), show the range of extension which has been retained at fingers, wrist and elbow. (Text, p. 97.)


GRAPH NO 1.
CASE NO 1.
(WRIST)
GAIN IN RANGE OF NORMAL TONUS IN STRETCHED MUSCLES - GREEN
GAIN IN RANGE OF ACTIVE MOVEMENT IN ANTAGONISTS ----- RED
NUMBER OF HOURS PER DAY STRETCH APPLIANCE WORN ------ BLUE
(O = LOCUS IN ARC OF MOVEMENT TO WHICH THE LIMB COULD BE MOVED BEFORE TREATMENT BY STRETCH WAS BEGUN)
RANGE OF MOVEMENT (DEGREES)
HOURS OF STRETCH PER DAY
TIME (MONTHS)
NOT IN SCALE
(3+)
(4)
0
10
20
30
40
50
60
70
80
0
4
8
12
16
20
24
3
6
9
12
15
18
21
24
27
34

GRAPH NO 2.

CASE NO 1
(ELBOW)



CASE NO. 2.

Age. 28 years.

Sex. Male.

Diagnosis. Right sided hemiparesis.

History.

In 1934, at the age of 7 years, he had rheumatic fever and chorea. In 1950 he was seen at the Medical O.P.D. with dyspnoea on exertion and signs of mitral stenosis and auricular fibrillation.

In 1953 he had a mitral valvotomy.

On the 7.10.54 he collapsed at work and was admitted to hospital in an unconcious state. He recovered conciousness within a few hours but had a complete flaccid paralysis of the right side accompanied by aphasia. A diagnosis of cerebral embolus from the left heart was made.

By January 1955, his speech had returned to a large extent and he could express himself adequately, though he spoke haltingly. He could walk with his right leg spastic in extension, the foot being dorsiflexed by a toe spring. There was no useful movement in the right arm. On the 22.4.55, six and a half months after the onset of his hemiplegia, (See initial examination) a ventral cock-up wrist splint was made and fitted.

He wore this appliance until the 27.6.55, on which date he was admitted to hospital with an epileptiform convulsion. He was an In-Patient for two weeks during which time he wore his splint only at night - i.e. for 8 hours per day. This convulsive episode had no effect upon his hemiparetic state and examination on discharge from hospital showed no change from the examination prior to his admission.

No further episodes interrupted his progress up to the date of my final examination on the 4.6.57, when I saw him, by arrangement, at the Whittington Hospital.

Other Forms of Treatment employed prior to Splinting.

From the onset of his hemiplegia he was given physiotherapy. Occupational therapy was instituted as soon as he was able to benefit from it.

During the month prior to splinting no improvement in the movement of the upper limb had been noted. His walking was continuing to improve with practice.

Joints Splinted and Type of Appliance Used.

The wrist joint was splinted in 30° extension with a ventral cock-up wrist splint. Later on, eighteen months after onset, when active extension of the wrist appeared to be permanently improved, a wrist and finger splint Type (a) was fitted which held the wrist extended to 30° and the fingers in line with the metacarpals.

Joints observed as Controls.

The elbow and finger joints were used as controls for the wrist joint during treatment with the wrist splint. Later, when the wrist and finger splint was used the elbow joint was used as a control.

Initial Examination 22.4.55.

Shoulder. Settles in adduction.
Active. Abduction 110°(4). Adduction - full (4+). Flexion, 80° (3+). Extension, 60° (4+). Rotation:- external 85°(3+). internal 85°(4)

Elbow. Settles at 35°.
Active. Flexion, 35° - full flexion (4). Extension, full flexion - 35° (3+).
Passive. Flex., 35° - 80°(A), 80° - full flexion (B). Ext., Full flexion - 80°(A), 80° - 30°(B), 30° - 0°(C).

Wrist. Settles in 60° flexion in pronation, and 0° in supination.
Active. Ext., 60°F. - 50°F. (3). Flex., 0° - 45°F. (3+). Adduction & abduction 2° - 3°(2). Supination 60°(3). Pronation 60°(4).
Passive. Ext., 60°F. - 40°F. (A), 40°F. - 70°E. (B-C). Flex., 70°E. - 60°F. (A). Abduction, Adduction, supination and Pronation - all showed slight to moderate tone.

Fingers. Resting position with hand passively dorsiflexed to 30° extension was as follows:- ½" - 2" (5th - 2nd). The thumb was flexed 45° at I.P. joints and was lightly opposed against the forefinger.
Active. Flex., - there was a weak but useful grip (3+). Ext., 0° (1). Abduction and Adduction 0° (0).
Passive. Examined with the fingers fully extended at the I.P. joints and flexed to 90° at the M.P. joints:- Ext., 90° - full extension (C). Flex., Full (A).

Reflexes.

All myotatic reflexes on the right side were moderately exaggerated and the right plantar response was extensor.

Co-ordination.

Moderate degree of inco-ordination, particularly when his eyes were closed.

Sensation.

No loss to touch or pin-prick detected. Muscle and joint sense appeared intact.

Mental State.

Cynical, depressed and aggressive.

2nd WEEK.

He has worn the splint constantly except for 10 minutes, night and morning, when washing the hand and forearm. He has found it comfortable. There are no skin abrasions and the splint is in good condition. There are marks on the flexor aspect of the wrist due to the $\frac{1}{8}$" ventilation holes, but these are not significant.

Examination.

Passive. Ext., 60°F. - 0°(A). (Gain 40°).
0°- 30°E. (B), 30°E - 70°E (B-C).

Active. Ext., 60°F - 30°F (3) (Gain 20°).

4th WEEK.

No complaints. Skin clear. Still wearing the splint constantly.

Examination.

Passive. Ext., 60°F. - 20°E. (A). (Gain 60°).
20°- E. - 70°E.(B-C).

Active. Ext., 60°F. - 0°(3). (Gain 50°).

6th WEEK.

No deterioration of splint. Skin clear. Still wearing it constantly.

Examination.

Passive. Ext. 60°F. - 40°E. (A). (Gain 80°).
40°E. - 70°E. (B).

Active. Ext., 60°F. - 20°E. (3) (Gain 70°).

9th WEEK.

Still wearing it constantly without complaint. He could use his hand much better while wearing the splint and he was resistant to my instructions to begin leaving it off 2 hours per day.

Examination.

Passive. 60°F. - 45°E. (A). (Gain 85°). 45°E - 70°E. (B).
Flex., 70°E. - 60°F. (A).

Active. Ext. 60°F. - 30°E. (3+). (Gain 80°).
The movement is rather slow. Repeated twelve times. The grip is materially

improved (4); perhaps due to increased
use of his hand.
Flex., $0^\circ - 45^\circ$ (3+).

It will be seen from these figures that, in this case, the release of spasm in the flexors was not accompanied by any detectable increase of tone in the extensors or "stiffness" of the joint due to immobilisation - as occurred in some cases.

<u>12th WEEK.</u>

My instructions to leave off the splint for 2 hours per day were not carried out, because three days after the last examination he was admitted to hospital following a convulsive episode (see History).

During his stay in hospital and since discharge he had worn the splint only during the night.

Skin clear. Polyurethane lining of splint still well attached to the polythene but it required washing.

Passive and active movement remained the same.

He was instructed to continue to wear the splint only at night.

<u>27th WEEK.</u>

I lost sight of this patient for 15 weeks and he gave the history that during the whole of that period he had not worn the splint at all. He did not see any point in wearing it as he was able to extend his wrist voluntarily as much as he wanted.

<u>Examination.</u>

<u>Passive.</u> Ext., 60°F. - 30°E. (A), (Gain 70°).
30°E. - 70°E. (B).
Flex., 70°E. - 60°F.(A).

<u>Active.</u> Ext., 60°F. - 30°E. (3) (Gain 80°).
This movement is still rather slowly performed though he was able to repeat it twelve times before fatigue occurred, and he was able to do this at intervals throughout a 3 hour period in the Department. He had maintained a firm grip (4).
Finger movement - as at initial examination.
No flicker of active extension.
Active elbow extension improved to 20° (Gain 15°). Passive movement - no change.

His active wrist extension appeared to have been maintained for 15 weeks following the discarding of his wrist splint. He was, however, disappointed that he was still unable to extend his fingers and he agreed to wear a new splint which would keep his fingers extended.

A wrist and finger splint (type A) was made and fitted. This held the wrist at 30° extension, the fingers in line with the metacarpals and the thumb fully extended.

29th WEEK.

He had not found the splint comfortable but had worn it constantly. Skin clear.

Wrist. Passive and active movement remained the same in range as at the last examination, but his wrist extension was a rather quicker movement. He repeated this movement 20 times before it 'fatigued'.

Fingers. The fingers settled at 1" - 3" (5th - 2nd) from palm. Thumb lightly opposed.

Passive. Only the last 20° of full extension showed slight spasticity (B).

Active. After gripping the examiner's finger tightly, the fingers relaxed on command to ½" - 2" from the proximal palmar crease. From this position of relaxation there was no flicker of active extension.

This splint had had the polyurethane lining removed before fitting. This had been done as an experiment to see if it would be sufficiently comfortable to wear without its lining. The patient was most aggresive about this lack of padding, and threw the splint down, saying that he would never wear it again, and demanding a new padded splint, (see Mental State).

I considered that he was too unstable to continue splinting and no appliance was given him. I did not see him again until the 20.3.56. (46th week).

46th WEEK.

He had now worn no splint for 34 weeks except for two weeks (weeks 27 and 28).

Wrist.

Passive. Ext. 60°F. - 40°E (A). (Gain 80°),
40°E. - 70°E. (B).
Flex. 70°E. - 60°F. (A).

Active. Ext., 60°F. - 25°E. (3+) (Gain 75°). He repeated this movement 25 times before it fatigued. The movement was lively during the first 20 movements.
Flex., 0° - 50°(3+).

Elbow & Shoulder movements showed no improvement in active or passive movement.

Fingers. Settling position 1" - 2½" (5th - 2nd). Thumb in mid opposed position lying lightly against the forefinger. They regained this position on relaxing after gripping my two fingers, but no active extension was seen in either fingers or thumb.

His mental condition seemed much improved and a new wrist and finger splint (type B) was made and fitted. He was told to wear it constantly. This splint held the wrist at 30 extension and the fingers in line with the metacarpals.

<u>48th Week.</u>

He had found the new splint comfortable and had worn it constantly. There were no skin abrasions.

<u>Wrist.</u> Active and passive movements showed no change.

<u>Fingers.</u> Settling position 1½" - 3" (5th - 2nd) from proximal palmar crease. They regained this position on relaxing after gripping my two fingers. The thumb also regained its original position.

<u>Passive.</u> There was only slight tonus (B) during the last 25° to full extension.

<u>Active.</u> The 5th, 4th and 3rd fingers extended 5°(3). The 2nd finger (forefinger) extended to 10°- 15° of flexion at the M.P. and I.P. joints (3+). This movement was quite lively.

Thumb:- no extension at M.P. joint but the I.P. joint extended to almost full extent (3+).

<u>50th WEEK.</u>

Still wearing the splint constantly. Skin clear.

<u>Wrist.</u> Active and passive movements - no change except for 10° more range of normal tone on passive movement.

<u>Fingers.</u>

<u>Passive.</u> Extension meets normal tonus (A) to fully extended position.

<u>Active.</u> No change from last examination.

<u>53rd WEEK.</u>

He had now worn the wrist and finger splint constantly for over 7 weeks. Thumb piece tended to slip down over the terminal phalynx and this has been allowed to flex. Appropriate adjustment was made.

<u>Wrist.</u> Active and passive movement showed little change.

<u>Fingers.</u> Passive extension met with normal tonus (A) to full extension.

Active extension had improved a little in the medial three fingers. These now extended

10° - 15°(5th - 3rd) at the M.P. and I.P. joints. Extension of the forefinger was a lively movement and was carried to within 15° - 20° of full extension at the M.P. joint, and to full extension at the I.P. joint.

I was unable to follow closely this patient's further progress. I instructed him to begin leaving the splint off progressively, 4 hours more each week, until he was not wearing it at all during the 16 hours of day. This would occupy 4 weeks. He was then to discard the splint.

I next saw him on the 28.8.56 (week 70 - by special arrangement.

<u>70th WEEK</u>.

He gives the history that he carried out my instructions carefully. He had discarded the splint for the past 13 weeks. Mental state more normal now.

Wrist.

Passive. Ext. 60°F. - 40°E. (A). (Gain 80°)
40°E. - 70°E. (B).
Flex. 70°E. - 60°F. (A).

Active. Ext. 60°F. - 40°E. (3+). (Gain 90°)
Flex. 40°E. - 60°F. (4).

The extensor movement was lively and strong and was repeated 30 times. It did not seem to be weakening even at the 30th movement but the patient refused to go on any longer.

Fingers.

Passive. Extension to 30° met with normal resistance (A). From there to full extension there was slight resistance (B).

Active. The forefinger extended to 20° flexion at the M.P. joint and fully at the I.P. joint. The mid, ring and little fingers extended to 35°, 35° and 45° respectively at the M.P. joints and almost fully at the I.P. joints of the mid and ring figgers, but to lesser extent at the I.P. joint of the little finger.

<u>NINETY-SIXTH WEEK.</u>

He had worn no appliance for thirty nine weeks. Occupational therapy had been continued throughout that period and he had used his hand freely at all times.

<u>Elbow</u> Settled at 35° flexion.

<u>Active.</u> Flex: 35° - full flexion (4+).
Ext: full flexion - 40° (4+).

<u>Passive.</u> Flex: 35° - 90°(A), 90° - full flexion (B).
Ext: full flexion - 70°(A), 70° - 0°(B).

Wrist. Settled at 40° flexion when pronated and 20° extension when supinated.

Active. Ext: 40°F. - 50°E. (4) (Gain 100°). He repeated this sixty times without fatigue.
Flex: 20° E. - 50°F. (4).
Supination 0° - 110° (3+).
Pronation 110° - 0° (4).
Abduction and adduction 10° - 15° (3+).

Passive. Ext: 40° - 60° (A) (Gain 100°), 60° - 80° (B-C).
Flex: 80°E. - 50°F. (A).
Supination 0° - 120° (A), 120° - 160° (B-C).
Pronation 160° - 0° (A).
Abduction and adduction 10° - 15° (A).

Fingers. Settled 1" - 2" (5th - 2nd) with the thumb slightly flexed and opposed.

Active. Full extension at I.P. and to 20° at the M.P. joints (4), (5th - 3rd). The forefinger could be fully extended. The thumb extended fully. The grip was firm (4) and could be released quickly on command to extend the fingers and thumb

Passive. Almost full extension could be obtained without resistance

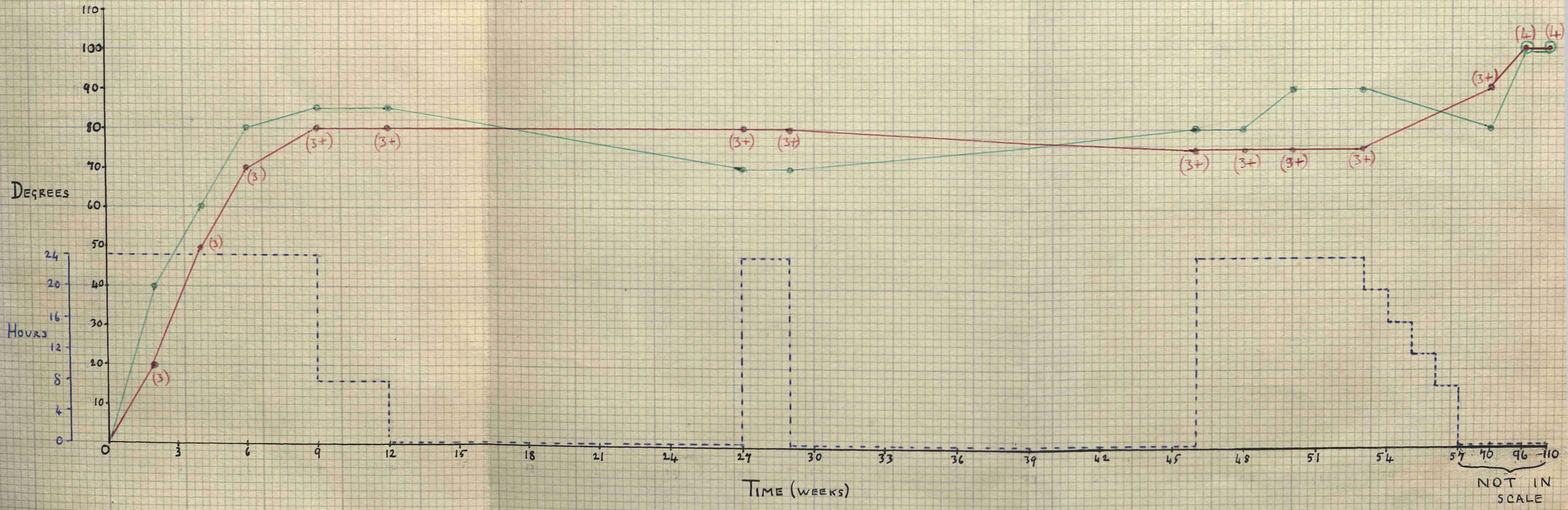
ONE HUNDRED & TENTH WEEK.

At this examination the findings were similar to those found at the previous examination - within the limits of experimental error.

Shows the patient wearing his type (a) splint - unpadded. (Text. p. 103)

Graph No 3
(For legend see graph No 1)

Case No 2
(Wrist)



CASE No. 3.

Age. 38 years.

Sex. Female.

Complaint. Chronic residual hemiparesis of the right side. (Duration, three years and three months.)

History.

When she was six years of age the patient contacted rheumatic fever. She recovered from this and remained well until the age of 35 years, when on the 4.4.52 she collapsed suddenly and was admitted to hospital in an unconcious state. She recovered conciousness within 24 hours and was found to have a complete right hemiplegia and motor aphasia. There was a rumbling diastolic murmer heard over the mitral area. No evidence of C.C.F. A diagnosis of cerebral embolus from the left heart was made.

Spasticity developed in both upper and lower limbs of the right side within a few days, and the reflexes became exaggerated.

Physiotherapy was given her and by the time of discharge, on the 19.7.52, she could walk with a toe spring and she was able to move the arm at shoulder and elbow. Movement of wrist and fingers remained almost completely absent.

On the 10.11.52 she was readmitted with a pulmonary infarct. She was discharged on the 7.2.53.

On the 12.7.53 she underwent mitral valvotomy.

She had no more episodes and when first seen in the Department on the 20.9.54 her condition was described as follows:- "Still has difficulty in walking. There is right facial weakness. Speech is fair. The right arm is wasted and the right hand is cold and blue. Fair grip but no extension of fingers. She abducts the arm quite well."

Walking exercises and exercises for her arm and hand were commenced. Heat and passive movement were also given to the upper limb.

This treatment continued until the 4.3.55 but no improvement resulted in the arm and hand though her walking did improve.

Occupational Therapy was prescribed to encourage her to make use of the slight grip in her right hand.

Betwen the 4.3.55 and the 11.5.55 four stellate ganglion blocks were produced at intervals of two weeks in an attempt to improve the vasomotor tone of the vessels of her hand and arm. Only a slight improvement resulted.

Other Forms of treatment employed prior to Splinting.

Physiotherapy, occupational therapy and stellate ganglion blocks were used as described above.

Joints treated and type of appliance used.

Only the wrist joint was splinted. The appliance used was a ventral wrist splint.

Joints observed as Controls.

The fingers, the elbow and the shoulder.

INITIAL EXAMINATION. 15.7.55.

Shoulder. Settled in adduction.
Active. Abduction 100° (3+). Adduction - full (4).
Flexion 60° (3+). Extension 45° (4).
Rotation:- external 90° (3+).
internal 90° (3+).
Passive. Abduction. 0° - 110° (A), 110° - 140° (B-C).
Contracture at 140°.
Adduction. 140° - 0° (A).
Flexion: 0° - 60° (A), 60° - 110° (B-C).
Contracture at 110°.
Extension: 0° - 45° (A). 45° - 70° (B).

Elbow. Settled at 30°.
Active. Flex: 30° - full flexion (4).
Ext: full flexion - 30° (3).
Passive. Flex: 30° - full flexion (A).
Ext: full flexion - 40° (A), 40 - 10 (B-C).

Wrist. Settled in 45° flexion with hand pronated and at 10° flexion when supinated.
Active. Flex: 10° F. - 45° F. (3+).
Ext: 45° F. - 30° F. (3).
Abduction and adduction 2° - 3° (2).
Supination 60° (3).
Pronation 60° (3+).

Passive. Ext: 45° F. - 20 E.° (A). 20° F. - 70° E.(B-C).
Flex: 70° E. - 45° F. (A).
Abduction, adduction, supination and pronation:- slight to moderate tone.

Fingers. Resting position, with hand passively dorsiflexed to 30°, 5th & 4th fingers 1" and 3rd & 2nd fingers 2" from proximal palmar crease. The thumb was opposed and flexed, touching the 2nd finger.
Active. Flex: - slight grip (3+). Ext: 0°(0).
Abduction and adduction 0°(0)
Passive. Full extension could be obtained (A-C).
Full flexion could be obtained (A).

Reflexes.
Were all slightly brisker on the right.

Co-ordination:- of the arm was quite good.

The splint was fitted and was seen to hold the hand extended to 20° extension. She was instructed to wear it 24 hours per day.

PROGRESS EXAMINATIONS.

1st. WEEK.
No skin abrasions. No oedema. She had found it comfortable to wear, and has worn it constantly except for removal to wash the hand night and morning.
Examination.
Active. Ext: 45° F. - 20° F(3). (Gain 10°).
Passive. Ext: 45°- 0°(A), (Gain 20°), 0°- 70° E(B-C).

2nd WEEK.
No abrasions or oedema. Finds that she can use hand a little while wearing splint - helps her to grip things better - e.g. a book. Pleased with her appliance and interested in the return of active movement.
Examination.
Active. Ext: 45° F. - 10° F.(3). (Gain 20°).
Passive. Ext: 45° F. - 10° F (A) (Gain 30°),
10° E. - 70° E. (B-C).

3rd WEEK.
No abrasions, oedema or complaints. Hand cold and rather cyanosed - as usual.
Examination.
Active. Ext: 45° F. - 0°(3). (Gain 30°).
Passive. Ext: 45° F - 20° E. (A). (Gain 40°).
20° E. - 70° E. (B-C).

4th WEEK.

Splint in good condition. No kin abrasions. No oedema. She still finds it comfortable and wears it constantly. To begin leaving off splint 1 hour per day each week.

Examination.

Active. Ext: 45°F. - 10°E. (3) (Gain 40°).
Passive. Ext: 45°F. - 20°E. (A) (Gain 40°).
20°E. - 70°E. (B-C).

To wear splint 23 hours per day next week; 22 hours per day the following week, 21 hours per day the week after, etc.

5th WEEK.

Splint in good order. Skin is a little "soggy" in the palm. To powder hand after washing.

Examination.

Active. Ext: 45°F. - 20°E. (Gain 50°).
Passive. I.S.Q.

6th WEEK.

Splint lining requires washing - this was done in the Department and the splint returned.

Examination.

Active. I.S.Q.
Passive. 45°F. - 30°E. (A), (Gain 50°),
30°E. - 70°E. (B).

7th WEEK.

No oedema. Skin - n.a.d. Splint - n.a.d.
Movement I.S.Q., except that active movement is now 3+.

8th WEEK.

No change. Movement I.S.Q.
Movement at end of 3 hours in the Department with splint off was still 45°F. - 20°E. (3+).
The patient was pleased with her progress. She could use the hand more freely during the four hours freedom from the splint.

10th WEEK.

Has been wearing the splint 18 hours per day. No change noted in movement at any joint.

12th WEEK.

Skin normal. Splint in good condition except for some yellow discolouration of the polyurethane lining. The patient says that she can extend her wrist voluntarily throughout the eight hours during which she leaves off the splint.

At this stage in her treatment the patient moved house out of London and it was not possible to arrange transport to bring her for further examination.

She was instructed to leave off her splint progressively, as before, for the next four weeks. One month later (16th Week) I received a letter from her which said that she had worn the splint as directed and that she could extend the wrist at will.

In reply, I directed her to wear her appliance at night only for the next fortnight and then to discard it - i.e. at the end of the 18th week of treatment.

34th WEEK.

She was seen at home four months later. At that time examination produced the following data:-

Wrist Joint. Settled at 50°F. when pronated.
Active. Ext: 50°F. - 20°E. (3+) (Gain 50°). She repeated this movement twenty times before it tired.
Passive. Ext: 50°F. - 40°E. (Gain 60°).

Elbow. Settled at 25°.
Active. Flex: 25° - full flexion (4)
Ext: full flexion - 25° (3+).
Passive. Flex: 25° - full flexion (A).
Ext: full flexion - 45°(A), 45° - 10°(B).

Shoulder. As at initial examination.

Fingers. The grip was firmer. Still no active extension.

99th WEEK.

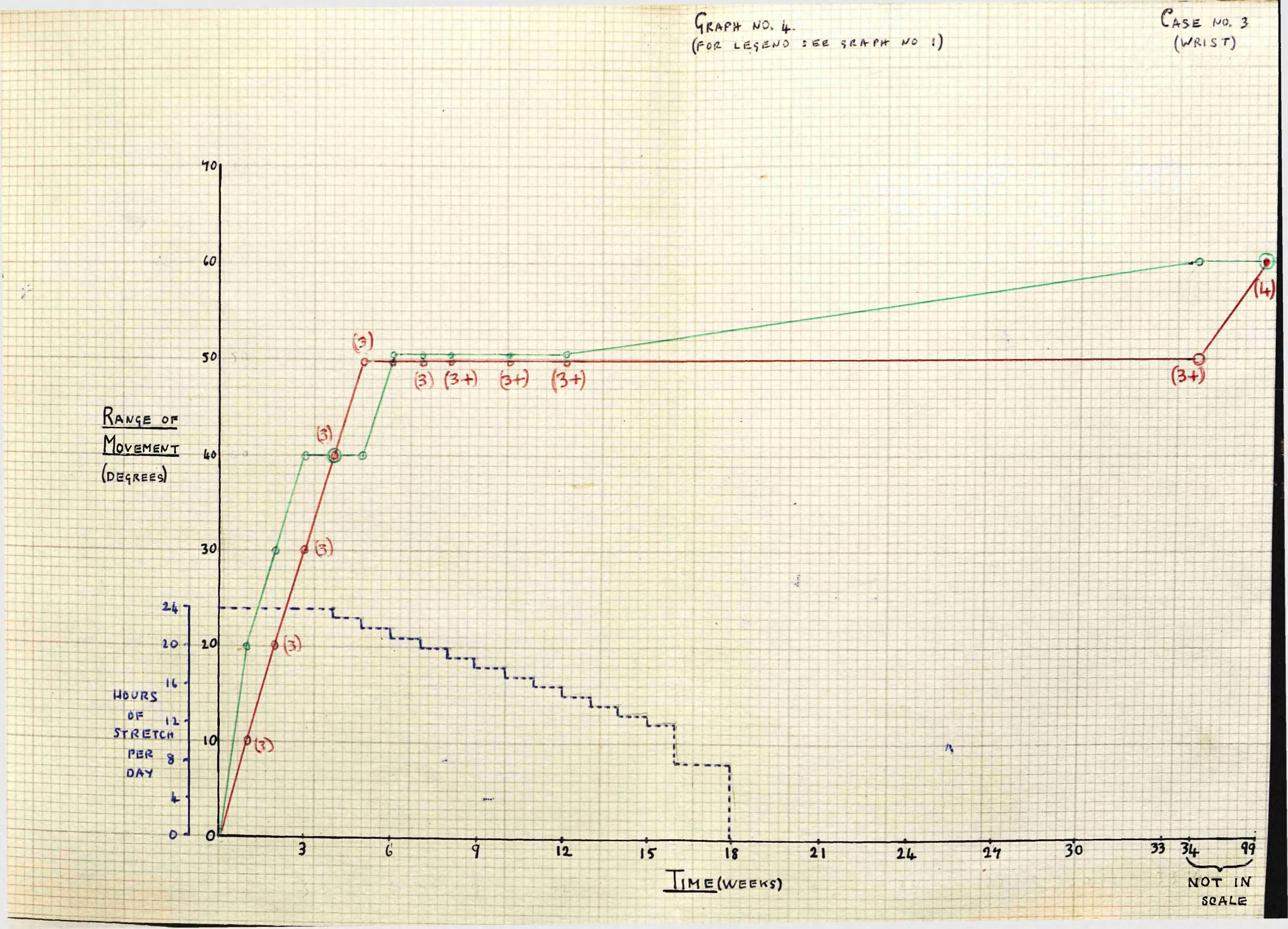
She was seen again at her home, and gave the history that she had been using her hand quite freely.

Shoulder. No change.

Elbow. Settled at 20°.
Actige. Flex: 20° - full flexion (4).
Ext: full flexion - 65°(4), 65° - 15°(3+).
Passive. Flex: 20° - full flexion (A).
Ext: full flexion - 40°(A), 40° - 10° (B).

Wrist. Settled in 60° flexion when pronated and 0° when supinated.
Active. Ext: 60° - 30°(4). She repeated this 45 times with fatigue.
Flex: 0° - 60° (4).
Passive. Ext: 60°F. - 40°E. (A), 40°E. - 70°E.(B-C).

Fingers. Settled 1" - 2" (5th - 2nd) with the thumb a little flexed at the I.P. joints and lightly touching the forefinger.
Active. Grip firm (4). Ext: 2" - 3" (5th - 2nd) from palm. The thumb also extended some ¾" from the forefinger.


GRAPH NO. 4.
(FOR LEGEND SEE GRAPH NO 1)
CASE NO. 3
(WRIST)
RANGE OF MOVEMENT (DEGREES)
HOURS OF STRETCH PER DAY
TIME (WEEKS)
NOT IN SCALE
(3)
(3+)
(4)
0
10
20
30
40
50
60
70
4
8
12
16
24
3
6
9
12
15
18
21
24
27
30
33
34
99

CASE No. 4.

Age. 64 years.

Sex. Male.

Complaint. Chronic residual hemiparesis of the right side. (Duration, one year and two months).

History.

On the 4.9.54 he developed a sudden onset of weakness in his right arm. This progressed, durimg the next few hours, to complete paralysis of the right side. He did not lose conciousness nor was his speech affected. The right lower limb became spastic in extension after about a week and he was then able to walk. His right upper limb remained completely paralysed for some two weeks and then recovered slowly over the next two months until he could use the hand and arm for many simple procedures. He could not however return to his work, as a cobbler, as his right arm movement was too ataxic for the accurate hammer work required in his trade. (He was right handed).

Other forms of treatment employed prior to Splinting.

He had not received any special treatment until six months before I first saw him (3.11.55) when he began Occupation Therapy (wood-work and basketry). Although he was reported to have improved in the quality of his work during these months he still lacked sufficient dexterity for his old occupation.

Joints treated and type of appliance used.

The aim of treatment was to improve his range of finger extension (wrist extension was already adequate) and he was fitted with a wrist and finger splint (type B) which held the wrist extended to 40°. The M.P. joints were fully extended and the I.P. joints flexed 10°- 15°. (See Photograph opposite).

Joints observed as Controls.

The shoulder and elbow joint on the right side.

INITIAL EXAMINATION. 3.11.55.

Only the upper limb was examined in detail.

Right Upper Limb .

Shoulder. Settled in adduction.
Active. Abduction 110° (4). Flex: 110° (4).
Adduction full (4+). Ext: 60° (4).
Rotation:- external 70° (3)
internal 70° (4).
Passive. Past the active ranges a moderate resistance was felt and he had a contracture limiting abduction and flexion to 145°.

Elbow. Settled at 15°.
Active. Flex: full (5). Ext: full flexion - 15° (4).
Passive. Flex: 15° - full flexion (A).
Ext: full flexion - 50° (A), 50° - 10° (B).

Wrist. Settled in 45° flexion when pronated and 15° extension when supinated.
Active. Ext: 45° F. - 35° E. (4+).
Flex: 15° E. - 40° F. (4+).
Abduction 5° (4+). Adduction 10° (4+).
Supination 140° (4). Pronation 140° (4+).
Passive. Ext: 45° F. - 40° E. (A), 40° E. - 60° E. (B-C).
Flex: 60° E. - 45° F. (A).
Supination met with slight resistance during the last 40° of the arc but no abnormal tonus was detected in the remaining movement of the joint.

Fingers. Settled ¼" - 1" from palm.
Active. Flexion (grip) (4).
Ext: ½" - 1½" (5th -2nd fingers)- (3).
The thumb could be separated ¾" from the side of the forefinger (3). Abduction and adduction (1)
Passive. With the M.P. joints flexed to 90° the I.P. joints could be extended passively to their full extent without resitance. From this position there was slight to moderate tonus (B-C) felt on full extension. There was no resistance to full flexion.

Reflexes.

The deep reflexes were all increased on the right side. The Babinski test was positive on the right side.

Co-ordination.

Co-ordination at the large joints of the upper limb was almost normal but movement of the fingers was clumsy. Actions such as buttoning his jacket were beyond him.

Sensation.

The patient complained of numbness of his fingers and objectively there was evidence of reduced sensation to pin-prick and light touch in the digits. Proprioceptive sensation seemed normal.

Mental State.

His morale was good. He was pleasant and co-operative most of the time, though he tended to become disgruntled if my opinion differed from his own.

18.11.55. Splint made and fitted.

PROGRESS EXAMINATIONS.

These were carried out at weeks 1, 3, 4, 7, 8, 9, 10, 14, 17, 18, 19, 22, 24, 36, 48, 75 and 81.

After the first week of splinting there appeared, on superficial examination, to be a marked improvement in finger extension - 3" to 4" from the palm, but after asking the patient to grip tightly and then extend the fingers it was found that he could not extend them beyond the original ½" - 1½". After a minute's relaxation however he could extend them to 1½" - 3" from the palm. At each subsequent examination the degree of true recovery of extension was taken as the range immediately after he had firmly gripped my two fingers six times. The graph is constructed from the figures obtained.

In brief, he derived improvement of finger extension to such a degree that with the wrist dorsiflexed to 30° he could open his fingers and extend his thumb sufficiently to carry out many useful activities - such as picking things up. In addition to the increased range, the "quickness" of the movement improved concurrently. He was one of the few patients in the series to get return of useful finger extension and to retain it.

At the 18th week he discarded the splint, and throughout the follow up period he maintained his improvement.

At the last follow up examination he could actively extend his fingers and thumb an average of 3". There was normal tonus from 90° - 20°.

WRIST.

Although the wrist joint was included in the splint it was not expected that further improvement in extension would be obtained since at "Initial Examination" extension to 35° was almost normal in power (4). This proved to be the case.

SPLINT.

The patient could put on and take off the splint without assistance. (See photograph of method under "Appliances".) He washed it once or twice a fortnight and, when discarded after eighteen weeks it had in no way deteriorated from its original state except that the polyurethane lining had, as usual, become rather yellowed in colour. He found the splint comfortable to wear at all times.

SKIN & JOINTS.

No skin trauma of any kind was seen throughout the period of splinting. Nor was any oedema observed. Stiffness on flexing the M.P. joints did not occur in his case - as it did in some others. It will be seen from the photograph that these joints were included in the band of plastics encircling the fingers and so prevented from undue extension strain (see description of wrist and finger appliance, type b.).

CONTROL JOINTS.

No constant change was found in the movement of the elbow or shoulder throughout the period of observation.

THE GRAPH.

This relates the increase in range of active extension of the fingers, in inches, to the time of treatment and observation, in weeks, and also to the number of hours per day during which the finger flexors were stretched.

The range (ordinate) is given as the distance from the palm of the hand to which the fingers could be actively extended. Each individual figure is a mean of the distance of each finger tip from the palm and the distance of the thumb from the forefinger. Measurement of these distances was a relatively simple procedure, a ruler being held beside or between the fingers and its end resting on the proximal palmar crease. (See "Examination Technique")

continued overleaf......

As an example:-

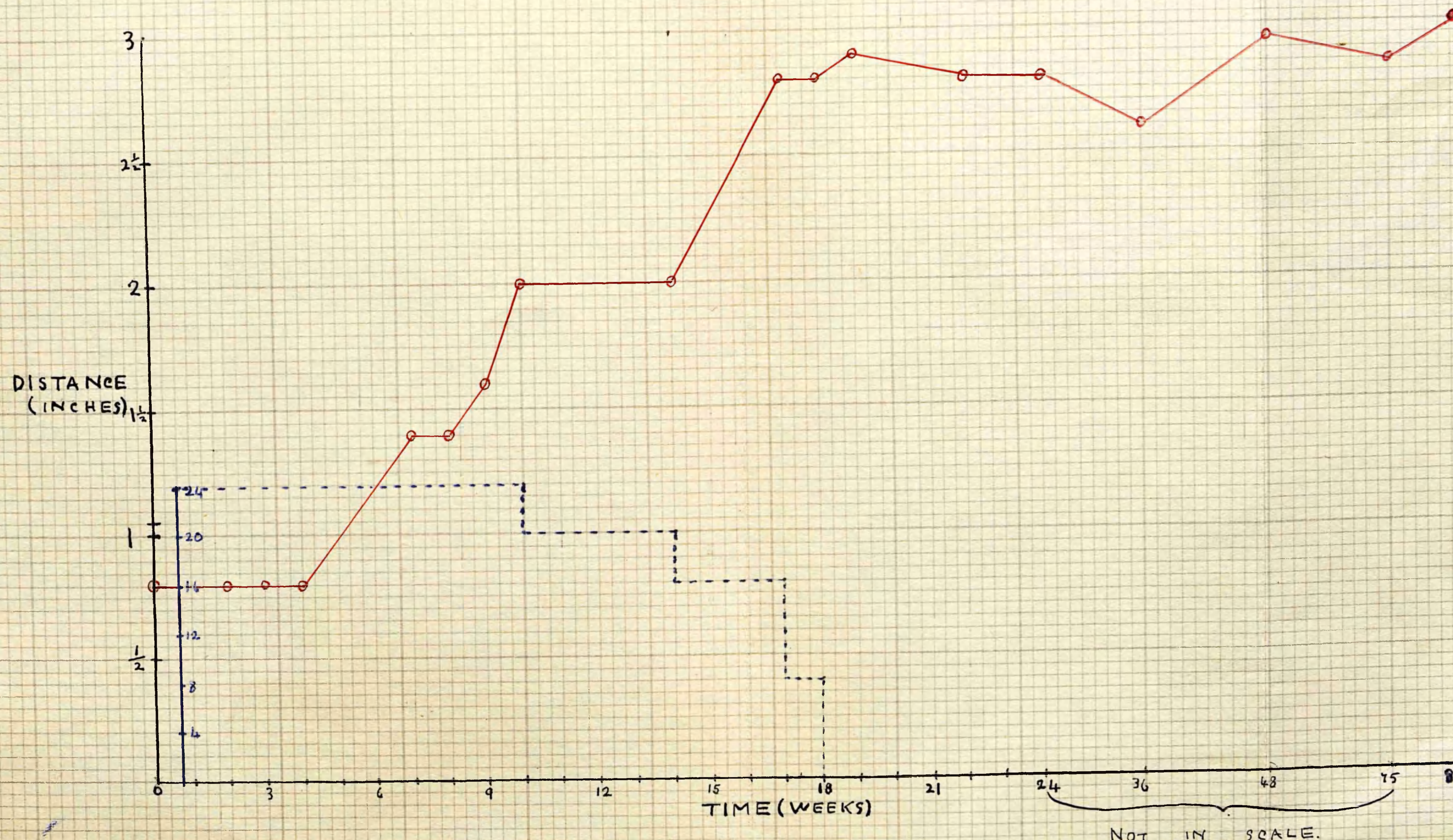
Fingers.	Distance.	
5th.	1"	from proximal palmar crease.
4th.	1½"	from proximal palmar crease.
3rd.	1½"	from proximal palmar crease.
2nd.	2½"	from proximal palmar crease.
Thumb.	1½"	from side of forefinger.
	8"	

The total figure is then divided by five and in the above example this gives one and three-fifths of an inch. In this way an overall picture of extensor range is given. Its limitation lies in its failure to reveal individual finger movement. In this case all the fingers and the thumb improved to an equal extent compared to their original range.

GRAPH NO. 5.

CASE NO 4
(FINGERS)

Case no. 4 The mean distance to which the fingers can be extended from the palm, and the thumb from the forefinger (ordinate) is related to the total period of treatment and observation (abcissa), and to the number of hours of stretching per day (inset ordinate).



CASE No. 5.

Age. 52 years.

Sex. Female.

Complaint. Chronic residual hemiparesis of the left side. (Duration, one year and four months).

History.

On the 15.8.54 she collapsed while doing housework. She was unconcious for five days. On recovery of conciousness she had a complete flaccid left hemiplegia. Her speech was slightly slurred. She was doubly incontinent. She was drowsy but obeyed commands if these were given forcefully. There was very marked nuchal rigidity. Her blood pressure was 180/120.

She showed no improvement over the week following recovery of conciousness. Ventricular aerography suggested the presence of a large clot and at operation on the 27.8.54 a large right sided clot was found, extending into the frontal lobe. The clot was evacuated. The patient recovered conciousness rapidly.

At examination on the 15.9.54 the right arm was still flaccid and immobile but there was a little voluntary flexion (only) of the left hip. The reflexes on the left side were moderately exaggerated, and the left Babinski response was positive. The patient had begun to complain of painful flexion spasms of the left leg. For this complaint she was put on "Artane". Over the next few weeks the patient reported that the drug was having little or no effect on her spasms. She was fitted with a walking calliper on the 11.11.54. This she wore during the day, while receiving training in walking by the Physiotherapy Staff. By the 25.11.54 she could walk slowly with one person steadying her.

Her ability to walk improved very slowly. She continued to have flexion spasms ad "Mysoline" was tried and proved ineffective. By April 1955, she had developed a 30° 'contracture' of the knee which was deemed to be fixed and a hamstring tenotomy was carried out on the 27.4.55. The leg was kept in Plaster of Paris for ten days following operation. This was followed by a regime of wearing her calliper during the day and a polythene-polyurethane splint at night. (This splint was made by the Physiotherapy Staff and I did not hear of it soon enough to include the further progress of the knee joint in this series.) The patient was a very poor historian and when questioned some months later, as to whether or not her nocturnal flexion spasms had abated after wearing the plastic splint at night, she was unable to give a reliable account. However, she did say then (18.8.55) that she had had only "occasional spasms recently." By that date she could walk safely on her own wearing the calliper and using a walking stick.

Other forms of treatment employed prior to Splinting.

To a large extent her rehabilitation programme was directed towards recovery of unassisted walking. She did, however, receive a certain amount of attention (heat and passive movements) to her arm in the six months following admission to hospital, but as no improvement whatsoever resulted this was discontinued.

Joints treated and type of appliance used.

Only the elbow joint was splinted and the fingers, wrist and shoulder joints were used as controls.

INITIAL EXAMINATION 6.12.55.

Only the upper limb was examined in detail. There was so little active movement present and such a marked degree of spasticity that I propose to condense the findings at this examination into a short paragraph.

At the shoulder joint there were about 40° - 60° of abduction, flexion, extension and external rotation (power 3+). Passive movement, past these ranges, met with marked spasticity, and there appeared to be a fibrous contracture limiting flexion and abduction to some 85°.

The elbow settled at 80° and there was some 10° - 15° of active flexion but no active extension. It could be passively extended (D) to 15° and from there she could actively flex the forearm to 100°(3+). Passive flexion from 100° to full flexion met with marked resistance, (D). From the fully flexed position it could be actively extended to 80°.

The wrist settled at 40° flexion in the fully pronated position and from there the only active movement was 15° - 20° of extension (3). Passive extension was strongly resisted (D). The fingers were clenched in the palm with the thumb flexed under them. No active extension was present but she had quite a firm grip when two examining fingers were pushed into her palm. Flexion spasm of the fingers was intense (E) and full passive extension could not be obtained with the wrist dorsiflexed to 30°.

Reflexes.

These were all exaggerated on the left side. The Babinski test was positive and the abdominal reflexes were absent on that side of the body.

Sensation.

There appeared to be no loss of sensation.

Mental State.

She was pleasant and very co-operative, but she was a little confused and her memory was poor.

PROGRESS EXAMINATIONS.

These were made at the 2nd, 6th, 10th, 14th, 18th, 21st, 38th, 50th, 67th and 82nd weeks. Throughout the period of treatment and observation the range of active movement and normal tonus at the shoulder, wrist and finger joints remained quite unaltered. Therefore, to avoid repetition it is proposed to give only the findings related to movement at the elbow joint. These will be shown in the form of a graph at the end of the case report.

SPLINT.

The lining required washing on several occasions but, apart from yellow discoloration of this inner layer, the splint remained in its original condition throughout the course of treatment.

SKIN & JOINTS.

During the first six weeks flexor spasm held the arm flexed strongly against the upper and lower anterior borders, and on removal of the appliance there were distinct lines of pressure in the skin underlying these hemi-circumferences. An extra, 3/16" thick, piece of polyurethane was glued over the offending parts and this, plus the decreasing spasm, prevented any further danger of skin abrasion. The skin over the point of the elbow was similarly protected with equal success.

The elbow joint became increasingly stiff and painful to passive flexion as time went by, and after five months it was painful to flex it past 70°. It was for this reason that the number of hours wear per day was reduced as from that time, and the patient told to massage and move the joint during the intervals of freedom from the splint. The pain and stiffness slowly disappeared during the following six weeks.

CONTROL JOINTS.

Movement and tone at the shoulder, wrist and fingers showed no change whatsoever during the period of observation.

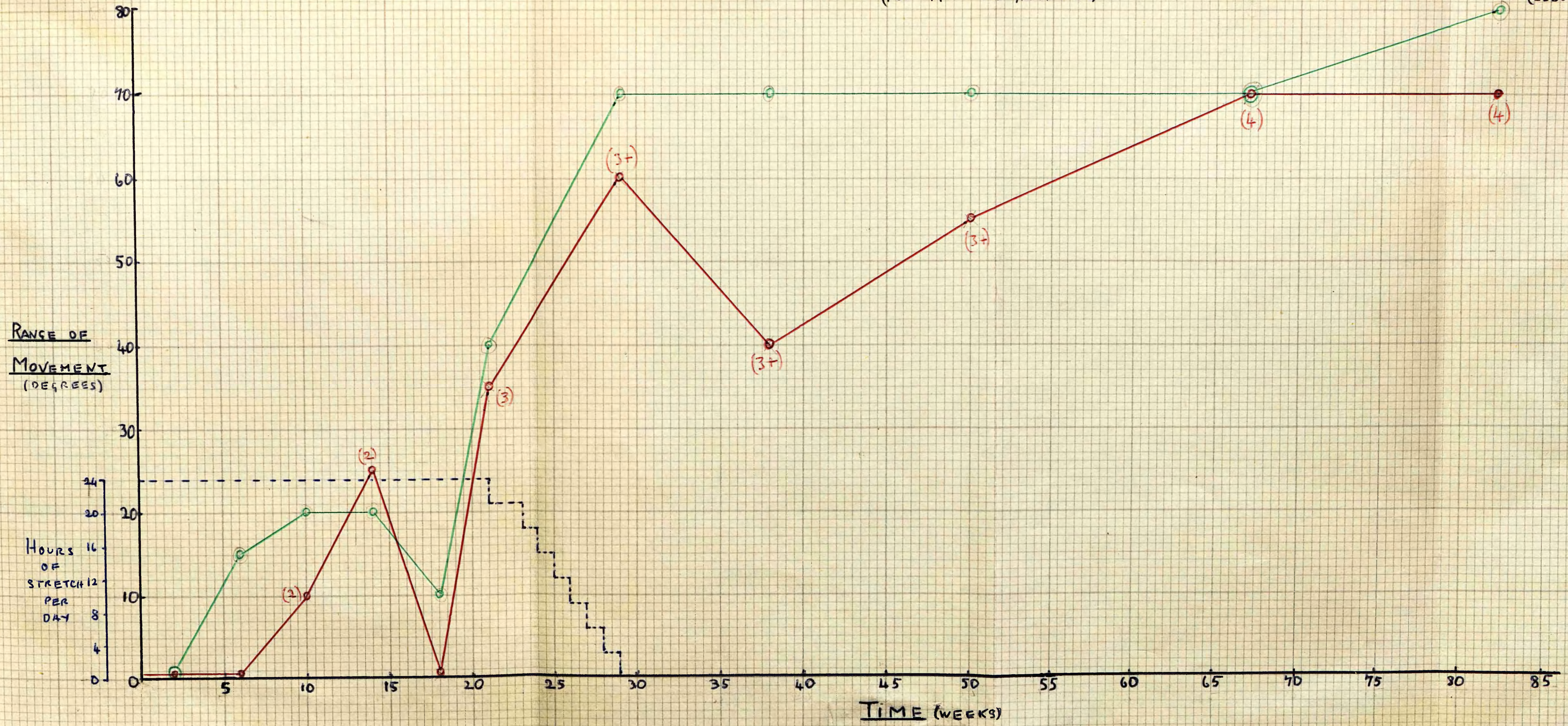
SUMMARY.

The elbow flexors were constantly stretched for five months and for diminishing daily periods over the next two months. Spasticity in these muscles was marked at first and responded slowly. An interesting thing about this case, which is not revealed by the graph, was the way in which spasticity was transferred from the flexor group to the extensor group as stretch of the former was continued. This happened in nearly all patients but was particularly clearly demonstrated in this case. The power of the flexors was however sufficient to overcome it so that almost full flexion from the extended position was always possible (3+).

It may be noted on examining the graph that release of flexor spasm and active extension movement were retained up to the time of writing though stretch of the flexors had been stopped for one year. This despite the fact that wrist and finger movement had not altered compared to the severe disability found at the "initial examination." It might be thought that it would therefore have been impossible to use the limb - with consequent loss of gain as happened with all [redacted] inactive patients. That this did not occur can I think be explained on the following grounds. When the gain in active extension of the elbow was established the patient became very keen indeed to maintain her progress. I explained to her that she must use the hand and arm as much as possible and this she contrived to do to a remarkable degree. She had a devoted husband and family and they helped her to get hold of domestic utensils such as brushes and mops and she would then do quite a lot of housework with consequent exercise of the elbow flexors and extensors.

GRAPH 6.
(FOR LEGEND SEE GRAPH NO. 1)

CASE NO 5.
(ELBOW)



CASE No. 6.

Age. 13 years.

Sex. Female.

Complaint. Residual hemiparesis of the right side. (Duration, seven months).

History.

She was admitted on the 16.5.55 complaining of pyrexia, headache, diarrhoea and rash of 3 - 4 days duration. She was found, on admission, to have severe diarrhoea, mild carditis and erythema multiforme. She was treated with antibiotics and made a full recovery, but during the convalescent stage she developed a right hemiplegia on the night of the 26.5.55. The hemiplegia was associated with hemi-anaesthesia, hemianopia, motor and sensory aphasia. The aetiology of this catastrophe remained obscure.

By the 24.9.55 considerable recovery had taken place. She could walk and climb stairs but she had little use in the hand. Her intelligence proved unimpaired. Understanding of spoken speech was normal but of the written word was still grossly impaired though improving. She could express herself adequately by speech or speech plus gesture.

I first saw her on the 6.10.55, but examination on that date was complicated by the fact that she had sustained a mild greenstick fracture of the right radius and ulna four days previously. The hand and forearm were in a Plaster slab. Movement of the upper limb could not therefore be assessed and movement of the lower limb only was examined.

Lower Limb.

Active Movement.

Hip. Flexion - full (4+). Extension - full (4+).
Abduction - 70° (4+). Adduction - 30° (4).
Rotation:- internal 50° (4), external 25° (4).

Knee. Flexion - 0° - 90° (4), 90° → full (4+).
Extension; full (5).

Ankle. Dorsiflexion 35° - 65° (4). Plantarflexion - full (5)
Inversion - 50° (3). Eversion - 0° (0).
Dorsiflexion was accompanied by inversion of the foot to some 50°.

There was only slight residual paresis of the facial muscles. Her speech was a little slurred and nasal but could be clearly understood. She expressed herself adequately though at times she had difficulty in finding the correct word.

The Plaster of Paris slab was removed on the 13.10.55., passive movements of wrist and fingers were given and active movement encouraged.

Other Forms of treatment employed prior to Splinting.

From the onset of her hemiplegia to the date on which she was fitted with a wrist and finger splint (22.12.55) she recieved treatment by physiotherapeutic methods six days per week. These methods consisted of passive movements of all the affected joints until active movement returned. She then received, in addition, instruction and practice in active movement. Half to three-quarters of an hour were thus occupied each day. After splinting the wrist and fingers, she continued with this treatment to all other affected joints.

A below knee iron was supplied on the 29.6.55, the purpose of which was to correct inversion of the foot and to assist dorsiflexion.

Speech therapy was commenced one week after the onset of the hemiplegia and continued for nine months.

Joints treated and type of appliance used.

A wrist and finger splint for use in cases of spastic paresis (type b) was used. This held the wrist extended to 50° and the fingers in line with the meta-carpals. (See photograph 2).

Joints observed as Controls.

The only joints at which the range of active movement was restricted were the wrist, fingers and ankle. Since a below knee iron was being used the latter joint could not be used as a control. Thus, as far as range of movement was concerned no control was used.

It may, however, be considered some evidence that improvement was due to splinting that the Physiotherapist treating the case, the Consultant in Paediatrics and the Medical Staff of his Unit were in agreement that no improvement in active extension of the wrist and fingers had occurred during the four weeks prior to the splint being applied. The ensuing rapid improvement in function of the wrist joint was also observed and agreed upon by these persons.

INITIAL EXAMINATION. 3.12.55.
UPPER LIMB.

Shoulder. Settled in adduction.
Active. Abduction - full (4). Flexion - full (4). Extension - full (4). Adduction - full (4). Rotation:- external - full (3+) internal - 50°(2).
Passive. There was no detectable increase in tonus except on internal rotation where there was slight resistance over the last 80° of the full arc.

Elbow. Settled at 15°.
Active. Flexion - full (4+). Extension - full (4).
Passive. Stretch Reflex comes in at 45° on both extension and flexion. Very slight increase in tonus, however.

Wrist. There was, by this date, no clinical or radiological evidence of any residual defect, following her greenstick fracture. Hand settled at 70° flexion with forearm and hand pronated, and at 0° when supinated.
Active. Flexion: 0°- 30°(2). Ext: 70°F. - 25°F. (3). Abduction and adduction:- 2°- 3°(2). Supination - pronation 100° arc (3).
Passive. 70°F. - 0°(A), 0°- 80°E.(B-C), 80°E. - 70°F. (A). There was slight tonus (B) during full pronation and supination. Abduction - adduction (B).

Fingers. Settled ½" - 1½" (5th - 2nd fingers) from proximal palmar crease with thumb flexed and opposed (see Photograph 1.).
Active. Extension - There was no flicker of active extension in fingers or thumb with the wrist joint extended to 30°; nor was there any active extension with the wrist joint flexed.
Flexion:- When the wrist joint was actively extended to its fullest extent, (25°F), the grip was slight. When the wrist was passively extended to 30°E. the grip was firm.
Adduction & Abduction - no active movement.
Passive. With the wrist held passively extended to 30° the inter-phalangeal joints could be fully extended (A) when the metacarpo-phalangeal joints were flexed to 90°. Holding the fingers thus, passive extension met with some tonus (B-C) through the 90° arc to full extension at the metacarpo-phalangeal joints. There was a similar degree of resistance (B-C) to passive extension of the thumb.

LOWER LIMB. (Only active movement was assessed)

HIP
Abduction - 70° (4). Flexion - full (4+).
Extension - full (4+). Adduction - 30° (4+).
Rotation:- internal 60° (4), external 25° (4).

KNEE
Flexion 0° - 90° (4), 90° - full (3+).
Extension, full flexion - full extension (4+).

ANKLE.
Dorsiflexion 35° - 65° (4), 65° - 75° (3+).
Plantar-flexion - full (5).
Inversion 50° (3+). Eversion 0° (0).
Dorsiflexion was accompanied by 45° inversion.

TOES. Flexion and extension movement was present.

FACE. - Only slight residual paresis was seen.

Reflexes.

All myotatic reflexes were exaggerated on the right side. The right plantar response was extensor. The abdominal scratch reflexes were absent on the right side.

Co-ordination.

This was very poor on the right side, especially in the upper limb.

Sensation.

This was moderately reduced to light touch and pin-prick, Muscle and joint sensation was also diminished a little; though it did seem too little reduced to account for the degree of inco-ordination found.

Speech.

Speech was still rather slurred and halting and I could not detect improvement compared with my last examination of her.

A wrist and finger splint was made on the 6.12.55 but was not fitted as an electromyographic examination at St. Thomas' Hospital had been arranged for the 19.12.55. The plan was to have this investigation made before splinting and to repeat it after the muscles had been stretched for a month or so.

ELECTROMYOGRAPHIC EXAMINATION. (19.12.55)

This was conducted by Dr. Philippe Bauwens, Physician in Charge of the Physical Medicine Department and the Electrodiagnostic Department of St. Thomas's Hospital, London.

The electromyograph used was a two channel instrument, with screen and loudspeaker. Surface electrodes, of the suction type, were employed.

Prior to testing the forearm muscle groups, the flexors in the upper arm were examined. There were no potentials in the resting muscles on the left side but there was a low continuous activity in those of the right side.

The flexor and extensor groups in the right forearm were then examined. The resting flexors showed a moderate amount of activity. No potentials were obtained from the resting extensors.

On slow, deliberate, passive extension of the right hand, a markedly increased activity was noted in the flexor group. The hand was maintained extended (to about 45°) and this activity was seen to fall quickly to a low level (lower than the original resting level) over some five seconds. This level remained unaltered during a period of observation lasting thirty seconds. The manoeuvre was repeated three times. On each occasion a similar chain of events was noted, but the flexor activity on passive stretch became progressively less, and fell more quickly, each time the hand was extended.

During this examination of the patient, another interesting feature was seen: prior to the passive extension movements described above, voluntary extension produced a barely perceptible activity in the extensors. Following them, there was a definite increase, potentials being seen and heard in appreciably greater numbers.

After the tests had been made the splint was fitted and the patient instructed to wear it constantly except for two five minute periods night and morning when the part was to be washed and powdered. (The splint was not quite finished in that a thumb extension strap had not yet been fitted.)

<u>SECOND WEEK</u>.

No pressure areas on the skin. Splint in good order. She had found it comfortable and had worn it as instructed.

<u>Wrist</u>.

<u>Passive</u>.	Ext:	70°F. - 30°E. (A). (Gain 30°).
		30°E. - 80°E. (B-C).
	Flex:	80°E. - 70°F. (A).
<u>Active</u>.	Ext:	70°E. - 20°E. (3) (Gain 45°).
	Flex:	0° - 15° (2).

<u>Fingers</u>.	Settling position ½" - 2" from palm.
<u>Passive</u>.	Carried out as at initial examination:- 90°flexion - 0° (A-B).
<u>Active</u>.	No active extension. Flexion and grip as before.

There was no change in active or passive movement of the thumb.

A thumb extension strap was added to the splint at this attendance, and she was instructed to wear the splint constantly. The patient quickly learned to put the splint on and to remove it without assistance - in the manner described when dealing with this type of splint (Page 38).

THIRD WEEK.

Skin clear. No oedema. Splint in good order. The thumb strap required adjustment to obtain full extension at the carpo-metacarpal, metacarpo-phalangeal and inter-phalangeal joints. This was done.

Wrist.

Passive.	Ext: 70°F. - 50°E. (A). (Gain 50°).
	50°E. - 90°E. (B).
	Flex: 90°E. - 70°F. (A).
Active.	Ext: 70°F. - 30°E. (3). (Gain 55°).
	Flex: 0° - 25°F. (2).

Fingers. Settled ½" - 2" from palm.

Active. Still no active extension in fingers or thumb. It was interesting to note that she could fully extend her fingers by pressing the back of her hand against a firm surface with the wrist fully flexed and the elbow extended. This could probably be explained as a mechanical stretch of the extensors - but it did give the impression of having an element of active extension.

Passive. No change.

To continue constant wear of the splint.

FIFTH WEEK.

Skin clear. No oedema. Splint in good condition. The thumb strap maintained the thumb fully extended. Wearing the splint constantly.

Wrist.

Passive.	Ext: 70°F. - 60°E. (A). (Gain 60°).
	60°E. - 80°E. (B).
	Flex: 80°E. - 70°F. (A).
Active.	70 F.° - 35°E. (3+). (Gain 60°). 0° - 35 F.° (2).

Fingers. Settled 1" - 3" from palm. Thumb in mid opposition.

Active. Still no active extension. Flexion - as before and grip firm.

Passive. There was still some resistance to extension (A-B). There was less decrease in tonus in the fingers than in the wrist.

SECOND ELECTROMYOGRAPHIC EXAMINATION.

She had worn the splint constantly for five weeks. Dr. Philippe Bauwens again conducted the examination.

The same electromyograph and electrodes, as were used on the 19.12.55, were again employed. The electrodes were attached over the flexor and extensor muscles in the forearm. The findings were as follows:-

(1) With the splint on (holding the wrist extended to 40° - 45°), there was a low level of spontaneous activity in the flexor group. There was no activity in the extensors. When the patient was instructed to flex her fingers and wrist, the flexor activity was much increased. On command to extend the wrist and fingers, there appeared, rather surprisingly, a few action potentials in the extensors.

(2) With the splint off
(a) there was very little activity in the resting flexors and none in the extensors.
(b) on the command to extend her wrist and fingers to the fullest possible extent, there was a quite marked activity in the extensors. (This was much more noticable than it had been at the previous examination.) There was no accompanying activity in the flexors.
(c) Passive extension of the hand to 45° (splint angle) produced no response in the flexor group, unless carried out rapidly. A rather low level of activity was then elicited. Passive extension past 40° produced a moderate response, even when the movement was slow.
(d) With the wrist firmly held, at 30°E., she was asked to extend her fingers. No activity in the finger extensors was noted on this attempt, nor was there any clinical evidence of finger extension.

__EIGHTH WEEK.__

Still wearing the splint constantly. Splint in good condition. Skin clear. No complaint of discomfort.

__Wrist.__

__Passive.__ Ext: 70°F. - 55°E. (A). (Gain 55°).
55°E. - 80°E. (B).
Flex: 80°E. - 60°F. (A).

__Active.__ Ext: 70°F. - 30°E. (3+). (Gain 55°).
Flex: 0° - 10°F. (2).

__Fingers.__ Settled 1" - 2" from palm. Thumb lying lightly against forefinger.

__Active.__ No active extension of fingers or thumb. Flexion as before.

__Passive.__ Taking, as before, the interphalangeal joint fully extended and the metacarpo-phalangeal joints flexed to 90° as the starting position (wrist 30° extension), there was normal resistance from 90° extension to 45° flexion. From that angle to full extension at the metacarpo-phalangeal joint there was B-C resistance.

The range of passive and active movement at the other joints remained the same as at the initial examination. Co-ordination remained poor. All forms of sensation were slightly reduced in the right limbs, especially in the hand and foot. The circumference of the right forearm, 3" below the tip of the olecranon process, was ½" less than that of the left forearm.

Instructed to leave the splint off 2 hours per day for the next two weeks and to make as much use of the hand as possible during these hours.

TENTH WEEK.

She had been leaving the splint off for 2 hours per day. Splint - some discoloration of the polyurethane lining, otherwise in good order. No skin abrasions. No oedema seen.

Wrist.

Passive.	Ext:	70°F. - 80°E. (A). (Gain 80°).
	Flex:	80°E. - 70°F. (A).
Active.	Ext:	70°F. - 40°E. (3+). (Gain 65°).
	Flex:	0° - 5° flexion (2).

Fingers.		Settled 1½" - 4" from palm.
Active.	Ext:	No active extension.
	Flex:	Grip firm for large objects but poor for smaller ones. The latter movement was executed slowly and seemed a little painful.
Passive.	Ext:	90° - 50° (A)., 50° - 0° (B-C).
	Flex:	Passive flexion at inter-phalangeal and metacarpo-phalangeal joints was restricted a little by pain and stiffness in these joints, but could be fully obtained by slow deliberate flexion.

There was no oedema of the hand or of the finger joints.

The fingers settled far enough from the palm to make her active wrist extension a useful movement. She could, for instance, dorsiflex her wrist and slip her fingers over a matchbox and pick it up. This sort of useful hand movement had previously been outside her scope, thus negating her good range at shoulder and elbow.

To leav e splint off for 4 hours per day.

TWELFTH WEEK.

Leaving splint off as directed - 4 hours per day. The skin was clear. Both hand and fingers showed slight oedema. Splint normal.

Wrist.

Passive.	Ext:	70°F. - 60°E. (A). (Gain 60°).
		60°E. - 80°E. (B).
	Flex:	80°E. - 70°F. (A).
Active.	Ext:	70°F. - 30°E. (3+) (Gain 55°). This movement was still performed rather slowly over the last 30°, but she could repeat it many times without fatigue.
	Flex:	0° - 15° flexion (2).

Fingers. Settled at 1" - 3" from palm with thumb lightly opposed.

Passive. Ext: $90° - 30°$ (A),
$30° - 0°$ (B).

Flexion of metacarpo-phalangeal and inter-phalangeal joints was still a little painful.

Active. $15° - 20°$ extension at I.P. and M.P. joints of all fingers, but no extension in thumb.

The grip was weak but useful even for two fingers, though the movement was rather slow and stiff.

Instructed to continue leaving off splint for 4 hours per day, and use hand as much as possible.

SEVENTEENTH WEEK. (24.4.56).

She had discarded the splint for 4 hours per day. Skin clear. Splint required no attention. There was still slight oèdema of hand and a just perceptible thickening of the metacarpo-phalangeal and interphalangeal joints. She was using her hand more and could do such things as hold a piece of bread with the right hand and butter it with the left. She could open doors with the right hand if the handle was of the lever type.

Wrist.

Passive. Ext: $70°$F. - $65°$E. (A). (Gain $65°$).
$65°$E. - $80°$E. (B).

Flex: $80°$E. - $60°$F. (A). Pain past $60°$ flexion.

Active. Ext: $60°$F. - $35°$E. (3+). (Gain $60°$).
This movement was rather quicker and she could repeat it at will.

Flex: No active flexion noted.

Fingers.

Passive. The degree of resistance to active extension had not materially altered since the last examination.

Active. Only $5° - 10°$ of active extension in fingers. Flexion as at last examination. The thumb could be flexed and opposed weakly. Only a few degrees of extension.

Examination of the C.N.S. revealed certain changes compared to the initial examination. The range of active flexion and abduction of the shoulder had decreased to $145°$. These were the only movements showing any change. Active and passive movement of the foot showed no change in spite of her hainv worn a below-knee iron. This appliance had however been left off for considerable periods of time owing to breakages.

Sensation had improved in that light touch was now equally well felt on both sides ecept in the fingers and toes of the right side where it was slightly reduced. Muscle and joint sense remained moderately reduced in the affected limbs.

She was instructed to leave off the splint one hour more per day, each week.

I did not, again, see this patient until the 15.11.56 (Week 46) when, by special arrangement I visited her at the residential school for cripples at which she was staying.

FORTY-SIXTH WEEK.

From the School Physiotherapiest in charge of this patient I learned that two weeks after I last saw her the splint was discarded altogether because of stiffness in, and pain on passive flexion, of the M.P. and I.P. joints. There had been only slight oedema visible. The patient herself had not complained of any discomfort. Since discarding the splint she had had no physiotherapy for her upper limb, attention having been concentrated on her walking. It had been noted that she used her right hand a good deal.

Examination.

UPPER LIMB.

Shoulder. There was a full active range (power 4) except for internal rotation which was somewhat limited and awkwardly performed (3). On passive movement no increased tonus was found.

Elbow.

Passive. On flexion and extension the stretch reflex came in at 45° but there was very slight increase in tonus from that point to full extent of both movements. It could not be detected unless the movement was rather quick - e.g. occupying half a second instead of the usual one second.

Active. Extension - full (4). Flexion - full (4).

Wrist.

Passive. Ext: 70°F. - 60°E. (A). (gain 60°).
60°E. - 85°E. (B).
Flex: 85°E. - 70°F. (A).

Active. Ext: 70°F. - 30°E. (3+) (Gain 55°).
This movement was performed quickly from 70° flexion to 0° and rather more slowly from 0° to 30° extension. She repeated it 20 times without evidence of fatigue.
Flex: 0° - 25° (2).
There was no active adduction or abduction.
Supination 110° (3+). Pronation 110° (3+).

Fingers. Settled 1" - 2½" from palm. After gripping tightly they relaxed quickly on command.

Active. Only 5° - 10° of active extension obtainable - no matter at what angle the wrist was held. Quite often attempts at active extension resulted in flexion of the fingers. The grip was firm with wrist actively extended to 30°. The thumb could be flexed and opposed (3) but there was only a flicker of extension. There was no voluntary abduction or adduction of the fingers.

Passive. With the M.P. joints flexed to 90° the I.P. joints could be fully extended (A). Holding them thus extended, passive extension at M.P. joints met with no resistance to 40°. From 40° - 0°(B-C). If the fingers were allowed to flex at the I.P. joints the M.P. joints could be fully extended without resistance (A). There was only slight resistance to full extension at both I.P. and M:P. joints of the thumb and no resistance to flexion.

LOWER LIMB.

This showed no measurable change from the findings at the initial examination. A below-knee iron was still required to obtain sufficient dorsiflexion of the foot for walking.

Light touch and muscle and joint sense remained slightly diminished on the right side, especially the hand and foot. No change from the last examination.

Co-ordination was poor in the upper limb and moderately diminished in the lower.

The myotatic reflexes were exaggerated on the right side, the right plantar reflex was extensor and the abdominal reflexes were absent on the right side.

SEVENTY-SIXTH WEEK.

By this time fifty seven weeks had elapsed since the appliance had been discarded. I obtained the history that she had been given diversional and occupational therapy to encourage use of her right hand during the five months prior to the present examination. She had been very co-operative in using the hand at every opportunity.

Examination.

There was no change in active or passive movement at the shoulder or elbow joints compared to the findings at the last examination. The wrist extensors were stronger and the joint could be extended to 40°. She repeated this movement forty times before tiring. During the last fifteen repetitions the range between 0° - 40°E. was obtained increasingly slowly.

Finger movement showed little change. Active extension was still limited to a few degrees. The grip was firm. Owing to the fact that the "settling position" of the fingers was 1½" - 3" (5th - 2nd) from the palm, when the wrist was actively held in 30° extension, she could make good use of the hand. She was able to pick up objects and to open doors. She could also use the hand to cut her food. Co-ordination, unfortunately, of the arm and hand, remained poor and function was thereby limited.

PHOTOGRAPHIC RECORD.

(1).

Taken before the splint was fitted, on the 19.12.55, shows the patient attempting to extend the wrist and to open her fingers.

(2) Shows the type (b) splint fitted on the 20.12.55.

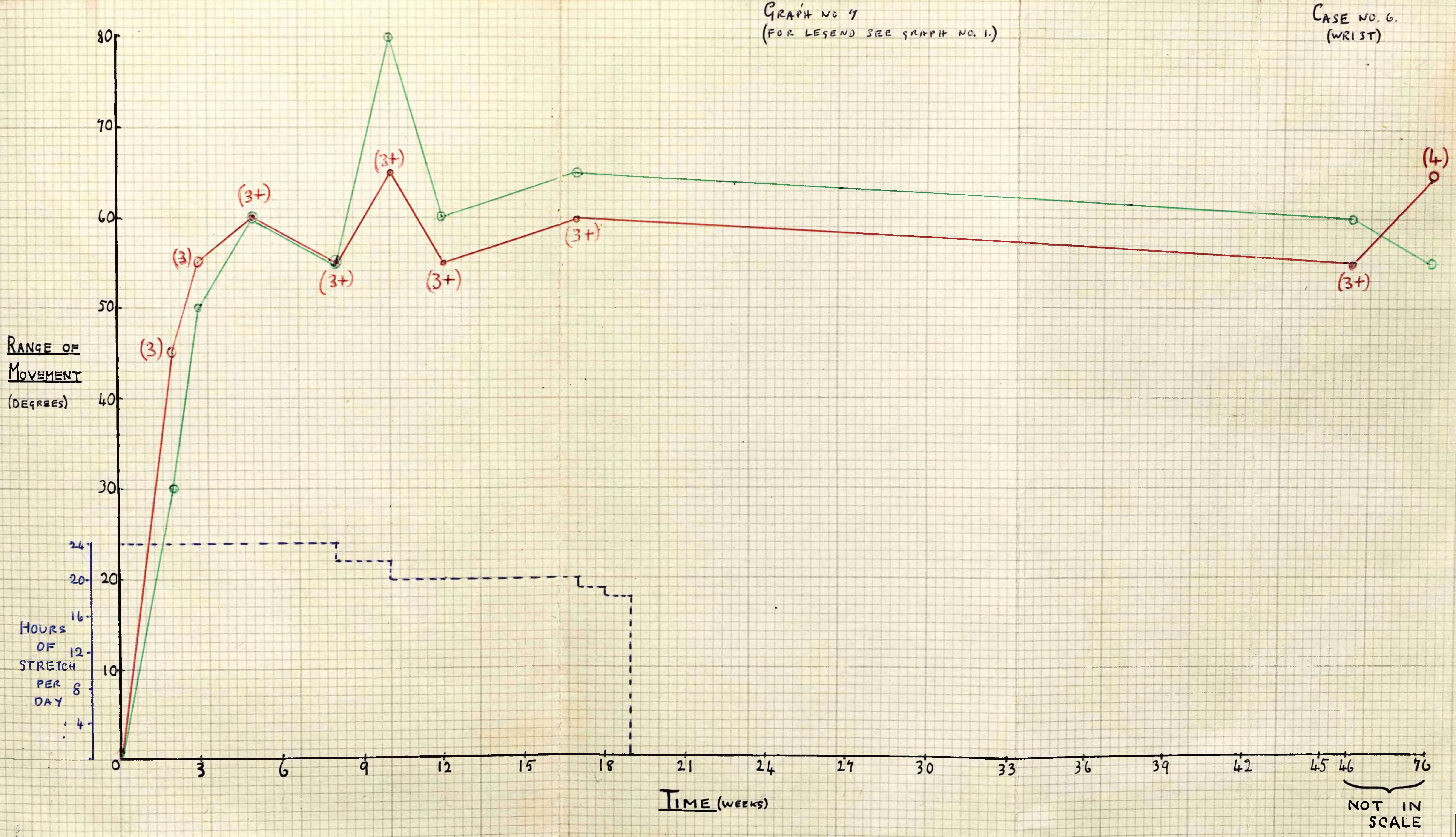
(3)

(4)

Shows her with the wrist in the "settling position."

Shows her actively extending the wrist and fingers.

These last two pictures (3 & 4) were taken on the 16.3.55 after three months treatment.



GRAPH NO 4
(FOR LEGEND SEE GRAPH NO. 1.)
CASE NO. 6.
(WRIST)
RANGE OF MOVEMENT
(DEGREES)
HOURS OF STRETCH PER DAY
80
70
60
50
40
30
20
10
0
24
20
16
12
8
4
(3)
(3)
(3+)
(3+)
(3+)
(3+)
(3+)
(3+)
(4)
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
46
76
TIME (WEEKS)
NOT IN SCALE

CASE No. 7.

Age.	72 years.
Sex.	Male.
Complaint.	Chronic residual hemiparesis of the left side. (Duration, one year and one month.)

History.

On the 3.11.54 he suddenly became paralysed on the left side. Consciousness was lost for only a few minutes. His speech was not affected.

He was admitted to hospital where a diagnosis of complete left hemiplegia was made. The aetiology was considered to be a cerebro-vascular accident.

He made a very slow and limited recovery but he never learned to walk without assistance.

Other forms of treatment employed prior to Splinting.

He was given physiotherapy and physical rehabilitation until five months prior to my first examination, at which time it was stopped as further improvement seemed unlikely.

Joints treated and type of appliance used.

Only the wrist joint was splinted - with a ventral type cock-up splint. This held the wrist extended to 20 .

Joints observed as controls.

The shoulder and elbow joints.

INITIAL EXAMINATION. 1.12.55.

Shoulder. Settled in full adduction.
Only 10° - 15° of any movement at the shoulder joint - either active or passive - except extension which had an active and passive range of 40°. The joint was severely contracted.

Elbow. Settled at 85°.
Active. Flexion. 85° - 110° (4).
Extension 110° - 85° (2+).
Passive. Flexion. 85° - full flexion (B).
Extension. Full flexion - 85° (B), 85° - 40° (C-D), contracture at 40°.

Wrist. Rested at 45° flexion when the forearm and hand were pronated, and at a similar angle when in mid-pronation - which was the furthest extent to which they could be passively supinated.

Active. Extension 0° (1). Flexion 45° - 55° (2).
No supination, pronation, abduction or adduction.

Passive. Extension. 45°F. - 35°F. (A), 35°F. - 30°E (D-E), contracture at 30°E.
Flexion. 30°E. - 55°F. (A).
Supination - from full pronation to mid-pronation.
Contracture at mid-pronation.
Pronation. Mid pronation - full pronation (A).
Abduction and adduction - only a few degrees were permitted (B).

Fingers. Tightly clenched in the palm.

Active. Extension. nil.
Flexion. Useful grip when the fingers pried open enough to slip two examining fingers into his palm.

Passive. Extension. To the level of contracture (40° at M.P. joints and 30° at I.P. joints) met with resistance (D).
Flexion. No resistance to full flexion.

Reflexes.

All myotatic reflexes were exaggerated on the hemiparetic side and the plantar response was extensor.

Sensation.

There was no loss of sensation.

ELECTROMYOGRAPHIC INVESTIGATION 19.12.55.

(Clinical examination of this date revealed no change from that on the 1.12.55).

A double channel electromyograph was used. Surface electrodes of the suction type were placed over the flexors and extensors in the forearm. The tests were conducted by Dr. Philippe Bauwens at St. Thomas's Hospital, London.

In the resting limb, moderate activity was present in the flexors and none in the extensors.

Passive stretching of the wrist flexors, obtained by dorsiflexing the hand without extending the fingers, resulted in a marked increase of potentials in these muscles. Stretch was maintained at full extension for 2½ minutes and over the first minute of this period of time flexor activity gradually diminished to a low level which remained constant during the following 1½ minutes. On release of the hand it quickly reverted to its usual position of 45° flexion, but the low level of activity in the flexors did not rise to its former level until some three minutes had passed. Attempts at active flexion of the wrist produced a just perceptible increase in the resting potentials of the forearm flexors. Attempts to actively extend the wrist produced no activity in the extensors.

The splint was fitted for the first time on the 20.12.55 and the Nursing Staff in charge of the patient were instructed to remove it only for a few minutes per day while the part was washed.

SECOND WEEK.

Skin clear. No oedema. He had found the appliance comfortable.

Wrist.

Passive.	Ext:	45°F. - 0° (A)	(Gain 35°).
		0° - 30°E. (D-E)	
	Flex:	30°E. - 55°F. (A).	
Active.	Ext:	45°F. - 10°F. (3).	(Gain 35°).
	Flex:	45°F. - 55°F. (2).	

To continue wearing the splint constantly.

FOURTH WEEK.

Skin clear. No oedema. No complaints. Splint in good condition. Control groups showed no change.

Wrist.

Passive.	Ext:	45°F. - 20°E. (A)	(Gain 55°).
		20°E. - 35°E. (C-D).	
	Flex:	35°E. - 55°F. (A).	
Active.	Ext:	45°F. - 20°E. (3+)	(Gain 65°)
	Flex:	45°F. - 55°F. (2).	

FIFTH WEEK.

Clinical examination revealed no change from the findings on examination at Week 4.

SECOND ELECTROMYOGRAPHIC EXAMINATION.

Dr. Philippe Bauwens again conducted the examination.

The same electromyograph and electrodes were again used. The latter were attached to the skin overlying the flexor and extensor muscle groups in the forearm. The findings were as follows:-

(1) Low level of activity in the resting flexors - much less than at the previous examination. No activity in the resting extensors.
(2) Voluntary extension of the wrist produced a marked activity on the extensor band, and a slight activity on the flexor band at the extreme of active extension range.
(3) Passive extension of the wrist to splint level produced no flexor activity. Past splint level a synchronous burst of potentials appeared.

The findings of such definite activity on voluntary extension was considered, by observers present, to be remarkable - in view of the complete absence of such activity at the previous examination.

SEVENTH WEEK.

Skin clear. No oedema. Splint in good condition. Still wearing the splint constantly.

On examination there was no change from Week 4.

To begin leaving splint off or 1 hour more per day each successive week.

TENTH WEEK.

Skin clear. No oedema. He had been leaving the splint off for 3 hours per day. He still found it comfortable. The polyurethane lining of the splint was rather soiled with perspiration and required washing.

Wrist. Now settled at 30° flexion in pronated position.

Passive. Ext: 30°F. - 20°E. (A). (Gain 55°).
20°E. - 35°E. (C-D).
Flex: 35°E. - 30°F. (A). Pain on passive flexion past 30°F.

Active. Ext: 30°F. - 25°E. (3+). He repeated this movement 20 times before fatiguing. After a two minute rest he again repeated this performance.
Flex: No active flexion from resting position of 30° with hand in mid-pronation.

Instructed to leave splint off 2 hours more per day during each successive week.

SIXTEENTH WEEK.

He was by then wearing the splint only at night. Skin clear. No oedema. No complaints. Splint showed no deterioration but lining again required washing.

Wrist. Rested at 45° in pronated position.

Passive. Ext: 45°F. - 25°E. (A), 25°E. - 35°E. (C-D).
Flex: 35°E. - 45°F. (A). Pain past 45°F.

Active. Ext: 45°F. - 20°E. (3+). He repeated this 20 times without fatiguing.
Flex: No active flexion from 45°F.

The control joints showed no change in the range of active or passive movement to that found at the initial examination. The splint was removed and taken away. No further splinting was advised. The patient had so little movement in shoulder, elbow or fingers, and was so poor mentally, that the gain in wrist movement did not help him to make use of his hand

FIFTY-FOURTH WEEK. (16.2.57)

The patient had not worn his appliance for nine months. He had received no treatment of any kind for his limb during that time. From the Nursing Staff I obtained the history that he had made no attempt to use his hand since the appliance had been removed.

Elbow.		Settled at 90°.
	Active.	Flex: 90° - 100°(3). Ext: nil.
	Passive.	Flex: 90° - full flexion (A). Ext: full flexion - 95°(A), 95° - 40° (C).
Wrist.		Settled at 50° flexion when pronated or in mid-pronation. Passive supination past the latter position was prevented by contracture.
	Active.	Ext: 50°F. - 40°F. (3). Flex: 40°F. - 50°F. (3). No other active movement.
	Passive.	Ext: 50°F. - 40°F. (A), 40°F. - 30°E. (C). Flex: 30°E. - 50°F. (A). Other movements - no change since initial examination.
Fingers.		Settled touching the palm except for forefinger (1" from palm). Thumb flexed and opposed.
	Active	Ext: nil. Flex: 5° - 10°(3). Grip weak.
	Passive.	Extension to contractural angles met with slight to moderate resistance (B-C). Contracture at 40 flexion, both M.P. and I.P. joints.

These findings were interesting, showing as they did that the gain in range of normal tonus and in voluntary movement, obtained by seven weeks constant stretch followed by nine weeks of stretch for diminishing periods during the day, had been completely lost after nine months freedom from stretch. It may be significant that he had not made any use of his gain in movement during that time.

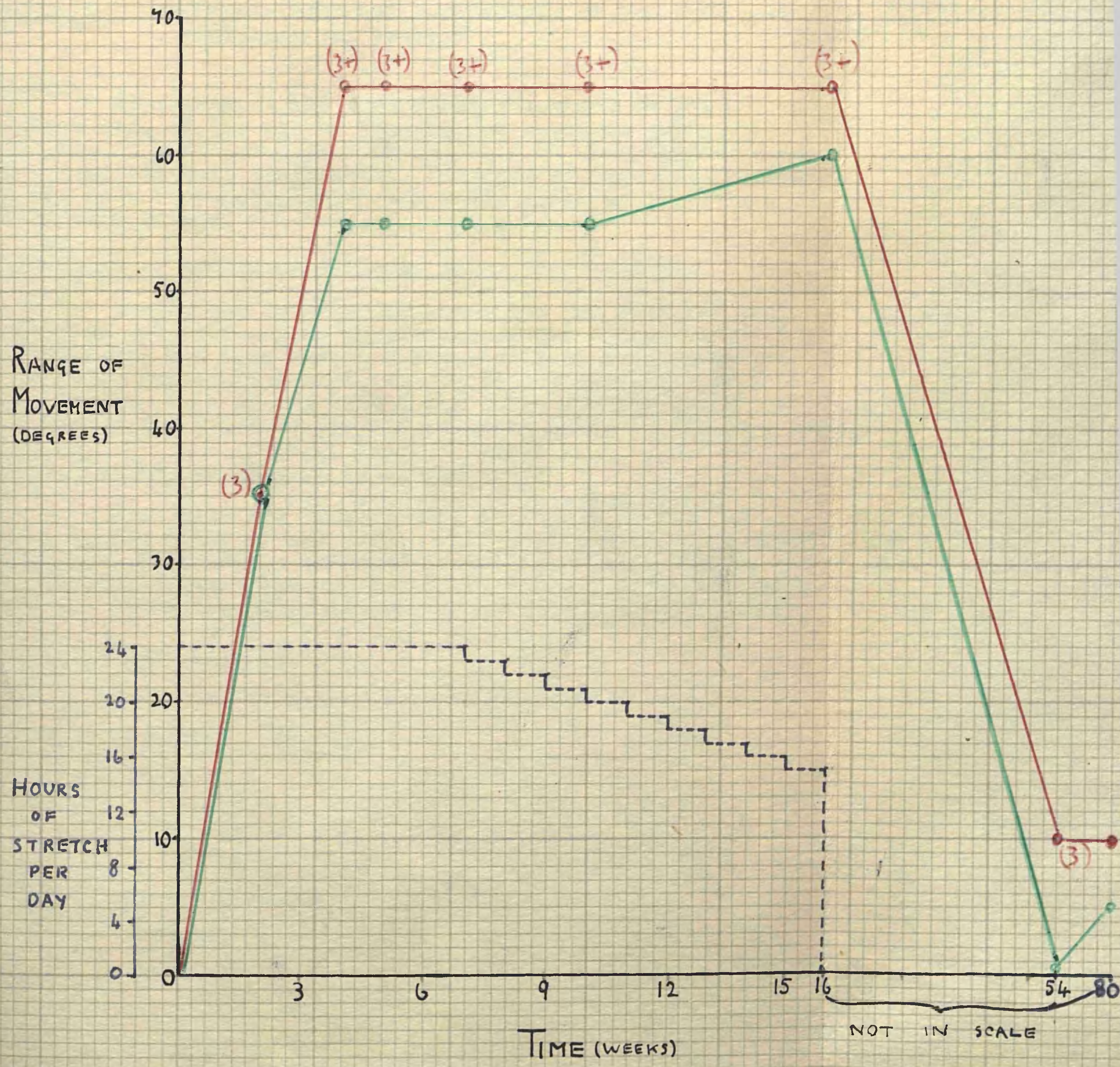
EIGHTIETH WEEK.

At this examination there was little change in the findings. He could still extend the wrist some 10° and there was about 15° of normal tonus on passive extension.

GRAPH NO 8.
(FOR LEGEND SEE GRAPH NO. 1)

CASE NO 4
(WRIST)

(Between P.P. 137-138)



CASE NO. 8.

Age. 62 years.

Sex. Female.

Complaint. Chronic residual hemiparesis of the left side. (Duration six years.)

History.

Hypertension had been first diagnosed at the age of 51 years and, at the age of 55, she had a sudden collapse with loss of consciousness. On recovery of consciousness she had a complete left hemiplegia. The date of this catastrophe was the 11th November, 1949 - six years prior to my first examination of her.

Other forms of treatment employed prior to Splinting.

During the intervening years she had received long courses of rehabilitation, physiotherapy and occupational therapy. She had been having occupational therapy at the Whittington Hospital, London, mainly basket weaving, for three months prior to the time I saw her. No improvement in movement of the wrist or fingers had been noted during that time

Joints treated and type of appliance used.

The wrist and fingers were treated. A wrist and finger splint (type b) was used. This held the wrist extended to 20° with the fingers extended to the range permitted by their contractures. The appliance was fitted on the 19.12.55, after the first electromyographic examination had been made.

Joints observed as Controls.

The shoulder and elbow joints.

INITIAL EXAMINATION. 19.12.55.

Left Upper Limb.

Shoulder. Settled in adduction.
- **Active.** Abduction - 85° (3+). Flexion 40° (4)
  Adduction - full. Extension 40° (4)
  Rotation - ext. 40° (3), int. 40° (4).
- **Passive.** Abduction to 90° (A), 90° - 110° (C-D).
  Flexion to 50° (A), 50° - 100° (C-D).
  Extension to 40° (A), 40° - 60° (C).
  External rotation to 45° (A), 45° - 90° (C-D).
  Internal rotation from 90° - 0° (A).

Elbow. Settled at 60°.
- **Active.** Flexion 60° - 135° (4)
  Extension 135° - 75° (3+).

Passive. Extension:- 135° - 70° (A), 70° - 20° (C-D).
Flexion:- 20° - 70° (A), 70° - 135°(B).

Wrist. Settled at 35° flexion with forearm and hand pronated, and at 20° flexion with hand supinated.

Active. Ext: 35° F. - 20°F. (3)
Flex: 20°F. - 35°F. (3+).
Abduction and adduction - nil.
Supination:- nil from the fully pronated position in which the hand habitually lay.

Passive. Ext:- 35°F. - 20°F. (A), 20°F. - 30°E. (C-D).
Flex:- 30°E. - 35°F. (A), 35°F. - 50°F. (C).
Abduction and adduction - contracted beyond some 10°.
Supination from full pronation to 90° (C).
Contracture at that point. No resistance (A) to full pronation.

Fingers. With the wrist held passively at 30°E. the fingers flexed firmly into the palm and the thumb was flexed beneath the forefinger.

Active. No flicker of active extension of fingers or thumb. Grip quite firm with wrist extended. With wrist flexed to its habitual position of 35°F. the grip was less firm but was still useful.

Passive. There was marked spasticity at both M.P. and I.P. joints during passive extension. Contractures at 25°F, M.P. and I.P. joints.
No resistance to full flexion from this extended position.

Left Lower LIMB.

No examined in detail. She could walk with a below knee iron and toe spring, using one stick. She had a spastic circumducting gait.

Reflexes.

All myotatic reflexes were exaggerated on the left side, and the left Babinski test was positive.

Co-ordination.

This could not be adequately assessed because of the small range of active movement. Within this range, however, it was good.

Sensation.

All forms of sensibility were slightly diminished in both upper and low limbs.

ELECTROMYOGRAPHIC EXAMINATION (19.12.55).

This was conducted by Dr. P. Bauwens, Consultant in Charge of Physical Medicine and Electrodiagnosis at St. Thomas' Hospital, London.

Two pairs of surface electrodes (suction type) were used. The electromyograph was a two channel type, demonstrating potentials on a screen and by loud speaker. By utilising both channels the activity in the flexor and extensor groups of muscles could be demonstrated simultaneously on the screen, the upper channel showing potentials in the flexor group and the low channel showing those of the extensor group.

Prior to examining the forearm muscle groups, the electrodes were placed over the flexor and extensor groups in the upper arm. Quite a high level of spontaneous activity was observed in both, and when voluntary extension was initiated against resistance there was an increase in activity in the flexors equal to that in the extensor group.

When the forearm flexor and extensor groups were examined it was found that there was a high level of continuous activity in the "resting" flexors and a much lower level in the extensors. On passive extension of wrist and fingers, activity greatly increased in the flexors. On maintaining extension at maximum range it was found that activity in the flexors slowly decreased to a low level - over a period of two minutes and remained steady at this low level during a further one minute period of observation. On release of passive extension activity slowly increased to its original level.

When, on command, the patient attempted to voluntarily extend her wrist there was a just perceptiable increase in the activity of the extensors. After the above passive movement had been carried out the patient was again requested to extend the wrist but no increase, compared to the original findings, was noted.

The splint was put on immediately following electromyography and the patient instructed to wear it constantly except when washing the part.

__4th. WEEK.__

She had worn the splint constantly except for five days. These five days were lost owing to collection of offensive perspiration in the lining of the splint which required washing on two occasions. These two washings occupied five days. The lining of the splint was removed in the Department and a new lining glued into place. There was a small amount of oedema on the dorsum of the hand and in the fingers. The skin was clear.

__Examination.__

The splint held the wrist in 20° extension and the fingers extended to 30° flexion at the M.P. and I.P. joints.

__Wrist.__		Settled at 30° flexion.
	__Passive.__	Ext: 30° F. - 5° E. (A). (Gain 25°).,
		5° F. - 30° E. (C-D).
		Flex: & other movements - no change.
	__Active.__	Ext: 30° F. - 5° F (3) (Gain 15°).
		Flex: 5° F. - 35° F. (3+).
		Other movements - no change.
__Fingers.__		Settled at 1" - 2" (5th - 2nd) from palm.
		Thumb opposed, (lightly).

Passive. Ext: Slight to moderate resistance only (B-C).
Active. Ext: Flicker of extension in forefinger.

5th WEEK.

Splint in good order. Skin clear. Slight to moderate oedema of dorsum of hand and of fingers.

Second Electromyographic Examination (25.1.56)

Dr. P. Bauwens again conducted the examination.

The same electromyograph and electrodes were employed. The electrodes were fixed of the flexor and extensor muscle groups in the forearm. The findings were as follows:-

With the splint off:-

(1) There was a marked reduction of spontaneous activity in the resting flexors - less than half the previous amount.

(2) The low level of activity in the resting extensors, found at the first examination, showed no change. On active extension of the hand a moderate number of action potentials were seen and heard - a definite increase compared to the original findings.

(3) Passive extension of the fingers and hand produced only a barely perceptible activity in the flexors up to (about) the angle at which the hand and fingers had been held by the splint. Further extension to the contractural limit produced a burst of potentials.

6th WEEK.

Splint in good condition. Skin clear. The oedema had increased and was moderate in degree. She had been wearing the splint constantly. A collar and cuff sling was provided and the patient instructed to keep the hend elevated in the sling.

Wrist. Settled at 30°F.

Passive Ext: 30°F. - 10°E (A) (Gain 30°),
10°E. - 30°E. (C-D).
Flex: 30°E. - 40°F. (A).
Other movements - no change.

Active. 30°F. - 5°F. (3) (Gain 15°), 5°F. - 20°F. (3).
Other movements - no change.

Fingers. No change from Week 4.

Patient instructed to leave splint off for 2 hours each day and during that time to carry out active and passive movement.

7th WEEK.

No change, except that the oedema is a little less.

To leave splint off for 3 hours each day.

8th WEEK.

Oedema still present and there was a line of pressure, but no skin abrasion, in the skin of the dorsum of the hand and wrist where an edge of the splint was pressing on the oedematous part. The lining was rather soiled. A new ventral type splint (type a) was made and fitted. It held the wrist at 25° extension and the fingers extended as far as was possible.

Wrist. No change except for a slight gain in active wrist extension, 30°F. - 0° (Gain 20°), and also in passive extension, 30°F. - 15°E. (A), (Gain 35°).

Fingers. Settled 1" - 3" (5th - 2nd) from palm. Thumb lightly opposed to the forefinger.

Passive. Slight resistance to full extension to contractural level.

Active. The forefinger extended 10° - 15°. No movement in the other fingers or thumb.

To leave splint off 4 hours per day.

9th WEEK.

The new splint was satisfactory and there was no pressure area. The oedema was only slight to moderate.

Examination. No change.

To continue leaving splint off for 4 hours per day.

11th WEEK.

There was still slight oedema of the hand and fingers. Skin was clear. Splint in good condition.

Wrist. Settled at 30°F. in pronated position.

Passive. Ext: 30°F. - 20°E. (A). (Gain 40°).
20°E. - 30°E. (C-D).
Flex: 30°E. - 55°F. (A).

Active. Ext: 30° - F. - 10°E. (3) (Gain 30°).
Flex: 0° - 30°F. (3+).

Fingers. No change in active or passive movement since Week 8.

Patient advised to leave splint off 6 hours per day.

12th WEEK.

Slight oedema persisted. Skin clear.

Examination. No appreciable change in active movement but passive range was 10° less.

To continue with 6 hours freedom from the splint, per day.

13th WEEK.

Slight oedema persisted in spite of maintaining the hand elevated in the sling.

Wrist. Settled at 30°F.

Passive. Ext: 30°F. - 10°E (A). (Gain 30°),
10°E. - 30°E. (B-C).
Flex: 30°E. - 30°F. (A). Pain past 30°F.

Active. Ext: 30°F. - 5°E (3+). (Gain 25°).
No active flexion.

Fingers.
Passive. There was almost normal tonus to full extension and the contractures seemed to have stretched - so that both the I.P. and M.P. joints extended to 15° flexion.
Passive flexion met normal tonus and was painless
Active. All fingers and the thumb extended 10° - 15°.
Grip was firm - no change from initial examination.

To continue leaving splint off for 6 hours per day.

15th WEEK.

There was a just perceptible oedema of the hand and fingers. Skin clear. Splint in good condition.
Examination - no change from Week 13.

To leave splint off one hour longer each week for two weeks and two hours longer for the succeeding two weeks.

19th WEEK.

At this time the patient was leaving her splint off for 12 hours per day.

Wrist. Settled at 30° F.
Passive. Ext: 30° F. - 15° E. (A). (Gain 35°),
15° E. - 30° E. (B-C).
Flex: 30° E. - 50° F. (A).
Active. Ext: 30° F. - 5° E. (3+) (Gain 25°). She seemed able to repeat this movement at will, without fatigue, but it was performed rather laboriously.
Flex: 5° E. - 10° F. (3+).

Fingers. Settled $1\frac{1}{2}$" - $3\frac{1}{2}$" from palm, (5th - 2nd).
Passive. Normal tonus to passive movement from full flexion to 20° F. at M.P. and I.P. joints, and back to full flexion.
Active. Only 5° - 10° active extension usually but once or twice she extended them 30° - 40° at both I.P. and M.P. joints from their settling position.

There was no constant change noted in movement at elbow or shoulder throughout the period of observation.

She was instructed to continue with progressive freedom from the splint - two hours per day longer each week, until it was being worn only at night. She was then to discard it.

31st. WEEK.

She gave the history that she had followed my instructions and had therefore not worn the appliance for ten weeks.
Occupational therapy had been continued thrice weekly and she had used her hand as much as possible. There was no oedema of the hand and all passive movements were pain-free.

Wrist. Settled at 40° flexion.
Active. Ext: 40° F. - 10° E. (3+). (Gain 30°).
Flex: 10° E - 40° F. (3+).

Passive. Ext: 40°F. - 10°E. (A) (Gain 30°)
10°E. - 30°E. (C).
Flex: 30°E. - 30°F. (A), 30°F. - 50°F. (C).

Fingers. Settled touching the palm with the thumb lightly opposed to the forefinger.
Active. Only a few degrees of active extension in fingers and thumb.
Passive. Some resistance (B-C) on extension to contractural level.

There was no change in the movements obtainable at the control joints.

55th WEEK.

A month after I last saw her occupational therapy had been stopped, and she had not made much use of her hand since that time. The main limiting factor had been the small range of movement possible at the shoulder and elbow.

Wrist. Settled at 40° Flexion.
Active. Ext: 40°F. - 5°F. (3+) (Gain 15°). She could only repeat this half a dozen times before tiring.
Flex: 5°F. - 40°F. (3+).
Passive. 40°F. - 0° (A), 0° - 30°E. (C). (Gain 20°).

Fingers. Settled touching the palm with the thumb lightly opposed to the forefinger.
Active. No active extension. Grip firm.
Passive. Moderate to marked spasticity on passive extension.

She was instructed to use her hand as much as possible.

75th WEEK.

She gave the history that she had been unable to do anything useful with her hand since I last saw her and she had therefore given up trying to use it.

Wrist. Settled at 40°F.
The range of active and passive movement had diminished to that found at the initial examination.

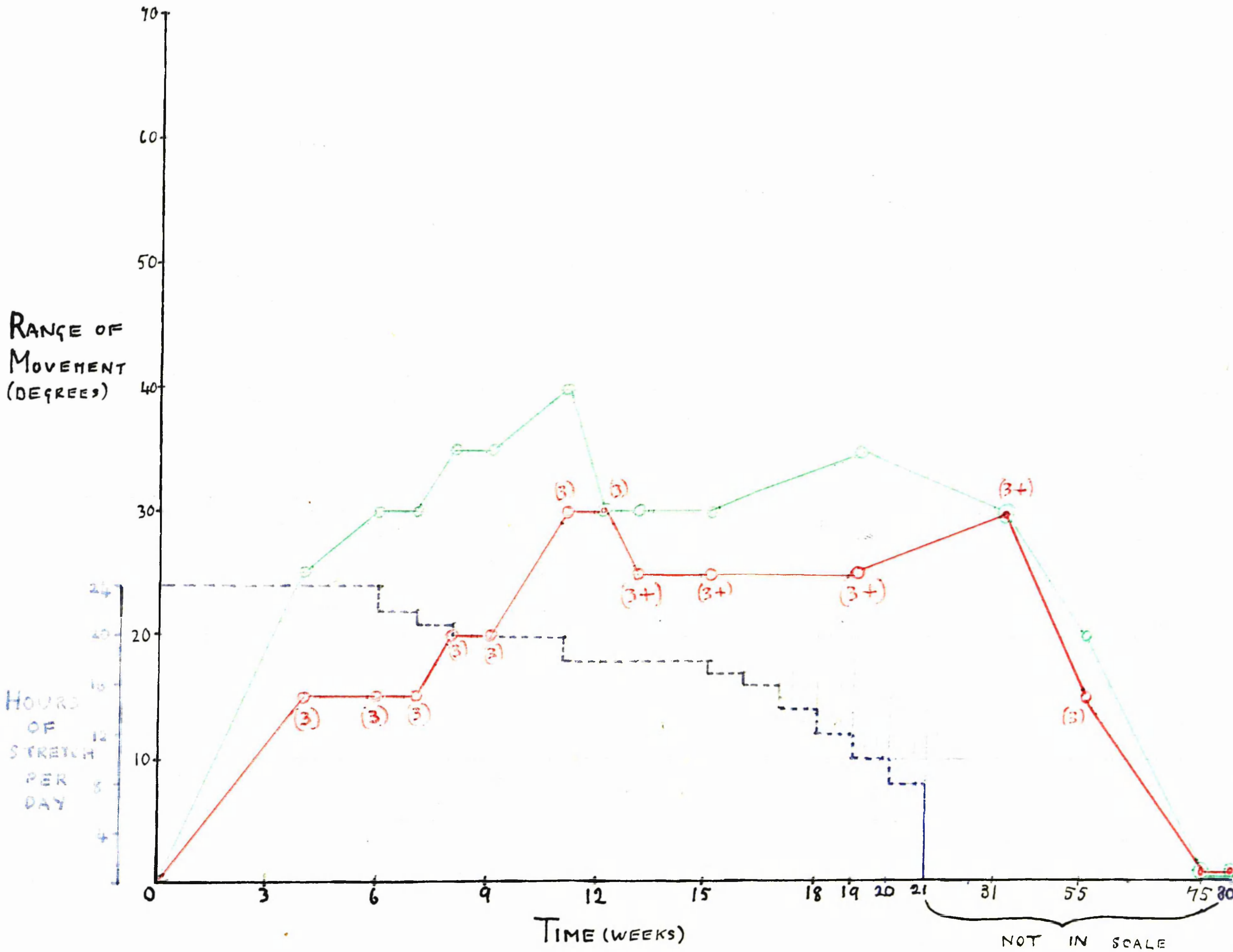
Fingers. Settled clenched in the palm with the thumb tightly opposed. Active and passive movement was similar to the findings recorded at the initial examination.

EIGHTIETH WEEK.

No change compared to the findings recorded at her previous examination.

Graph No. 9
(For legend see graph No. 1)

Case No. 8
(Wrist)



CASE NO. 9.

Age. 51 years.

Sex. Female.

Complaint. Residual hemiplegia of the right side. (Duration one year.)

History.

At the age of 26 years she had been diagnosed as suffering from mitral stenosis.. From then until the age of 50 years she had had no marked disability from this condition except a certain amount of dyspnoea on exertion and some swelling of the ankles, - and this only for the previous 4 - 5 years.

On the 17.10.54, at the age of 50 years, she was admitted to hospital following a sudden onset of right sided paralysis and loss of speech on the 13.10.54. Consciousness was not lost. On admission she presented the signs of mitral stenosis, auricular fibrillation, congestive cardiac failure and right sided hemiplegia. The last named was attributed to embolism from the left heart.

Movement of the right lower limb improved slowly until by the 9.12.54 she was able to walk, her foot dorsiflexed with a B.K. iron, and with the support from one assistant. The right hip and knee were spastic in extension and the foot held in plantar flexion. There was no recovery of movement in the upper limb. She was discharged home on the 24.12.54.

Seen in the O.P.D. on the 18.4.55 she was walking rather better but there was no improvement in the arm or hand.

By the 18.8.55 she was walking with only the support of one stick. The right upper limb remained almost completely paralysed.

Other forms of treatment employed prior to Splinting.

From the date of admission to hospital until the time when I first saw her she had received regular hemiplegic rehabilitation from the Physiotherapy Staff; both as an In-Patient and as an Out-Patient. Her walking had improved with this regime but there had been no improvement at all in her arm and hand.

Joints treated and type of appliance used.

A ventral cock-up wrist splint was fitted one year after the onset of her hemiplegia. This was followed four months later by a wrist and finger splint (type A).

Joints observed as Controls.

The elbow and shoulder joints.

Initial Examination. 18.10.55.

Right Upper Limb.

Shoulder.		Settled in adduction.
	Active.	Abduction and flexion 15° (3). Extension 20° (3+). Adduction - full (3+). Rotation - nil.
	Passive.	Outside of the ranges shown above there was marked resistance (D) to all movements. There appeared to be a contracture at 50° abduction.
Elbow.		Settled at 90°.
	Active.	Flex: 90° - 110° (3). Ext: nil.
	Passive.	Flex: 90° - 110° (A), 110° - full flexion (B). Pain on full flexion. Ext: full flexion - 90° (A), 90° - 15° (D).
Wrist.		Settled at 35° flexion in mid pronation.
	Active.	No active movement apart from a 45° arc of supination and pronation.
	Passive.	Ext: 35° F. - 30° E. (D). Flex: 30° E. -35° F (A). All other movement met with moderate to marked resistance.
Fingers.		Settled tightly clenched into the palm with the thumb strongly opposed and flexed.
	Active.	Slight voluntary grip. No other active movement.
	Passive.	Intense spasticity (E) on active extension.

Right Lower Limb. (Only the knee and ankle were examined and these not in detail).

Knee. Settled at 30° when standing.
Sitting, with hip and knee joints flexed to 90°, she could actively extend the knee to 25°. The movement was slow and spastic. From this position she could actively flex

the knee to 100°. This movement was even more slow and spastic, though gravity was assisting it.

Ankle. Settled at 50°.
No active dorsiflexion. If passively dorsiflexed to 80° she could actively plantar flex to 45° (3+).

Reflexes.

All myotatic reflexes were exaggerated on the right side. The Babinski test was positive. The right abdominal reflexes were abset.

Sensation.

All forms of sensation appeared to be reduced on the right side thought to what degree was difficult to ascertain owing to the low level of cerebration shown by this patient.

Mental State

Slow cerebration. Depressed and over-emotional. Pleasant personality. She was grateful for the interest taken in her and promised full co-operation in any method designed to improve her condition. Her speech was slurred but intelligible and she could express herself adequately.

28.10.55.

A cock-up wrist splint was made and fitted which held the wrist in 15° extension. A previous attempt to make a wrist and finger splint (type A) had failed owing to the extreme spasticity of the fingers. When the wrist was held extended to 20° it was impossible to extend the fingers sufficiently to make it worth while including them. It was hoped that, later, when the spasm of the wrist flexors was abated a type (a) splint could be made.

Progress Examinations.

Examinations were conducted at weeks 1, 2, 3, 4, 5, 7, 12, 13, 16, 18, 20, 22, 24, 26, 75, 87. The details of the changes in range of active and passive movemant of the wrist joint found at these times have been condensed in graph form, (see end of the Case).

By week 16, spasticity of the wrist flexors had abated to such an extent that it was necessary to force only the fingers into extension while a wrist and finger splint was made, and this was successfully carried out. From that week onward she discarded her old splint and wore the wrist and finger appliance (type a). This new splint held the wrist in 20° extension, the M.P. joints fully extended, the proximal I.P. joints in 30° flexion and the distal I.P. joints in 20° flexion.

FINGERS.

The progress of finger movement following application of this splint can be given briefly as follows:- after two weeks there was a very marked release of spasm in the finger flexors. Thirty minutes after removal of the splint the fingers had settled in a relaxed position $\frac{3}{4}$" - 2" (5th - 2nd) from the proximal palmar crease and the thumb lightly opposed. Full passive flexion of the I.P. joints was free, but passive flexion of the M.P. joints, past 45°, caused pain. Extension of the I.P. joints to the angle at which they were held in the splint was free (A), but from there until full extension moderate resistance (C) was encountered. Full extension at the M.P. joints met with normal tone (A). She could grip three (examining) fingers with slight pressure (3+), and could release them on command, but only a few degrees of active extension was noted.

From this date (week 18) onwards, she left off the splint for progressively longer periods (see graph). The release of flexion spasm of the fingers remained abated to the degree described above and showed no sign of returning. Active extension, however, remained at best a matter of 5° - 10° and showed no tendency to improve beyond this range.

The "stiffness" and pain noted on passive flexion increased up to the 18th week, and thereafter decreased until it was only mild at the 26th week.

SPLINT.

At week 16, when the original wrist splint was replaced, it was unchanged from its condition when made except thatthe lining had absorbed a considerable amount of perspiration and required washing. By the time of the last examination (week 26) the second splint was in perfect order and was clean and wholesome, having been washed at weekly intervals as directed. The patient, at no time, complained of discomfort from the splints.

SKIN & JOINTS.

Examination at week 2 revealed a very slight oedema of the dorsum of the hand. She was given a collar and cuff sling in which to elevate her hand and forearm during the day, and instructed to elevate her arm on a pillow at night. She was also told to passively, and if possible, actively move her wrist and fingers each time the appliance was removed for washing (or for free periods later in the course of treatment.) Under this regimen the odema remained just perceptible until week 22 when it disappeared entirely.

The M.P. joints, after the first two weeks wear of the wrist and finger splint, became "stiff" and painful on full passive flexion, as already noted. This was probably due to their being held rather too fully extended by the splint.

The wrist joint and the I.P. joints showed little tendency towards stiffness.

CONTROL JOINTS.

No constant change was noted in either active or passive movement at these joints throughout the period of treatment and observation.

SEVENTY-FIFTH WEEK.

I did not see this patient again until eleven months later. By that time she had not worn any appliance for just over one year. The history was obtained from the patient, and her family, that she had made little or no use of the hand since the appliance was removed. This was attributed to the poor movement at the shoulder and elbow joints. She had had no occupational therapy during the above period.

Shoulder. Settled in adduction, internally rotated.
Active. Abduction 10°. Flexion 0°.
Extension 25°.
Rotation: internal 15°, external 0°.
Passive. Abduction 50° (A). Flexion 20° (B).
Extension 30° (A).
Rotation: internal 80° (A), external 80° (C).

Elbow. Settled at 75°.
Active. Flex: 75° - 100° (3). Ext: nil from settling (position.
Passive. Flex: 75° - full flexion (A).
Ext: full flexion - 90°(A), 90° - 20° (C).

Wrist. Settled at 35° flexion in mid pronation.
Active. Ext: 35° F. - 25°F. (2).
Flex: 35° - 45° (2).
Abduction 0° (0). Adduction 0°(0).
Supination 90° - 120° (2). Pronation 0° (0).
Passive. Ext: 35° - 15° F. (A), 15°F. - 40°E. (C).
Flex: 40°E. - 50°F. (A).

Fingers. Settled tightly clenched in the palm.
Active. Ext: nil in either fingers or thumb.
Flex: with wrist flexed to 25° she had an appreciable grip (3+).
Passive. With the wrist extended 30° the I.P. joints could not be extended fully, even when the joints were held in 90° flexion. There was also marked resistance to full extension at M.P. joints.

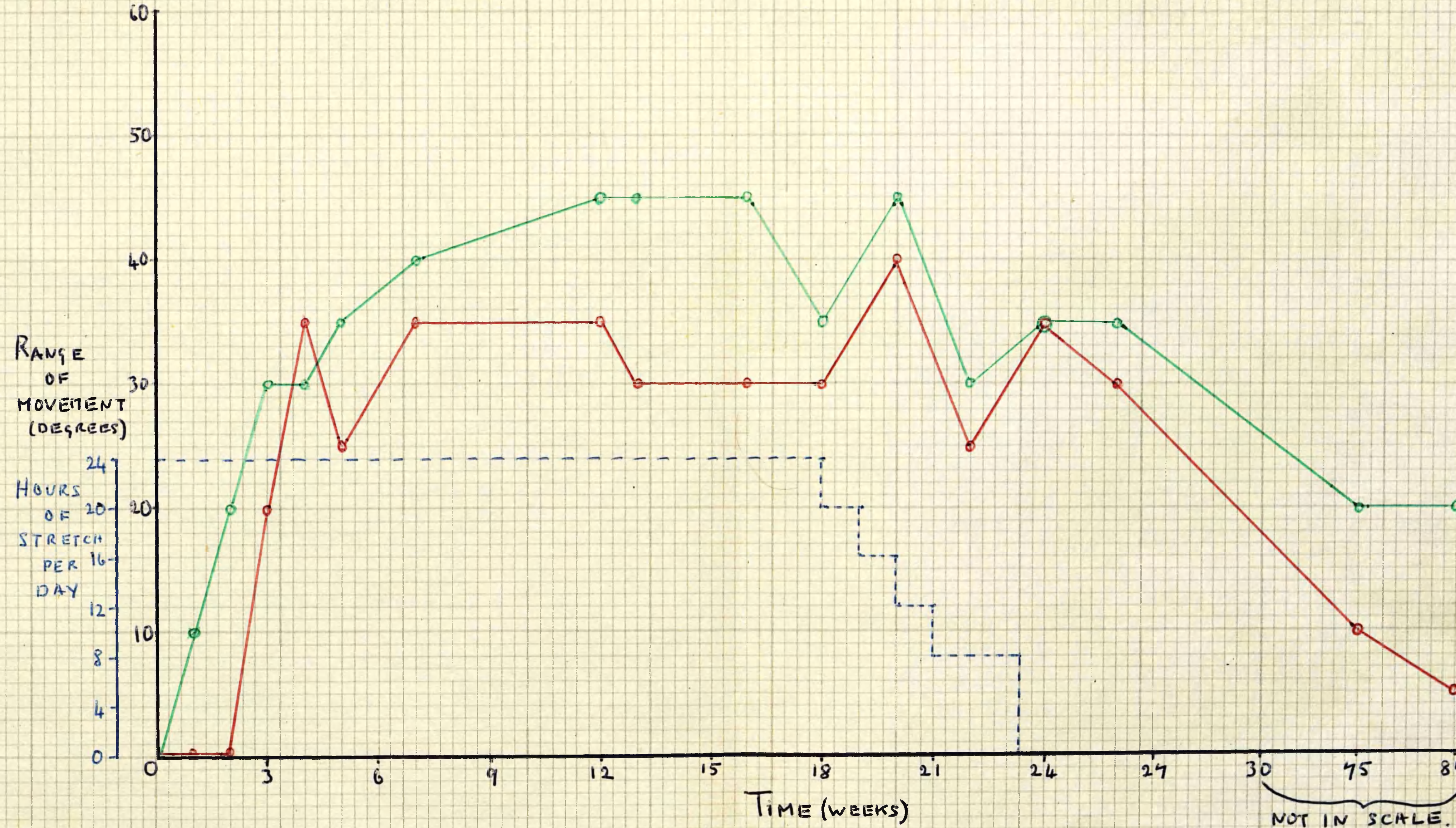
EIGHTY-SEVENTH WEEK.

Examination at this time showed no change from the findings at the seventy-fifth week.

SUMMARY.

The wrist flexors were constantly stretched for four months and then stretched for progressively shorter daily periods for a further five weeks. She obtained a considerable range of normal tonus and of active extension during this time but both were almost entirely lost during the course of the year which followed cessation of stretch. The spasticity shown by the flexors of the fingers responded surprisingly quickly to a seven week period of stretch but this was entirely lost during the ensuing year. It may be noted that she made no use of her gain in movement after stretching was stopped.

GRAPH NO 11.
(FOR LEGEND SEE GRAPH NO 1.)



CASE No. 10.

Age. 75 years.

Sex. Female.

Complaint. Chronic residual hemiparesis of the left side. (Duration - one year and six months.)

History.

She had a cerebrovascular accident in May, 1954, leading to a left hemiplegia. She was admitted to hospital and after six months was discharged, able to walk with a stick. At home she became bed-ridden and was again admitted on the 14.5.55. She was found, then, to have a fibrous flexion contracture of the left knee (40°) and no useful movement in the left arm which was spastic. It was held in flexion at the elbow and adduction at the shoulder.

Other forms of treatment employed prior to Splinting.

In July 1955 serial plasters were ordered for the leg but were discontinued after three weeks as the patient would not tolerate them. No treatment was given to the left upper limb.

Joints treated and type of appliance used.

A ventral wrist splint was used. (Her fingers presented multiple fibrous contractures, and it seemed that no useful purpose would be served by including them in the splint). The wrist joint was held flexed by marked spasm and passive extension to only 10°E. could be obtained. The splint held the wrist joint in 10°flexion.

Joint observed as Control.

The elbow joint.

INITIAL EXAMINATION. 21.11.55.

Left Upper Limb.

Elbow. Settled at 80°.

Active. Flex: 80°- full flexion (4).
Ext: full flexion - 90°(3).

Passive. Ext: 80°- 25°(D). Flex: 25°- full flexion (A).

Wrist. Settled at 70° flexion in the pronated position.

Active. Ext: 70° F. – 50° F. (3).
Flex: 50° F. – 65° F. (3+).
No other active movement.

Passive. Ext: 60° F. – 45° F. (A)., 45° F. – 10° E. (D).
Flex: 10° E. – 65° F. (A).
Supination 20° (C) from the fully pronated position in which it was habitually held.

Fingers. Settled ½" – 2½" (5th – 2nd) from palm.

Active. Useful grip. There was some 10° – 15° of active extension.

Passive. Marked spasticity felt on extending the fingers to their contractural angles (40° – 45° at M.P. and I.P. joints).

Reflexes.

The tendon reflexes were exaggerated on the left side. The Babinski test was positive on the left

Sensation.

No reduction detected.

Mental State.

Pleasant and co-operative, on the whole.

PROGRESS EXAMINATIONS.

This case showed a surprisingly quick response to treatment. By the end of the first week of constant splinting, the hand settled at 60° flexion and, from there, could be voluntarily extended (3+) to 20° F. – a gain of 30°. With time there was a further slight improvement – to 10° of flexion (3+) – by the fourteenth week. It may be noted that the splint held the wrist at this angle. The range of normal tonus kept pace with the active range. Between 10° F. and 10° E. there was still marked resistance felt.

As no further improvement seemed likely it was decided to discontinue treatment at the fourteenth week and observe whether or not this rather short period of stretch had effected any permanent change in the spasticity of the wrist flexors. Examination at the 24th. week (29.4.56) revealed that the range of normal tonus on passive extension had remained unaltered (60° F. – 10° F.) but active extension had diminished by 10° (60° F. – 20° F.)

SPLINT.

The splint caused no complaints, and with fortnightly washing by the Nursing Staff remained in good condition.

SKIN & JOINT.

Some excessive perspiration occurred in the palm of the hand under the splint and her hand required to be washed and powdered twice daily. No skin pressure areas developed, nor did oedema of the hand make an appearance.

CONTROL JOINTS.

The elbow joint showed no constant change during the period of observation.

This photograph shows the hand in its original "settling position" of full pronation and 70° flexion at the wrist joint.

54th WEEK.

Active and passive movement had returned to their original state as found at the initial examination. Movement at her other joints showed no change.

She had made no use of the hand since the appliance was removed ten months previously.

79th WEEK.

No change from the findings at the last examination.

CASE NO. 11.

Age 47 years.

Sex. Male.

Complaint. Residual hemiparesis of the left side. (Duration, one year.)

History.

He had a sudden loss of consciousness on the 1.3.54 and remained unconscious for two days. When consciousness returned he could not move his left arm or leg and the left side of his face was weak. Admitted to hospital on the 4.3.54.

(His condition on admission and the progress reports up to the 11.3.55 are copied from his In-patient case papers. I first saw this patient on the 11.3.55 and only the data subsequent to that date are based on my own observations.)

Condition on Admission. 4.3.54.

B.P. 250/140. Left ventricular hypertrophy. No evidence of heart failure. Reflexes on left side exaggerated. Left plantar response extensor. All forms of sensation reduced on left side. Spastic paralysis of left arm and leg. Left facial weakness.

5.3.54. Neck stiffness developed. C.S.F. pressure 240mls. Zanthochromic. No fresh blood. Severe headache. Irritable.

15.3.54. Neck stiffness abated. Otherwise I.S.Q. To have physiotherapy.

23.4.54. Hemiplegia - no change. Temp. 100°F. Crepitation at bases. Deep venous thrombosis left calf. Physiotherapists giving heat and passive movement to paretic side.

15.5.54. Today for the first time he demonstrated some active flexion of elbow and fingers. Leg still shows no active movement.

11.7.54. Practically complete left hemiplegia with marked constant spastic flexion deformity of both upper and lower limbs. Tone and reflexes much increased. The leg often goes into flexion spasm at hip, knee and ankle. There is loss of touch, position, and vibration sensibility on the left side. Left facial weakness still present. Ocular movements normal. Papilloedema right fundus but normal fields.

7.9.54. Long leg calliper (left) was supplied on the 1.9.54. This appliance controls flexion fairly well and the patient can walk with assistance. However, he complains that it is too heavy. He still gets painful flexion spasms at night.

1.11.54. Flexion is partly controlled by the calliper but pressure from the ring is eroding the skin of the thigh. Unsafe, therefore to continue with calliper and Orthopaedic Surgeon requested to see patient regarding hamstring tenotomy.

3.11.54. Orthopaedic Surgeon's notes:- "It requires thirty minutes of passive extension by physiotherapy staff to get leg into calliper and involves pain for the patient. On examination left knee is held flexed to 120°. Active extension is possible to 90° and then pain and hamstring tension results. There is weak active dorsiflexion of the foot to 80°. There is considerable spastic flexion and adduction deformity at the hip joint which can be overcome passively. I would like to see patient in calliper."

5.11.54. Patient in calliper. "Patient stands with hip flexed 20° - 25°, and 20° abduction is actively obtainable. I advise hamstring tenotomy."

8.11.54. "Operation under Omnipon and scopolamine and local anaesthetic. Subcutaneous tenotomy of semi-membranosis enable knee to be extended actively to 40° and maintained there. Biceps not cut until effect of this evaluated. Do later if necessary."

9.12.54. Severe flavine sensitivity rash followed the operation. Now nearly cleared up.

18.12.54. Orthopaedic Surgeon's notes:- "The left knee has contracted again. Voluntary extension is possible to only 90°.

20.12.54. "Tenotomy of the hamstrings on both sides of the knee carried out under local anaesthetic. Plaster back slab applied to maintain maximum extension."

11.1.55. Orthopaedic Surgeon's notes:- "Haematoma behind knee. Active extension possible to only 60°. Passive extension to 35° without delay. More passive extension could have been got in a few minutes. For aspiration and manipulation tomorrow."

12.1.55. Operation under general anaesthetic. "Haematoma aspirated. Fixed flexion by ligamentary contraction present at 30°. Manipulated to 10°. Pipe stem plaster applied from thigh to ankle."

22.1.55. Orthopaedic Surgeon's notes:- "Plaster bivalved. Active extension to 40°. Passive extension to 20°. Reapply P.O.P. except for physiotherapy periods."

27.1.55. Orthopaedic Surgeon's notes:- "Pressure sores on ankle and thigh from the plaster. The leg immediately flexes on removal of the plaster."

8.2.55. Walking quite well in the P.O.P. To continue with P.O.P. Sores still open and troublesome. Finds P.O.P. intolerable for more than a few hours per day..

Other Forms of Treatment Employed Prior to Splinting.

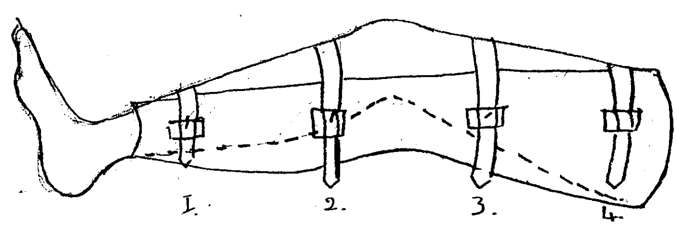
These have already been described in the History.

Joints treated and type of appliance used.

A long leg splint was cut out to extend from just above the mallioli to 2" above the junction of the middle and upper one thirds of the thigh. 1/8" polythene and 3/16" polyurethane were used. The patient was placed in the position described for moulding leg splints and his knee carefully extended passively to 45°. It was considered doubtful whether the plastics would mould to the double curve presented by this angle, but after the warm plastics had been wrapped round in the best alignment possible flexion spasm subsided and the leg could be well extended. The plastics were adjusted accordingly. During the ten minutes allowed for setting no flexion spasm developed. This was most surprising as all previous attempts to extend the knee past 45° had resulted in a flexion withdrawl reflex . The absence of this phenomenon was attributed to the heat of the plastics.

A mould of the almost fully extended leg was thus obtained. After this mould had been removed and the leg cooled, the knee slowly flexed to 70°. A detailed examination was then carried out.

Difficulty in putting on the finished splint without heating the leg was foreseen, and four one foot ong straps and buckles were fitted, (see diagram). By providing these long straps it was hoped that it would be possible to get the ankle and thigh of his flexed leg into the splint and tighten straps 1. & 4. Then it was planned to very gradually tighten all the straps in turn - see diagram.



Joints observed as Controls.

All other joints on the paretic side.

INITIAL EXAMINATION. 11.3.55.

I saw this patient for the first time on this date, almost exactly one year after the onset of his hemiplegia. I had been asked to see him with a view to making a plastic splint for his leg as he could not tolerate his P.O.P. splint.

By this time the pressure sores at the back of his thigh and ankle caused by the P.O.P. were almost healed. These had been very troublesome and had resolved only after the plaster splint had been left off except for a few hours per day following bivalving of the plaster on the 22.1.55. Only occasionally had it been fitted for longer than 4 - 6 hours per day since that time.

Examination.

Left Lower Limb. Only active movement examined, except at knee.

Hip. Settled at 20° flexion and 30° internal rotation.

Active. Flexion 20° - 100°(4).
Ext: 100° - 20°(3).
Abduction 30°(3+). Adduction 30°(3+).
Rotation:- internal 30°(3)
external 10°(3)

Knee. Settled at 80°.

Active. Flex: 80° - 110°(4). Ext: 110° - 80°(3+).

Passive. Ext: 110° - 80°(A), 80° - 45°(C-D).
Attempts to passively extend past 45° flexion invariably produced a flexion withdrawal of the limb.

Ankle. Settled at 40°.

Active. Dorsiflexion. 40° - 75°(3). This movement was accompanied by some 25° of inversion.
Plantarflexion. 75° - 30°(4).

Toes. There was a few degrees of active flexion and extension.

Measurement of thighs.

Left.	14"	circumference 3" above patella
	15¾"	" " 6" above patella.
Right.	15⅜"	" " " " 3" " "
	17¾"	" " " " 6" " "

Left Upper Limbs. (Only active movement was assessed.)

Shoulder. Settled in adduction.
Flex: 50° (4). Abduction 80°(4).
Ext: 55° (4). Adduction full (5).
Rotation:- external 60°(3), internal 60°(4).

Elbow. Settled at 30°.
Flex: 30°- full flexion (5).
Ext: full flexion - 75°(4), 75°- 20°(3).

Wrist. Settled at 30° flexion when pronated and 10° extension when supinated.
Ext: 30°F. - 25°E. (4).
Flex: 10°E. - 35°F. (4).
Abduction 10°(4). Adduction 20°(4).
Supination 150°(4). Pronation 150°(4).

Fingers. Settled lightly on palm with thumb resting against forefinger.
Ext: The fingers could be separated 2½"- 4" (5th - 2nd.) from the proximal palmar crease (3+), and the thumb extended almost fully at I.P., M.P. and C.M. joints (3+).
Flex: Firm grip.
No adduction or abduction was seen.

Reflexes.

All myotatic reflexes on the affected (left) side were markedly exaggerated. The plantar response was extensor and was accompanied by a withdrawal reflex of the limb. The abdominal reflex was absent on the left side.

Co-ordination.

This could be assessed only in the upper limb. It was found to be quite good within the range of active movement permitted.

Sensations.

All forms of superficial sensation were quite markedly impaired on the left side. Muscle and joint sense seemed less affected. There was no visual field defect.

Mental State.

He was depressed, somewhat aggressive and rather sceptical about the value of the plastic appliance. He gave the impression that prior to his cerebrovascular accident he had been a lively and witty personality but his wit at the time of examination was used, mainly, to give added weight to his criticisms.

The above examination was carried out after the splint had been moulded and the leg had cooled and the knee had returned to its former resting state of 80° flexion. The fact that his flexion spasm had so completely abated during application of the warm plastics had stimulated my interest sufficiently to examine in some detail the range of passive and active movement - especially of his lower limb. At the time I was interested only in the effect of the hot plastics on his flexion spasm but it was to prove fortunate that the examination had been detailed when, five weeks later, the effect of stretching his spastic flexors was observed.

15.3.55. The finished splint was successfully fitted by the method outlined when describing the type of appliance used. It was in fact quite easy to achieve full extension in this way. The splint and the securing straps were sufficiently strong to abort flexion spasms at their onset and when each spasm abated the leg could be extended a further 30°- 40° and the straps buckled before another spasm began.

17.3.55. He could walk well while wearing the splint. He found it much more comfortable than the P.O.P. splint and also much lighter. The latter quality enabled him to walk with more freedom.
The lower end of the splint was too close to the malleoli and tended to rub the skin over the medial malleolus. An inch and a half was taken off the bottom and an extra ¼" thick layer of polyurethane padding was glued on to give extra protection. The splint held the knee just a little flexed (5°- 10°).

21.3.55. The splint was satisfactory. I instructed the patient to wear it as much as he could tolerate. He was discharged home on this date.

PROGRESS EXAMINATIONS.

FOURTH WEEK.

The patient had taken my advice very literally and he had, in fact, not taken off the splint since I last saw him. He had found it comfortable, he could walk well in it during the day and it had stopped his flexion spasms at night.

On removal of the splint the skin over the back of the thigh was red and showed a ring of pressure, but it was not broken. The polyurethane lining over this part was rather frayed. The extra thick lining at the back of the ankle was also frayed and broken in one or two places. The rest of the lining was intact but a considerable amount of perspiration had been absorbed. The lining was therefore washed in the Department and fresh ½" thick bands were glued onto the polythene round the top and bottom of the splint.

Examination.

Knee. Settled at 5°.

Active. Flex: 5° - 110°(3). Ext: 110°- 5°(3+) (75°Gain). He repeated this movement six times before it fatigued. After a moment's rest he repeated it a further six times.

Passive. Ext: 110° - 45°(A), 45° - 5°(B).

Hip and ankle movement showed no detectable change from the findings at the initial examination except that hip extension had improved:-
Active, 100° - 10° (3).
There was no change in thigh measurements.

The patient walked a distance of 100 yards without his splint, using a walking stick held in his right hand. He remained in the Department for two hours and at the end of that time he could still extend his knee to 5°(3) but only once before fatigue occurred. On attempting to walk, his knee extension was not strong enough to take his weight for more than a few steps. Resistence to passive extension had also increased, 80° - 5°(B-C).

The splint was again fitted and he was instructed to wear it constantly except for two ten minute periods morning and night. During these intervals he was to wash his leg and to actively flex and extend the knee.

SEVENTH WEEK.

The patient was presented in a talk at the A.G.M. of the "Society for the Care of the Elderly" held at the Whittington Hospital, London, on May 7th, 1955. His recovery of active extension of the leg and his ability to walk without his splint was demonstrated.

He had now worn the appliance constantly for seven weeks. He had found it comfortable. There were no marks on his skin and there was no oedema of the foot. The splint was in good order. He gave the history that he only rarely got flexion spasms of his knee and that spasms were aborted within a few seconds by counter-pressure from the splint. Rather more often he experienced flexion spasms at the hip which raised up his extended limb. These always occurred at night and the weight of the bedclothes was usually enough to overcome them before much pain developed.

Examination.

Knee.		Settled at 5°.	
	Active.	Flex: 5° - 110° (3).	Ext: 110° - 15°(3+).
	Passive.	Flex: 5° - 110° (C).	Ext: 110° - 5°(A).

No change at the other joints.

He was instructed to continue to wear his splint constantly.

NINTH WEEK.

Skin clear. Splint required no attention. No flexion spasm of the knee or hip since last examination.

Examination.

No change since last examination except that active knee extension was a quicker movement and again reached 5°. It was repeated twenty times before fatiguing. He was also able to walk about the Department for an hour without his knee giving way.

It was thought that, since flexion spasm seemed to be abated, a lighter splint of strengthened 1/16" polythene could be used. A new splint of this thinner material was therefore made later that day but for some reason his knee could only be extended to 20 during the moulding process. This was most probably due to excitement during moulding since just prior to the plastics being applied his leg was extended to 5°.

The completed splint thus held his leg at 20° but since this degree of flexion did not interfere with his walking it was decided to let him have it. (The original splint was retained in the Department.) He was instructed to wear it constantly.

<u>THIRTEENTH WEEK</u>.

He had found the lighter splint more comfortable. The skin was clear and the splint in good order. He had had no flexion spasms of his knee and only occasionally of his hip.

<u>Examination</u>.

<u>Knee</u>. Settled at 20°.

<u>Active</u>. Flex: 20° - 90°(3). Ext: 90° - 20°(4).

<u>Passive</u>. Flex: 20°- 40°(B), 40° - 110° (C).
Ext: 110° - 20°(A), 20° - 5°(C).

It was interesting to note that he could now only extend his knee to 20° and that passive extension past that point met with moderate resistance. (The new splint held the knee at that angle.)

<u>Other Joints</u>:- no change except improvement in dorsiflexion of the foot:- Active 40°- 80°(3+).
Passive. 40°- 75°(A), 75°- 90°(C).

Thigh circumference - no change.

The patient was instructed to continue wearing the splint constantly.

<u>SEVENTEENTH WEEK</u>.

No change from Week 13, except that knee extension had become stronger (4+).

To leave splint off 2 hours per day.

<u>TWENTY-THIRD WEEK</u>.

Skin clear. No oedema. Splint required no attention. Patient wearing it 22 hours per day.

<u>Examination</u>.

<u>Knee</u>. Settled at 20°.

A <u>Active</u>. Flex: 20° - 80°(3).
Ext: 80° - 30°(4+). Extension was a very strong quick movement. Flexion had a smaller range and was slow and laborious.

<u>Passive</u>. Flex: 20° - 110° (C).
Ext: 110° - 20° (A), 20° - 5°(C).

No change in either passive or active movment at any other joint.

The patient remained unsplinted in the Department for 2½ hours and during that time the power and range of his knee movement did not alter. He walked about quickly and with assurance using one walking stick. His gait was circumducting because of the spasticity which now affected his knee extensors. Dorsiflexion of the foot was good, as usual, and there was no need for a toe raising appliance.

To leave splint off 4 hours per day.

<u>TWENTY-FIFTH WEEK.</u>

The patient came to the O.P.D. - by Public Transport - to ask if he could begin to leave off his splint for 6 hours per day. The Firm for which he had worked prior to his cerebrovascular accident had offered to take him back for three mornings per week in his old job (book-keeping). The Firm's car took him to and from work and he found it awkward getting in and out of the car while wearing his splint. He was therefore advised to leave it off for six hours each day, 8.0.a.m. - 2.0.p.m. This period of time covered his morning's work.

<u>Examination.</u>

No change, except that active knee extension had improved 10°, compared with the last examination.

<u>THIRTY-SECOND WEEK.</u>

He had been leaving the splint off for six hours per day as instructed. Skin clear. Splint in good condition.

<u>Examination.</u>

<u>Knee</u>. Settled at 20°.
<u>Active.</u> Flex: 20° - 70°(2).
Ext: 110°- 20° (4+), from the passively obtained position of 110°.
<u>Passive</u>. Flex: 20° - 110°(C-D).
Ext: 110°- 25°(A), 25°- 5°(C).

No change at any other joint.

To leave splint off 10 hours per day.

<u>THIRTY-FOURTH WEEK.</u>

Patient reported that since last attendance he had only worn the splint at night as he did not see any point in continuing to wear it during the day as he now had no tendancy to flexion at the knee. He had found no such tendancy even at night, before going to bed, in spite of being on his feet a good deal during the day. It was, therefore, decided to try discarding the splint altogether.

Examination.

On observing him walking unclothed his hip extension was seen to be almost full as he carried his weight forward on his left leg. Presumably the leverage of his foot against the ground when walking gave him the added extension. Examination lying down showed an active range of 100°- 15°(3+).

Another interesting factor at this examination was the quickness of his knee extension. When he sat in a chair he could, with gravity assisting, flex his knee to 80°. From this position he could kick out his foot very quickly indeed - to the usual limiting angle of 20°. This movement was as quick and forcible as a similar movement with his right foot.

The thigh muscles showed no change in circumference, despite his increased activity, and his quadricep exercises. He was instructed to begin resisted exercise - using a weight of 4 lbs.

Active and passive motion showed no change since the last examination.

To discard the splint entirely. (It was kept in the Department to ensure that this was done.)

THIRTY-NINTH WEEK

He had had no appliance of five weeks. He gave the history that he had not noted any weakness in his knee extension nor had he had any difficulty in walking. There had been no flexion spasms of either knee or hip. He was still at work three half days per week.

Examination.

Knee.		Settled at 15°.
	Active.	Flex: 15°- 70°(2). Ext: 110°- 15°(4+).
	Passive.	Flex: 15°- 110°(C).
		Ext: 110°- 10°(A), 10° - 5°(C).
Ankle.		Rested at 40°.
	Active.	Dorsiflexion 40°- 70°(4), 70°- 80° (3).
		Plantarflexion 80°- 40°(4+).
	Passive.	Dorsiflexion 40°- 75°(A), 75°- 95°(C).
		Plantarflexion 95°- 40°(A).

Thigh muscle wasting showed no improvement. In spite of this his leg extension was very strong. He held it extended to 15°, against gravity, for one and a half minutes before fatigue set in.

FORTY-THIRD WEEK.

He had worn no appliance of 9 weeks. He had continued to exercise his quadriceps frequently against a 4 lb. resistance. Still at work - no addressing and stamping letters. Not done book-keeping for some time because he had made too may errors.

ExaminationT

No change from last examination except that he maintained extension against gravity for 2 minutes before fatiguing.

FORTY-SEVENTH WEEK.

No detectable change at either knee joint or control joints.

FIFTY-FIRST WEEK.

He had worn no leg appliance for 17 weeks. Still at work. Still doing quadricep exercises. He had been able to use Public Transport without difficulty for many weeks.

Examination.

Knee.		Settled at 15°.
	Active.	Flex: 15° - 90° (2). Ext: 110° - 10° (4+).
	Passive.	Flex: 15° - 35° (A), 35° - 110° (C-D).
		Ext: 110° - 15° (A), 15° - 5° (C).

It may be noted from the above figures that there was, on this date, for the first time a small range throughout which both flexion and extension met with normal tonus (15° - 35° - 15°). Active extension had improved a further few degrees over the angle in which the knee was held by the splint. This may have been due to the intermittent extension force exerted by the movements of walking.

There was a small gain in bulk of the thigh (¼") measured at a point 5" above the upper border of the left patella.

He kept his knee extended against gravity for 2½ minutes.

There was no change at any other joint.

FIFTY-SEVENTH WEEK.

He had, by the date of this examination, worn no leg appliance of any kind for 23 weeks. He was still at work, part-time, and using Public Transport.

Examination.

Left Lower Limb.

Hip.		Settled at 10° flexion.
	Active.	Flex: 10° - 100° (4). Ext: 100° - 10° (3+).
		Abduction 40° (3+). Adduction 30° (4).
		Rotation, 30° internal and 10° external.
Knee.		Settled at 15°.
	Active.	Flex: 15° - 70° (2). Ext: 110° - 10° (4+).
	Passive.	Flex: 15° - 40° (A), 40° - 110° (C-D).
		Ext: 110° - 15° (A), 15° - 5° (C).
Ankle.		Rested at 50°.
	Active.	Dorsiflexion 50° - 80° (3+).
		Plantarflexion 80° - 40° (4+).
	Passive.	Dorsiflexion 50° - 70° (A), 70° - 90° (C).
		Plantarflexion 90° - 40° (A).
Toes.		Only a few degrees of active flexion and extension.

Left Upper Limb. (Only active movement examined)

Shoulder. Rested in adduction.
Flex: 50° (4). Abduction° 90 (4).
Ext: 45° (4). Adduction full (5).
Rotation:- external 100°(3+), internal 100°(4)

Elbow. Rested at 20°.
Flex: 20° - full flexion (4+).
Ext: full flexion - 60°(4), 60°- 20°(3).

Wrist. Rested at 40° flexion when pronated and 20° extension when supinated.
Flex: 20°E. - 40°F. (4).
Ext: 40°F. - 30°E. (4).
Adduction and Abduction 10°- 15°(3+).
Supination 130°(4). Pronation 130°(4+).

Fingers. Rested ½" - 1" (5th - 2nd) from palm and the thumb lightly opposed.
Flex: firm grip.
Ext: 2" - 4" (5th - 2nd) from palm and the thumb well extended (3+).

Reflexes, co-ordination and sensation showed no change from the findings of the initial examination.

Measurements of Thighs and Calf.

Thigh.	**Left.**	14⅛" circumference	3"	above patella.
		15⅞" "	6"	" "
	Right.	15½" "	3"	" "
		17½" "	6"	" "

Calfs. (Measured round thickest part)
Left. 12⅞". **Right.** 12⅝"
It may be noted that the circumference of the left calf was greater than of the right.

Walking.

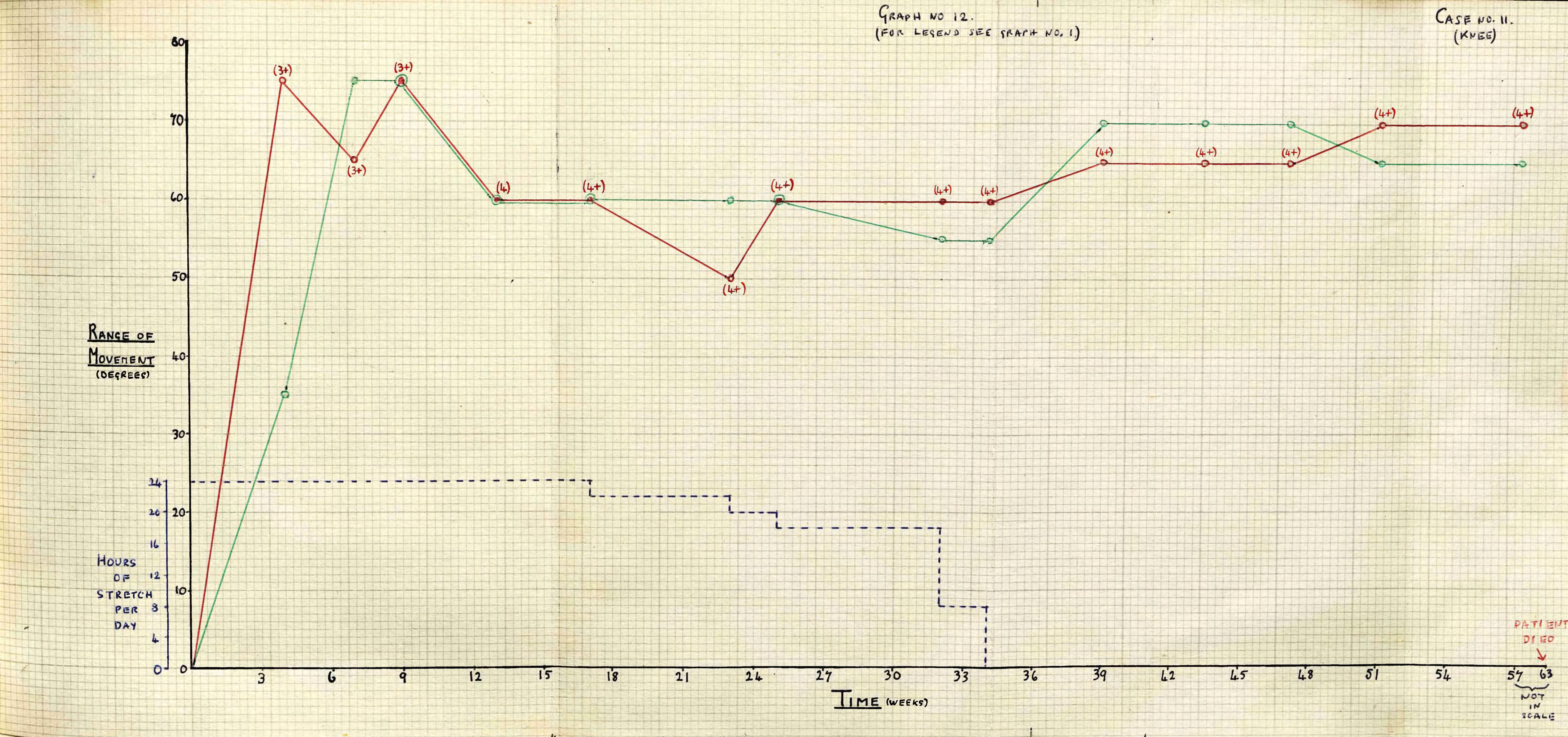
The patient could walk very well though his gait was still spastic and circumducting. He could walk without the aid of a stick but was rather quicker when using one. There was no evidence of his tiring during a two hour observation period. During the examination he successfully maintained his knee extended against the action of gravity for 2½ minutes.

Mental State.

He was proud of his ability to hold a part-time job though somewhat disappointed about his diminished mental agility. This had prevented him getting back to his old post of book-keeper. He was, however, a great deal more hheerful, and optimistic than when seen for the first time a year previously.

I did not see this patient again. A few months later, on enquiring at the Whittington Hospital as to his progress, I was informed that he had died suddenly on the 2.6.56, from a second cerebrovascular accident. He had maintained his improvement until the time of his death.

Photograph taken at 39th week of treatment. (Text, p.163).



GRAPH NO 12.
(FOR LEGEND SEE GRAPH NO. 1)
CASE NO. 11.
(KNEE)
RANGE OF MOVEMENT (DEGREES)
HOURS OF STRETCH PER DAY
TIME (WEEKS)
(3+)
(4)
(4+)
PATIENT DIED
NOT IN SCALE

CASE No. 12.

Age. 62 years.

Sex. Female.

Complaint. Chronic residual hemiparesis of the left side. (Duration, one year.)

History.

On the 19.10.54 she collapsed in the toilet, losing conciousness. She remained unconcious for several hours. On regaining the concious state she was unable to move the left leg or arm, and was mentally confused. Admission to hospital was arranged the same day. She remained an In-Patient for many months during which time a certain amount of active movement returned to the limbs. Her mental state did not improve sufficiently for her to make use of the active movement in her lower limb, and she never learned to walk in spite of prolonged attempts at rehabilitation. Her left arm and hand did not recover any useful movement.

I first saw this patient on the 27.8.55.

Other forms of treatment employed prior to Splinting.

During the year she was in hospital she had been given the benefit of all the usual forms of hemiplegic rehabilitation, for both the upper and lower limbs.

Joints treated and type of appliance used.

A wrist and finger splint (type A) was used. (See photograph opposite). It held the wrist extended to 30°E. and the fingers and thumb slightly flexed at the M.P. and I.P. joints.

Joints observed as Controls.

The shoulder and elbow joints.

INITIAL EXAMINATION 21.10.55.

Shoulder. Settled in adduction.

Active. Flex: 70°(3+). Abduction 90°(3+).
Ext: 50°(3+). Adduction - full (4).
Rotation:- external 70°(3),
internal 70°(3).

Passive. Flex: 0° - 80°(A), 80° - 120°(C).
Ext: 0° - 45° (A), 45° - 70°(C).
Abduction: 0° - 90°(A), 90° - 130°(C).
Adduction: full (A).
Rotation: external 0° - 80°(B). Pain and stiffness prevented further movement.
internal rotation was free of resistance.

Elbow. Settled at 75°.

Active. Flex: 75° - 110°(3). Ext: 110° - 90°(2);

Passive. Flex: 75° - full flexion (A).
Ext: full flexion - 90°(A), 90° - 15°(B-C).

Wrist. Settled at 70° flexion when forearm and hand pronated, and at 15° flexion when supinated.

Active. Ext: 70°E. - 45°F. (3).
Flex: 15°F. - 70°F. (3+).
No range of adduction or abduction.
Supination: 45°(3) from full pronation.
Pronation: 45°(3+).

Passive. Ext: 70°F. - 25°F. (A), 25°F. - 60°E.(B-C).
Flex: 60°E. - 70°F. (A).
There was slight resistance to full supination and normal resistance back to full pronation.
Abduction and adduction presented no detectable resistance.

Fingers. Settled ½" - 1½" (5th - 2nd), and the thumb was lightly held against the forefinger.

Active. The forefinger could be separated 2½", the middle finger 2" and the 4th and 5th fingers 1" from the proximal palmar crease. She could fully extend the I.P. joint of the thumb (3). The grip was weak but useful.

Passive. With the M.P. joints flexed to 90° the I.P. joints could be fully extended (A). Held in this position and extended passively:- 90° - 40°(A), 40° - 0°(B-C). There was no resistance to passive flexion of the fingers.

The lower limb was not examined.

Reflexes.

Myotatic reflexes were all a little exaggerated on the left side and the left plantar response was extensor.

Sensation.

Sensation was difficult to assess because of the patient's poor mental condition, but there appeared to be a diminished sense of light touch.

Co-ordination.

There was marked inco-ordination of the left arm. This was so gross as to suggest some loss of muscle and joint sensation.

The wrist and finger splint was put on and the Nursing Staff instructed to remove it only when washing the patient.

PROGRESS EXAMINATIONS.

1st WEEK.

She had worn the splint constantly. Skin clear. No complaints.

Examination, of wrist.

Passive. 70°F. - 10°E. (A). (Gain 35°). 10°E. - 60°E. (B-C), 60°E. - 70°F. (A).

Active. 70°F. - 15°F. (3) (Gain 30°). She could hold this position for only a second or two. 15°F. - 70°F. (3+).

Fingers.

Passive. Ext: 90°- 30°(A), 30°- 0°(B-C). Flex: No resistance to full flexion.

Active. All four fingers could be separated 4" from palm (3). The thumb fully extended at I.P. joint and a few degrees at the M.P. and C.M. joints (3).

2nd WEEK.

Still wearing the splint constantly. Skin clear. No oedema.

Examination. Active and passive movement showed no change apart from a further gain of 20° in passive extension of the wrist, i.e. 70°F. - 30°E. (A). (Gain 55°).

3rd. WEEK.

Wearing splint constantly. Skin clear. No oedema.

Examination. The only change from the 2nd week was that active wrist extension was 70°F. - 0°(3). (Gain 45°).

4th WEEK.

Splint still being worn 24 hours per day. Skin clear.

Examination. On this date she could extend her wrist less well - 70°F. - 10°F. (3). No other change noted.

6th WEEK.

Examination. She had regained her former range of voluntary extension of the wrist, 70°F. - 0° (3). Otherwise no change.

7th WEEK.

Skin clear. Wearing the appliance constantly. No change in passive or active range. Slight oedema of the hand. To begin leaving the splint off 2 hours per day.

9th WEEK.

Skin clear. Slight oedema of dorsum of hand.

Examination. There was a marked improvement in extension of the wrist: - 70°F. - 30°E. (3). She repeated this three times before the muscles fatigued. To leave splint off 4 hours per day.

10th WEEK.

Skin clear.

Examination. She had maintained wrist extension to 30°E. (3). She repeated this five times before fatiguing. The patient, on this date, was badly orientated and complained of abdominal pain and vomiting.

The further history of this patient is that she was transferred to a surgical ward and an inoperable carcinoma of the bowel was found at laparotomy. This took place one week after my last examination of her. It was considered inadvisable to continue her splinting and her appliance was discarded.

Four months later the patient was still alive and was in surprisingly good general condition, though mentally poor. A limited examination at this time provided the following date:-

26th WEEK.

Wrist.

Passive. Ext: 70°F. - 20°E.(A), 10°E. - 60°E.(B-C). Flex: 60°E. - 70°F. (A).

Active. The patient could not (or would not) extend the wrist at all.

Fingers. Settled $1\frac{1}{2}$" - $\frac{1}{2}$" from palm.

Passive. 90° - 50° (A), 50° - 0° (B-C).

Active. No active extension of the fingers or thumb. Grip weak.

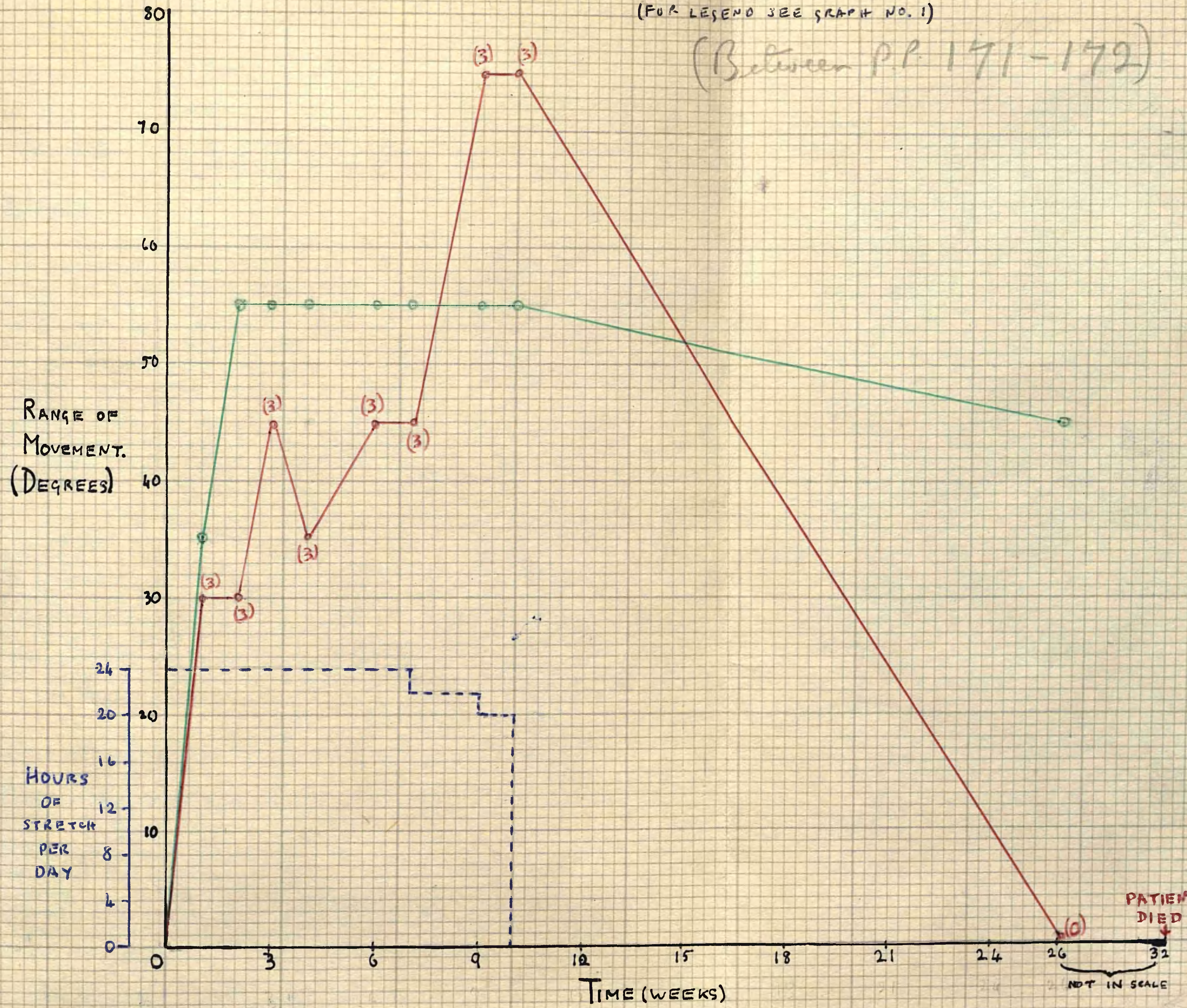
Passive movement at elbow and shoulder showed no change from the ranges found during the initial examination. She was not asked to attempt voluntary movement.

The patient died six weeks later.

GRAPH NO 13.
(FOR LEGEND SEE GRAPH NO. 1)

CASE NO 12.

(Between P.P 171-172)



CASE No. 13.

Age 70 years.

Sex. Female.

Complaint. Chronic residual hemiparesis of the left side. (Duration, one year and six months.)

History.

On the 7.5.54 she collapsed, losing consciousness. She remained unconscious for 24 hours and on recovery was found to have a left hemiplegia. She was admitted to Hackney Hospital where the diagnosis of cerebrovascular accident and left hemiplegia was made. She was discharged in October 1954. She remained at home until February 1955 when she was admitted to the Whittington Hospital. Her condition then, as described in her notes, was "left facial weakness, flexion contractures of the left wrist, elbow and shoulder. There is only a few degrees range of movement at these joints. There is also a flexion contracture at the left hip and the left knee, both of these joints having about 30° range of flexion and extension. There is gross oedema of both legs."

She was treated medically for C.C.F. and when her oedema had gone she was supplied, on the 16.4.55, with a polythene plastic splint for her knee. The knee could only be extended to 40° at this time. Two months later, on the 7.6.55, the knee could be extended passively to 25° and the splint was heated and remoulded to that angle. With the splint holding her knee at 25° flexion she could walk with assistance. (This splint was made by the physiotherapy staff, and I did not hear of it until it was too late to include the progress of the knee joint in my series of cases.)

On the 17.11.55 I was asked to try the effect of a plastic splint on this patient's wrist and fingers.

Other forms of treatment employed prior to Splinting.

During her stay in Hackney Hospital and during the first two months as an In-Patient at the Whittington Hospital, her hand and arm had been treated with wax baths and passive movement. In May 1955 physiotherapy for her upper limb was discontinued because no improvement had been obtained and attention was directed solely to her lower limb in an attempt to get her walking.

Joints treated and type of applianced used.

A wrist and finger splint (type a) for use in spastic paresis was fitted. It held the wrist at 15° extension and the fingers extended to the level of contractures. The thumb, too, was held extended.

Joints observed as Controls.

The shoulder and elbow joints on the hemiparetic side.

INITIAL EXAMINATION. 17.11.55.

Shoulder. Settled in adduction.
Active. Abduction 10° (3). Flex: 0° (0). Ext: 10° (3). Adduction full (4). Rotation 0° (0).
Passive. There was a contracture at 40° adduction.

Elbow. Settled at 80°.
Active. Flex: 0° (1). Ext: 0° (0).
Passive. Flex: 80° - 110° (B). Ext: 110° - 80° (A), 80° - 25° (D).

Wrist. Settled at 50° flexion in pronated position.
Active. No flicker of active movement.
Passive. 50° flexion - 15° extension (C-D). There was a fibrous contracture at 15° extension.

Fingers. Resting position - with the wrist passively held extended to 15° - the 5th - 2nd fingertips rested on the proximal palmar crease. The thumb was flexed under the fore-finger, the I.P. joint being flexed to 90°.
Active. Flex: 0° (1). Ext: 0° (0). Abduction 0° (0). Adduction 0° (0).
Passive. From the resting position to 25° flexion at the M.P. joints, and 20° at the I.P. joints, there was marked tonus and further extension was prevented by fibrous contractures.

The lower limb was not examined since, being already under treatment (see History) it could not be a reliable control.

Reflexes.

All myotatic reflexes were exaggerated on the left side.

Sensation.

Reduced to touch and pin-p rick in both upper and lower left limbs, particularly marked in hand and foot.

PROGRESS EXAMINATIONS.

The release of spasm in the wrist flexors and the return of active movement in their antagonists will be given in graph form at the end of the case. Detailed examinations of wrist joint movement will not be given since, apart from the above features, nothing worthy of note was seen. The effect on the fingers will however be given in some detail in the text.

1st. WEEK.

The fingers settled 3" from palm and the thumb was lightly opposed to the forefinger. Passive movement - only slight tonus. No skin abrasions. No oedema of fingers or hand. She found the splint sufficiently tolerable for constant wear.

3rd WEEK.

The fingers remained extended as before. Both the hand and fingers showed moderate oedema. She was given a sling to keep the hand and forearm raised.

She complained of aching in her hand and wrist, but said that it was not severe and she did not wish the splint to be removed.

4th WEEK.

Fingers and thumb settled extended as before, but there was no active movement and passive flexion was painful beyond a small range. The flicker of flexion movement in the fingers seen at the initial examination was lost - possibly due to oedema. There was rather less oedema of the hand and fingers.

6th WEEK.

Splint still in good condition but the lining required washing. No skin abrasions though there was a line of pressure along the dorsum of the wrist - not significant as it represented merely a depression in the small amount of oedema still remaining. She complained of mild aching in her elbow joint.

9th WEEK.

No oedema of hand detected but there was a small amount in the fingers. Fingers settled fully extended to contracture angle at both I.P. and M.P. joints. They had no active move- and were stiff on passive flexion, pain occurring beyond a few degrees range. To leave splint off for 2 hours per day.

11th WEEK.

Fingers a little less stiff. The splint had been removed for 2 hours per day over the past two weeks and the patient had carried out passive movements during that period of time. Otherwise no change. To leave splint off 4 hours per day.

13th WEEK.

The splint was in good condition and there were no skin abrasions or depressions. Slight oedema of hand and fingers. The patient had been wearing the appliance 20 hours per day without complaint, since the last examination.

Examination.

The fingers adopted resting positions (average) as follows:- M.P. joints - 40°; proximal I.P. joints 10°; distal I.P. joints 40°.

Passive. M.P. joints. Ext: $40^\circ - 20^\circ$ (A). Flex: $20^\circ - 65^\circ$(A) passive flexion past 65° caused pain.

I.P. joints. (proximal) Ext: $75^\circ - 10^\circ$(A)
Flex: $10^\circ - 75^\circ$(A).
(distal) Ext: $70^\circ - 10^\circ$(A)
Flex: $10^\circ - 75^\circ$(A).
This range applied to all the distal I.P. joints except that of the ring finger which had a smaller range.

Active. No active movement.

To leave splint off for 6 hours per day.

16th WEEK.

Fingers — no measurable change from last examination. The patient was wearing the splint without complaint for 18 hours per day. It was in good condition ad still maintained wrist extension at 15° and finger extension to contractural level, though the distal I.P. joints may have been a little flexed. With the hand strapped into the splint it was difficult to assess, exactly, the degree of flexion at the finger joints as they were partially obscured by the splint. To leave the splint off for 12 hours per day.

19th WEEK.

Fingers - There was at this time no sign of oedema and passive movement at the M.P. and I.P. joints was freer than before, and also less painful. There was an overall gain in range of passive movement of some 20°. For the first time there was a flicker of extension in the forefinger and also a few degrees of flexion in the same finger.

The polyurethane lining of the splint required further washing. It had come loose from the polythene a little way in some places. The patient had no complaints and was wearing her appliance 12 hours per day. To discard splint.

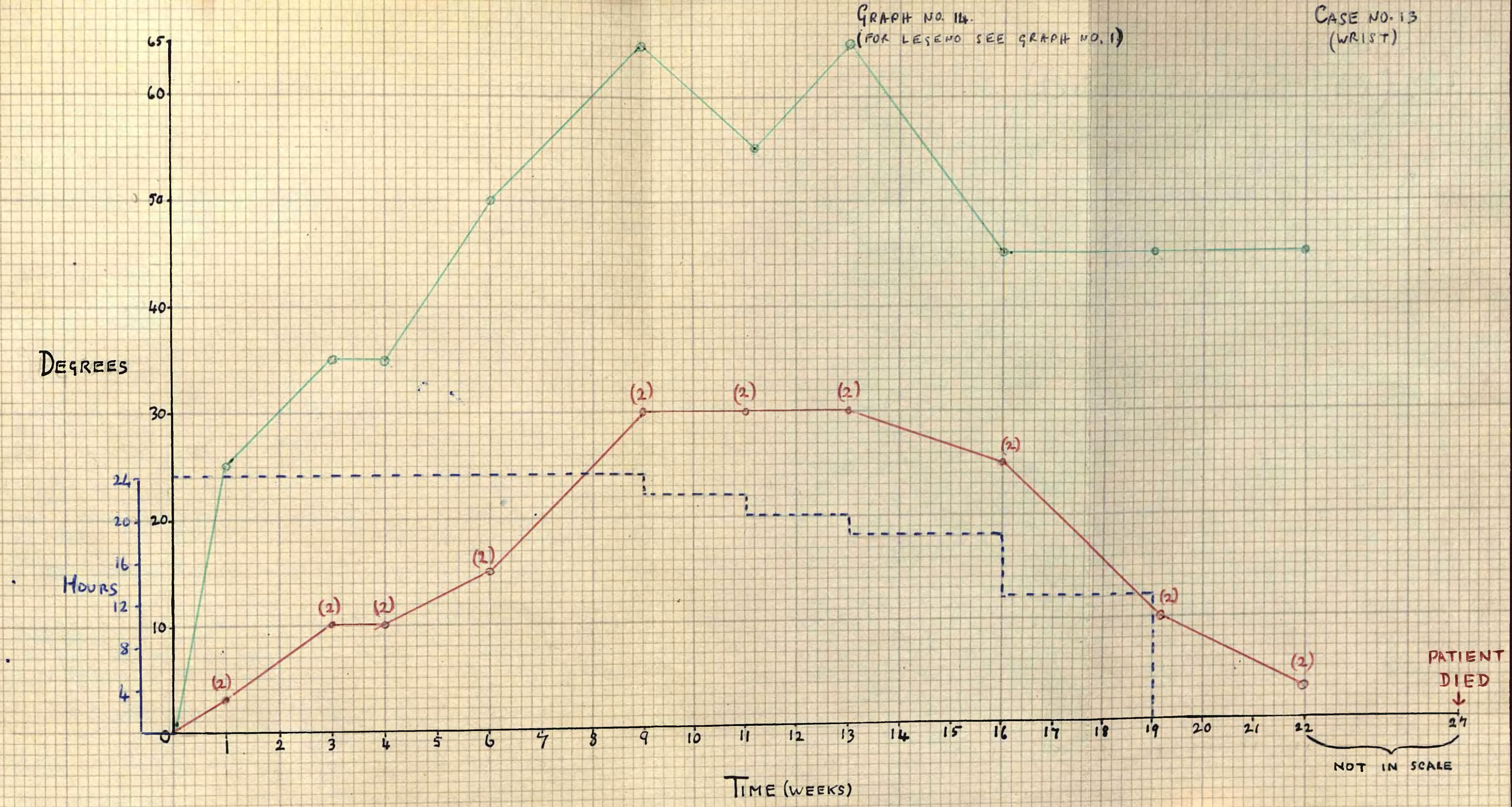
22nd WEEK.

The fingers. had maintained their range of passive movement though the splint had been discarded. The fingers adopted the following resting positions:- M.P. joints 30°;
proximal I.P. joints 10°;
distal I.P. joints 30°.
The range of normal tonus on passive movement was unchanged. No active movement was seen.

I did not see this patient again. She died five weeks after my last examination.

<u>SUMMARY.</u>

The wrist and finger flexors were constantly stretched for nine weeks and thereafter for diminishing dialy periods for ten weeks. This patient was interesting in that a much greater gain in the range of normal flexor tonus than in the range of active extension was obtained. The small amount of active movement present in the other muscle groups on the affected side suggests that this was due to the fact that few intact motor pathways had been spared by her cerebrovascular accident. What little active wrist extension resulted was soon lost as the periods of stretch diminished. She was in any case quite unable to make any use of the temporary improvement in the hand and wrist owing to the lack of movement at her elbow and shoulder.


GRAPH NO. 14.
(FOR LEGEND SEE GRAPH NO. 1)
CASE NO. 13
(WRIST)
DEGREES
HOURS
TIME (WEEKS)
PATIENT DIED
NOT IN SCALE
65
60
50
40
30
20
10
24
20
16
12
8
4
0
1
2
3
4
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9
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27
(2)

CASE NO. 14.

Age. 82 years.

Sex. Female.

Complaint. Chronic residual hemiparesis of the left side. (Duration - one year, three months.)

Case History.

On the 1.8.54 she wakened in the morning with a left hemiplegia. She improved quickly and by the 4.9.54 she was walking without aids and using her left hand for domestic duties. On that date another episode of left sided weakness took place. Again she recovered the use of her left leg and was able to walk but her left arm and hand remained paralysed. On the 1.10.54 she developed weakness of both legs which lasted for a few hours and then passed off. She did not loose conciousness at any time. Admission to hospital was obtained on the 5.10.54. During her stay in hospital she had several further episodes, mainly affecting the left side. She gradually spent more and more time in bed and when I examined her onthe 15.11.55, she could not stand or walk.

Other Forms of Treatment employed prior to Splinting.

Several attempts were made to keep her ambulant, but these were finally stopped as the disease process so frequently interupted progress. She received no treatment for her left arm and hand apart from training in the performance of passive movements.

Joints treated and type of appliance used.

An elbow splint was made which maintained the elbow extended to 20°.

Joints observed as Controls.

The left shoulder and wrist joints.

Initial Examination. 15.11.55.

Left Upper Limb.

Shoulder. Settled in adduction.

Active. Abduction 35° (3+). Flexion 15° (3+).
Extension 0° (0). Rotation 0° (0).
Adduction - full (3+).

Passive. Movements past the above ranges caused pain and distress and were not therefore properly assessed. There appeared to be a severe contracture of the joint.

Elbow. Settled at 80°.

Active. Flex: 80° - 110° (3+). Ext: 110° - 80° (3+).

Passive. Ext: 80° - 20° (C). Flex: 20° - 110° (A).

Wrist & Fingers.

There was only a few degrees of active movement. The grip was feeble. Flexor spasm was moderate in degree. The fingers were moderately contracted, (about 30° at M.P. and I.P. joints).

The Other Limbs.

All showed evidence of spasticity, but the left leg was more spastic than the right.

Reflexes.

The myotatic reflexes were exaggerated on both sides but rather more so on the left. The Babinski test was positive on both sides.

Sensation.

The patient was moderately confused and accurate estimation of sensory loss was not possible. There did, however, appear to be some loss to touch on the left side.

Mental State.

She was pleasant and co-operative, but her cerebration was very slow. She was over-emotional, laughing or crying unnecessarily.

Progress Examinations.

She was examined on weeks 1, 2, 4, 7, 10, 13 and 15. An unusual feature of this case was the rapidity with which voluntary elbow extension recovered. Within a week she could extend the elbow to 40° (3), representing a gain of 40° (see photograph). Flexor spasm had also abated, and extension to 20° met milder resistance (B-C).

As the weeks passed the gain increased slightly to 45° (3) and passive extension was only slightly resisted by the flexors.

At week 13 she had yet another cerebrovascular accident affecting the left side, and by week 15 no active movement was noted, in the left arm, at any joint. This may to some extent have been due to her general condition which was, at that time, very poor. It remained poor and application of the splint was discontinued. She died a few weeks later.

SPLINT.

The first splint was not a very well made example and caused a pressure ring over the wrist (but no skin abrasions). A new one was made and fitted at week 7, and this proved satisfactory.

SKIN & JOINTS.

The skin remained clear (apart from the pressure ring mentioned above), and no oedema developed in the hand or forearm. The elbow joint became a little stiff and painful on passive flexion, after the 4th week, but this never became pronounced.

CONTROL JOINTS.

During the period when active extension of the elbow was recovering no change was noted at the shoulder or wrist.

Photographs of this Case overleaf...............

Photographs.
Taken at the end of the 2nd week of treatment. The show the patient actively flexing and extending her elbow. Extension was possible to 40° - a gain of 40° over her original active range of extension.

CASE No. 15.

Age. 45 years.

Sex. Female.

Complaint. Hemiparesis of the right side.
(Duration, two months.)

History.

This patient, a hypertensive subject, suffered a sudden loss of consciousness on the 20.7.55. On return of consciousness there was a complete loss of voluntary movement of the right side of the face and the right upper and lower limbs. Her speech was markedly affected.
13.8.55 - Speech almost back to normal. No voluntary movement of the upper or lower limbs except flexion at hip, knee and ankle which could be performed as a complete movement but not as individual movements. B.P. 180/100.
5.9.55 - Walking unaided with two sticks, and a below knee iron assisting dorsiflexion of the foot. There was no movement in the upper limb except slight flexion of the fingers.

Other forms of treatment employed prior to Splinting.

The patient was admitted to hospital immediately after the onset of her cerebrovascular accident. Physiotherapy and rehabilitation were begun a week later for both upper and lower limbs. As extensor spasm soon developed at the knee joint and some hip movement returned she became able to walk with a below knee iron and a stick. The upper limb however was still almost completely paralysed at the end of the third month, (see examination). Splinting of the wrist joint at night was also used during the third month.

After constant splinting was begun in the fourth month physiotherapy was discontinued to the splinted joints but continued, twice weekly, to the other joints.

Joints treated and type of appliance used.

A ventral type wrist and finger splint (type a) was fitted at the beginning of the fourth month. An elbow splint was fitted at the beginning of the fifth month and at the same time the wrist and finger splint was replaced by a wrist splint.

Joints observed as Controls.

The shoulder and elbow joints were observed as controls when the wrist and fingers were splinted. Later the controls were the shoulder and finger joints when the elbow and wrist joints were splinted.

INITIAL EXAMINATION. (27.10.55)

LOWER LIMB. Only active movement was examined.

Hip. Flex: 100° (4+), Abduction 20° (3+), Adduction 20° (4), Ext: full (4+). Rotation 5° - 10° (3).

Knee. Settled at 10°. Flex: 10° - 90° (3). Ext: 90° - 10° (3+)

Ankle. Settled at 40° plantar flexion. Dorsiflexion 0° (0). Plantar flexion 40° - 30° (3+) Inversion 0° (0), Eversion 0° (0).

Toes. Only a flicker of active movement.

UPPER LIMB.

Shoulder. Settled in adduction.
Active. Abduction 45° (3+), Flex: 30° (3), Ext: 45° (3+), Adduction - full (4). Rotation; ext. 45° (3), int. 25° (3).
Passive. Abduction 0° - 50° (A), 50° - 160° (C). Flexion. 0° - 40° (A), 40° - 130° (C). Extension. 0° - 35° (A), 35° - 70° (C). Rotation. ext. 0° - 60° (A), 60° - 100° (C), Pain past 100°. int. 100° - 0° (A).

Elbow. Settled at 80°.
Active. Flex: 80° - 120° (3+). Ext: 120° - 90° (3+).
Passive. Ext: full flexion - 80° (A), 80° - 10° (D). Flex: 10° - 70° (A), 70° - full flexion (C).

Wrist. Settled at 30° flexion, when in mid pronation. There was a little oedema of the wrist and hand.
Active. Flex: Nil. Ext: 0° (1). Abduction and Adduction 5° - 10° (2). Supination - 50° (3). Pronation - 10° (3).
Passive. Ext: 30° F. - 20° F. (A), 20°F. - 50°E. (D). Flex: 50°E. - 30°F. (A), Pain past 30°F. Abduction and adduction 5° - 10° (C). Supination (from mid prone position) 45° (C). Pronation (from mid prone position) 90° (C).

Fingers. Settled at ½" - 1" from palm (5th - 2nd) and the thumb flexed under the forefinger.
Active. Flex: - grip was slight. Ext: nil.
Passive. With the wrist at 30°E. and the M.P. joints flexed to 90° there was slight resistance (B) to full extension at the I.P. joints. Held extended at the I.P. joints, there was marked resistance (D) to full extension of the fingers at the M.P. joints. The thumb flexors showed similar spasticity.

Reflexes

On the right side the myotatic reflexes were much exaggerated, the abdominal reflexes were absent and the Babinski test was positive.

Co-ordination.

Too little movement was present to assess co-ordination.

Sensation.

Neither light touch or muscle and joint sense was diminished. Vision was unaffected.

At the time of this initial examination she had been wearing a wrist and finger splint for one month, but only at night. She was instructed to begin wearing it constantly day and night except for two ten minute intervals night and morning for washing the part. This original splint held the wrist extended 5° - 10° , and the fingers flexed, 20° at M.P. and 30° at I.P. joints.

When plotting the graph of this patient's progress the gain in range of active and passive movement obtained after splinting will be given as compared with the initial values found at the above examination. The preceding month's splinting, even though the splint was only applied at night, may have abated the flexion spasm to some extent, but this will be ignored because of the lack of exact data, regarding active and passive movement, prior to this period of splinting.

SECOND WEEK.

She had worn the splint constnatly except for two ten minute washing periods daily. The skin was clear. Slight oedema. No complaints. Splint held the wrist at 10 extension.

Wrist.		Rested at 10°F. in mid-pronated position.
	Passive.	Ext: 30°F. - 0° (A) (Gain 20°) 0°- 50°E. (D).
		Flex: 50°E. - 30°F. (A). Pain past 30°F.
	Active.	Ext: 30°F. - 0°(2). (Gain 30°).
		Flex: Nil.

Fingers. Rested 1" - 3" (5th - 2nd) from palm. Thumb flexed lightly against forefinger.

Active movement showed no change.

Resistance to passive movement was lessened, 90° - 0° (C).

THIRD WEEK. No change.

FOURTH WEEK.

Still wearing splint constantly. Skin clear. No complaints. Splint in good order. Rather more oedema of hand and fingers. No change in active or passive movement of wrist or fingers. No change in elbow or shoulder movement.

It was thought that a new wrist splint to hold the wrist in more extension might improve dorsiflexion. Since the fingers had shown only slight improvement over the [redacted] months treatment only a wrist splint (volar type) was made. This held the wrist at 35°E. An elbow splint was also made which maintained the elbow at 10° - 15°.

FIFTH WEEK:
Owing to aching of the flexor muscles of the elbow she had only tolerated the elbow splint for eighteen hours per day. She had found that she was obliged to remove it at about 2.0.a.m. each morning, because of this pain. She gave the history that she had had pain in this region prior to splinting, but that it had increased in the past week. She had worn the wrist splint constantly as directed and had had no discomfort from it.

There was a ring of pressure in the skin opposite the anterior parts of the upper and lower borders of the elbow splint. The skin was not broken or abrased. The skin of wrist and hand was clear. Slight oedema of hand and fingers. Both splints were in good condition. She was instructed to elevate the arm on pillows while in bed. It was hoped in this way to lessen the oedema.

Elbow. Settled at 50°.
Active. Flex: 20° - 100° (3+).
Ext: 100° - 70° (3+), 70° - 60° (2). (Gain 20°).
Passive. Flex: 50° - 90° (A), 90° - full flexion (C).
Ext: full flexion - 60° (A), (Gain 20°), 60° - 10° (D).

Wrist. Settled at 0° in mid prone position.
No change in active or passive movement.

Shoulder and finger movement showed no change from the findings at the initial examination.

She was instructed to continue wearing the wrist splint constantly and the elbow splint for as long as she could tolerate it.

SIXTH WEEK.
The pain in the upper arm had lessened but she had continued to remove the elbow splint for six hours per day. On examination of the skin there was less marked pressure rings over biceps and forearm. Skin of the wrist and hand clear. Moderate amount of oedema of wrist and fingers.

Elbow. Settled at 50°.
No change in ative or passive movement.

Wrist. Settled at 0° in mid prone position.
Active. Ext:: 30°F. - 5°E. (2). (Gain 35°).
Flex: Nil.
Passive. Ext: 30°F. - 10°E. (A), (Gain 30°), 10°E. - 50° (D).
Flex: 50°E. - 30°F. (A). Pain past 30°F.

To continue wearing splints constantly.

EIGHTH WEEK.

Only slight pain was felt in the upper arm. Wearing the elbow splint for 20 hours per day. Skin clear. Slight oedema of fingers and hand.

Elbow. Settled at 45°.
- Active. Flex: 45° - 90° (3+).
  Ext: 90° - 70° (3+), 70° - 50° (2). (Gain 30°).
- Passive. Flex: 45° - 90° (A), 90° - full flexion (C).
  Ext: full flexion - 50° (A), (Gain 30°).
  50° - 5° (B-C).

Wrist. Settled at 0° in mid prone position.
No change in active or passive movement.

It may be seen from the above figures that active extension of the elbow had only slightly improved though there was an appreciable lessening of resistance to passive extension. There was no change in movement at the shoulder joint but the fingers were rather less spastic on passive extension (C). The grip had improved a little. There was also a flicker of extension at the I.P. joints of the fingers.

ELEVENTH WEEK.

She had had no ache in the elbow flexors since her last examination. She had been wearing both the elbow and wrist splints constantly. Skin clear. Splints not deteriorated. The elbow splint held the elbow at 10° and the wrist splint held the wrist extended to 30° E.

Elbow. Settled at 40°.
- Active. Flex: 40° - 95° (3+).
  Ext: 95° - 70° (4), 70° -40° (2) (Gain 40°).
- Passive. Flex: 40° - 90° (A), 90° - full flexion (C-D).
  Ext: full flexion - 45° (A), 45° - 5° (B).

Wrist. Settled at 0° in mid prone position.
- Active. Ext: 30° F. - 10° E. (2) (Gain 40°).
  Flex: 0° (0).
- Passive. Ext: 30° F. - 25° E. (A) (Gain 45°) 25° E. - 50° E (C).
  Flex: 50° E. - 20° F. (A). Pain past 20° F.

No change in other wrist movement.
Fingers showed no further improvement.
No change in shoulder movement.

THIRTEENTH WEEK.

Still wearing wrist and elbow splints constantly. No complaints. Skin clear. Very slight oedema of hand and fingers. She gave the history that for the past month she had elevated her arm on pillows at night.

Elbow. Settled at 30°.
- Active. Flex: 30° - 90° (3+).
  Ext: 90° - 45° (3+), 45° - 30° (2) (Gain 50°).
- Passive. Flex: 30° - 80° (A), 80° - full flexion (C).
  Ext: full flexion - 35° (A), (Gain 45),
  35° - 5° (B).

Wrist. Settled at 5° flexion in mid prone position.
Active. Ext: 30°F. - 10°E. (2) (Gain 40°). This movement was performed slowly and with great effort.
Flex: 0° (1).
Passive. Ext: 30°F. - 15°E. (A), (Gain 35°).
15°E. - 65°E. (C).
Flex: 65°E. - 15°F. (A), 15°F. - 35°F. (B).
Pain past 35°F.

Fingers. Settled touching the palm except for the forefinger (1" from palm). Thumb opposed and flexed.
Active. No extensor movement. Grip very feeble.
Passive. 90°F. - 0° (C).

NO change in shoulder movement.

FIFTEENTH WEEK.
Wearing splints constantly. No discomfort. Skin clear. Slight oedema of hand and fingers. Splints in good order.
Elbow. Settled at 35°.
There was no change in active or passive movement compared to the findings at Week 13.
Wrist. Settled at 10°F. in mid prone position.
Active. 30°F. - 0°(2), (Gain 30°).
Flex: 10°E. - 10°F. (2).
Passive. Ext: 30°F. - 10°E. (A), (Gain 30°),
10°E. - 65°E. (B-C).
Flex: 65E. - 0°(A), 0°- 40°F. (B). Pain past 40°F.

The patient was instructed to leave splints off for one hour per day.

SEVENTEENTH WEEK.
She had been leaving the splints off as directed. Skin clear. Slight oedema of hand and fingers. No complaints.
Elbow. Settled at 30°.
Active. Flex: 30° - 100°(3+).
~~Ext~~ F: 100°- 60°(3+), 60° - 35°(2), (Gain 45°).
Passive. The last 25° of this extensor movement was still very slow and laboured. The harder she tried the more difficult it became.
Passive. Flex: 20° - 70°(A), 70° - full flexion (C-D).
Ext: Full flexion - 50°(A), 50°- 50°(B).

i.e. the gain in range of normal tonus was only 30° at this examination but there was much less resistance (B) to the remaining 45° of possible extension compared to the findings at the initial examination. Alsothe

passively extended elbow showed no tendency to flex past 20° when freed of restraint. (See photograph on previous page).

Wrist. Settled at 0° in mid prone position.

Active. Ext: 30° F. - 10° E. (2), (Gain 40°).
Flex: 0° - 10° (2).

Passive. Ext: 30° F. - 15° E. (A), (Gain 35°)
15° E. - 60° E. (C).
Flex: 60° E. - 0° (A), 0° - 30° F. (B). Pain past 30° F.

Instructed to leave splints off for 2 hours per day for the next week then 3 hours per day the following week.

NINETEENTH WEEK.

She had worn the wrist splint as instructed, but for the past week she had worn the elbow splint only 4 hours per day as her arm had begun to ache again. Skin clear. No oedema. Splints in good condition.

Elbow. Settled at 20°.

Active. Flex: 20° - 115° (3+).
Ext: 115° - 55° (4), 55° - 20° (2+). (Gain 60°).

Passive. Flex: 20° - 65° (A), 65° - full flexion (C).
Ext: full flexion - 45° (A), (Gain 35°),
45° - 5° (B).

Wrist. Settled at 10° F. when held in full pronation and 0° in supination.

Active. Ext: 30° F. - 20° E. (3), (Gain 50°).
Flex: 0° - 10° (3).

Passive. Ext: 30° F. - 25° E. (A), (Gain 45°),
24° E. - 50° E. (C).
No change in other wrist movements.

To wear the wrist splint 19 hours per day for the next 2 weeks and to try to wear the elbow splint as much as possible.

TWENTY-FIRST WEEK.

She had only worn the elbow splint 5 hours per day, but had worn the wrist splint 19 hours per day. Skin clear. No complaints except a mild ache in the elbow again.

Elbow. Settled at 15°.

Active. Flex: 15° - 10° (4).
Ext: 100° - 65° (4), 65° - 30° (3) (Gain 50°).

Passive. Flex: 15° - 80° (A), 80° - full flexion (C).
Ext: full flexion - 35° (A), (Gain 45°),
35° - 0° (B).

Wrist. Settled at 30° F. in pronated position and 0° in supinated position.

Active. Ext: 30° F. - 10° E. (3) (Gain 40°).
Flex: 0° - 20° F. (3).

Passive. No change. (Gain 45°).

Fingers. Still no active extension. Slight grip.

<u>Shoulder.</u> Active abduction had improved to 60° (Gain 15°) and flexion to 40° (Gain 10°). No change in other movements.

Patient instructed to discard elbow splint (Kept in Dept.) and to wear the wrist splint 17 hours per day.

<u>TWENTY-THIRD WEEK</u>

She had had no elbow splint for two weeks. Wrist splint had been worn for 17 hours per day.

<u>Elbow.</u> Settled at 20°.

<u>Active.</u> Flex: 20° - 100° (3+).
Ext: 100° - 60° (4), 60° - 30° (3+). (Gain 50°).
She could not voluntarily extend past 30° but when she relaxed the force of gravity was sufficient to extend the elbow to 20°.

<u>Passive.</u> Flex: 20° - 85° (A), 85° - full flexion (C-D).
Ext: full flexion - 30° (A), (Gain 50°),
30° - 0° (B).

<u>Wrist.</u> Settled at 35° F. in pronation and 0° in supination.

<u>Active.</u> Ext: 35° F. - 20° E. (3+). (Gain 50°).
Flex: 0° - 10° F. (3).

<u>Passive.</u> Ext: 35° F. - 30° E. (A), (Gain 50°),
30° E. - 55° E. (C).
Flex: 55° E. - 10° F. (A), 10° F. - 35° F. (B).
Pain past 35° F.

Fingers and shoulder - no change.

To wear wrist splint only at night (i.e. 8 hours per day).

<u>TWENTY-FIFTH WEEK.</u> (19.4.56).

Muscles of arm still ache a little. Otherwise no complaints. Skin clear. No oedema.

<u>Shoulder.</u> Rested in adduction.

<u>Active.</u> Abd: 50° (3+). Flex: 20° (3).
Add: full (4). Ext: 50° (3).
Rotation:- int: 20° - 30° (3),
ext: 60° (3).

<u>Passive.</u> No appreciable change from the findings at first examination.

<u>Elbow.</u> Settled at 15°.

<u>Active.</u> Flex: 15° - 100° (4), 100° - 125° (3).
Ext: 100° - 70° (4), 70° - 30° (3+), 30° - 15° (2).
(Gain 65°).

<u>Passive.</u> Flex: 15° - 85° (A), 85° - full flexion (C).
Ext: full flexion - 25° (A), (Gain 55°),
25° - 0° (B).

<u>Wrist.</u> Settled at 40° F. in prone position and 0° in supine.

<u>Active.</u> Ext: 40° F. - 10° E. (3+). (Gain 40°).
Flex: 0° - 15° (3+).

Passive. Flex: 60° E- 10° F. (A), 10° F. - 45° F. (B).
Ext: 40° F. - 30° E. (A), (Gain 50°),
30° E. - 60° E. (C).

Fingers. Settled ½" - 1" (5th - 2nd) from palm with the thumb flexed and opposed.

Active. Ext: 0° (1)
Flex: slight grip.

Passive. Ext: 90° - 0° (C).
Flex: 0° - 90° (A).

I was not able to follow this patient's further progress closely. She was instructed to wear the wrist splint at night for a further two weeks and then to discard it.

SEVENTY-THIRD WEEK.

She had worn no appliance for 56 weeks, the findings were as follows:-

Shoulder.

Active. Abd: 65° (3+). Add: full (4).
External rotation 70° (3+).
Internal rotation 45° (3+).
Flex: 10° (3). Ext: 60° (3+).

Elbow. Settled at 15°.

Active. Flex: 45° - 110° (3+).
Ext: 110° - 30° (3+ - 2) (Gain 50°)
On relaxation gravity extended the joint to 15°.

Passive. Flex: 15° - 90° (A), 90° - full flexion (C).
Ext: full flexion - 30° (A), 30° - 0° (B)

Wrist. Settled at 45° F. in full pronation and 0° in full supination.

Active. Ext: 45° F. - 5° E. (3) (Gain 35°).
Flex: 0° (1).
Abd: 30° (3). Add: 10° (3).
Supination 0° - 120° (3+).
Pronation 0° from supinated position. She could not voluntarily pronate the hand.

Passive. Ext: 60° F. - 20° E. (A), (Gain 40°).
20° E. - 60° E. (C).
Flex: 60° E. - 60° F. (A). Add: 30° (A).
Abd: 10° (A). Supination 0° - 90° (A), 90° - 180° (B-C).
Pronation 180° - 0° (A).

Fingers. Settled 1" (5th - 2nd) from palm with thumb tucked under the forefinger.

Active. Ext: 0° (0). Tended to flex on attempts at voluntary extension.
Flex: Slight grip.

Passive. Ext: 90° - 0° (C). Flex: 0° - 90° (A).

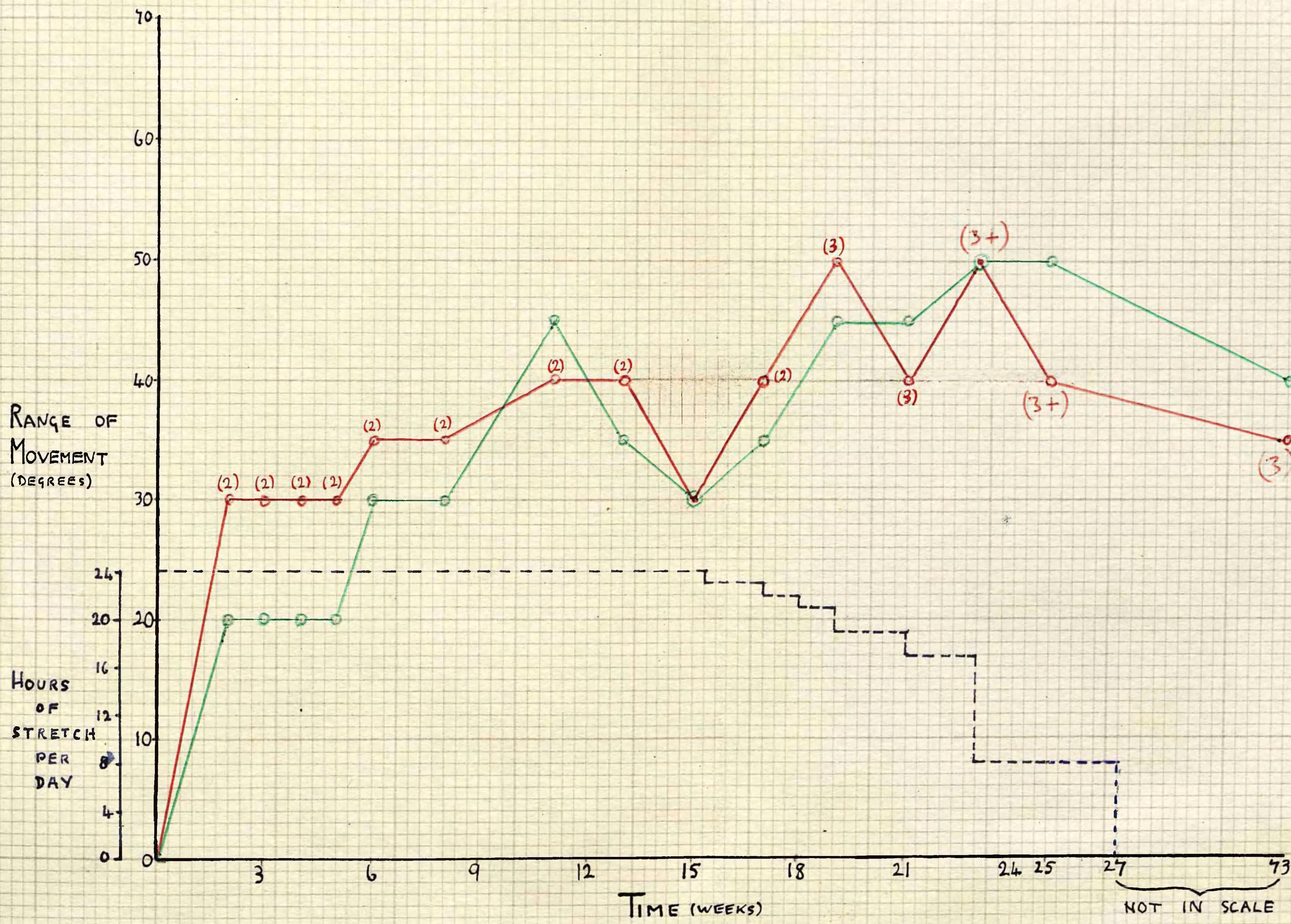
SUMMARY.

Her elbow flexors were submitted to seventeen weeks stretch and her wrist flexors to twenty-seven weeks stretch.

At the final follow up examination fifty-six weeks after the wrist appliance, and sixty-six weeks after the elbow appliance, had been discarded the stretched muscle groups retained their gain almost intact. Movement at the control joints showed little change throughout the period of observation despite the fact that the duration of her hemiplegia had been only three months when muscle stretch was begun.

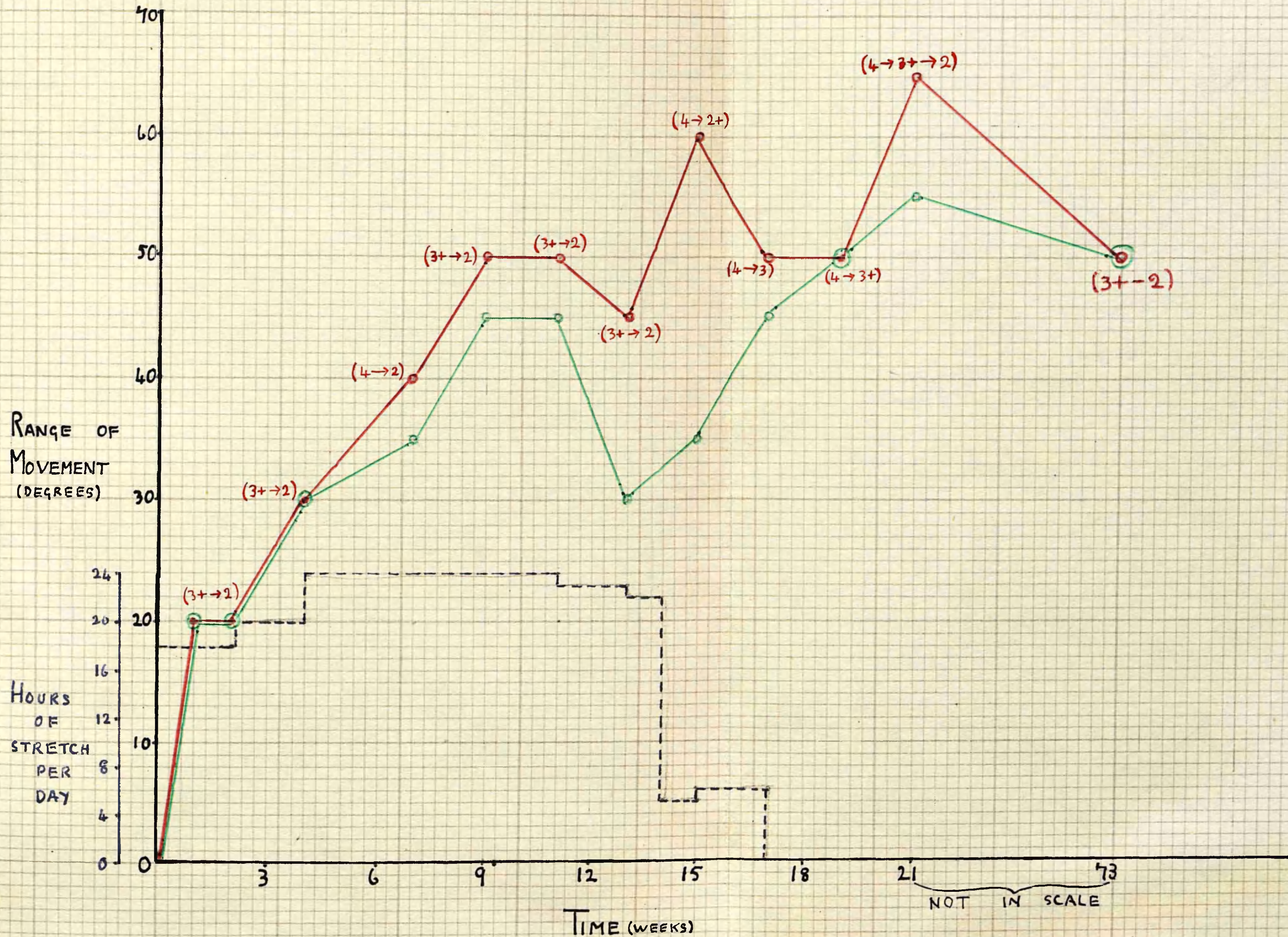
GRAPH NO. 16
(FOR LEGEND SEE GRAPH NO. 1)

CASE NO. 15
(WRIST)



GRAPH NO. 17
(FOR LEGEND SEE GRAPH NO. 1)

CASE NO. 15
(ELBOW)



CASE No. 16

Age 68 years.

Sex. Female.

Complaint. Left sided hemiplegia. (Duration, two months).

History.

This patient was admitted on the 21.7.55 complaining of headache and neck stiffness, of four days duration. Lumbar puncture revealed the presence of red blood cells and some xanthochromia. An arteriogram revealed the presence of an aneurism of the right internal carotid artery. On the 25.7.55 the right common carotid artery was ligated. Two days later she noticed a weakness of her left arm and leg. This weakness slowly increased over the next few days until she had a complete, flaccid left hemiplegia. Over the next six weeks there was some recovery of movement at the hip. The knee became held in flexion but no movement was seen either at that joint or those joints distal to it. The upper limb remained completely paralysed and flaccid.

Previous History.

This was relevant to the findings at the initial examination and also to the course of her recovery, and is therefore recorded. She had a most unfortunate history. At three years of age she had diphtheria. At four years she had poliomyelitis; she could not walk until six years and thereafter only with the help of appliances. At ten years of age she had chicken-pox and convulsions. At twenty years she developed rheumatoid arthritis which, in combination with her residual paresis of the lower limbs, was responsible for her spending most of her years in institutions. She had nevertheless been able to get about with bilateral callipers and elbow crutches up until her admission to the Whittington Hospital, and the subsequent onset, there, of hemiplegia.

Other Forms of treatment employed prior to Splinting.

She had had heat and passive movements for the lower limb but without any discernible improvement. The patient had been very adverse to passive movements as they caused her pain. The upper limb, remaining flaccid, had received no attention.

Joints treated and type of appliance used.

The left wrist and knee joints were splinted, the former with a ventral wrist splint and the latter with the usual type of knee splint. The wrist was held in 30° of dorsiflexion and the knee at 25°.

Joints observed as Controls.

The hip and ankle were compared with the knee. The shoulder and elbow were compared with the wrist.

INITIAL EXAMINATION. 22.9.55.

Examination of this patient's joints was unsatisfactory for three reasons. Firstly, the patient, though a pleasant personality, was of a very hysterical nature and screamed wildly on any examination (e.g. passive movement of the knee joint) which caused her pain, even though the examination was carried out with the utmost care. She was furthermore very reluctant to attempt voluntary movement. Secondly, though there was clinically no evidence of acute arthritis, there was considerable evidence of proliferative arthritis in the joints of the lower limbs, and this might well have been responsible for some curtailment of joint range. Thirdly, though she gave the history of having been able to use both her upper limbs well, and equally well, prior to her "stroke", there was the history of poliomyelitis affecting the lower limbs since childhood.

On carrying out as accurate an examination as was possible, under the circumstances, the following salient points emerged. The left upper limb was completely paralysed except for a few degrees of movement at the shoulder and a flicker of flexion at the elbow. The latter joint had a passive range of full flexion - 15° and showed only minimal evidence of arthritic change. There was a good range of passive movement at the wrist joint but there was evidence of chronic arthritic changes. When pronated the hand lay flexed to 45°. There was no active movement. The fingers too had quite a good passive range, though there were multiple arthritic deformities present.

The hip was held flexed to 80° and there was a further 10°- 15° of voluntary flexion. She could also abduct and adduct the limb through a few degrees range. She could not extend it and passive extension met with moderate resistance. The knee lay flexed to 110° , from which angle no active extension was seen. If carefully extended passively a moderate tonus was felt in the hamstrings. Extension was permitted to 25°. There was no active movement at the ankle which was held plantar-flexed to 45°.

She could move her right arm and leg through an almost normal range, though the power of the lower limb was weak (3+ - 4). There was a good deal of wasting of both thigh and leg muscles, equal on both sides. The upper limb musculature was poor but there was no wasting.

Reflexes.

Absent in the upper limb. The left knee jerk was weak but rather easier to elicit than that on the right side. The Babinski responses were difficult to elicit because of gross deformity of all the toes, on each foot, but there was a definite withdrawal reflex of the whole of the left leg on stimulation of the side of the foot. This was not obtained on the right side.

Sensation.

The patient would no co-operate sufficiently well so assess sensation.

Mental State.

This has already been commented upon. Without going into detail her state of mind might best be summed up by saying that she was a very "difficult" patient.

PROGRESS EXAMINATIONS.

These were carried out at intervals of three weeks until the time of her death from broncho-pneumonia in February 1956.

Her arm and hand remained flaccidly paralysed throughout. The splint was satisfactory and she wore it constantly, rather surprisingly, without complaint until shortly before her demise. No flicker of voluntary movement returned to the wrist joint nor was any improvement noted in the neighbouring joints.

The leg did rather better. After nine weeks of constantly wearing her knee splint she was able to maintain the knee extended to 25° for a few moments against the action of gravity. After allowing it to remain flexed for a few seconds she again extended it to its previous angle. As the weeks went by it became easier for her to extend the knee and less easy to flex it. Exact evaluation of tone in the flexors and extensors was not possible in this case, mainly because of the complication presented by her painful knee joint. There did, however, appear to be a progressive increase of tone in the extensors and a simultaneous lessening of tone in the flexors.

All attempts by the Physiotherapy Staff to re-educate her walking met with failure. The added weakness of her hemiparesis, on top of her previous complaint, was impossible to cope with. The most important single cause was a continuing weakness in the hip extensors - she remained unable to extend the leg to more than 30° flexion and even this was a very weak movement. 10° - 15° of dorsiflexion and plantarflexion of the foot returned during the 4th. month of her illness, but this was not constantly seen thereafter.

SPLINT.

The appliances remained in good condition throughout.

SKIN & JOINTS.

No skin pressure areas developed and no joint "stiffness" was noted. The patient seemed content to wear the splints, and made no protest at their continued use.

CONTROL JOINTS.

Return of movement, or its absence, has already been noted.

CASE No. 17.

Age. 77 years.

Sex. Female.

Complaint. Chronic residual hemiparesis of the right side. (Duration, three years).

Case History.

She had been bed-ridden for eighteen months following a fracture of the neck of the right femur. She was mentally confused and unco-operative.

A very brief outline of this case will be given, as she wore the elbow splint, with which she was fitted, for only two weeks. She is included in the series because even within that short space of time she made an unexpectedly quick response.

When first seen on the 22.11.55 her elbow settled at 60° and she could voluntarily flex it to 130° . From there she could extend it back to 60° (2) but no further. Passive extension from 60° - 15° was obtainable against moderate resistance.

Her elbow was splinted at 15° and at the end of two weeks constant wear she could extend the elbow to 30° (2) - (see photographs) - and passive extension to this angle met with less resistance

At this point she refused to wear the splint any longer saying that it had "cut her skin". On examination no marks of any kind were seen but she would not be reassured. My powers of persuasion failed to make her alter her mind and splinting was discontinued.

Examination a week later revealed that her active movement had reverted to the original range and that flexor tonus was again equal to its former degree.

THE POLYTHENE-POLYURETHANE SPLINT.

MATERIALS.

POLYETHYLENE (POLYTHENE).

This plastic was discovered in 1935 and has a chemical structure similar to paraffin wax but has a much higher molecular weight and possesses therefore very different physical and mechanical properties. Polythene is a solid polymer of the gas ethylene (C_2H_4) and is manufactured by subjecting ethylene to a very high pressure at a temperature around 200°C. Chemically it is a saturated hydro-carbon in which the individual molecules are of the order of 1,00 carbon atoms long, i.e.....

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 H H H H H H H H H H H
-C-C-C-C-C-C-C-C-C-C-C-     (Scales, in Nangle, 1951).
 H H H H H H H H H H H
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It belongs to a group of plastics described as thermoplastics which melt at a certain degree of temperature and are then malleable. On cooling they retain the moulded shape. If heated again to this degree of temperature they again melt and can be remoulded. Polythene melts at 120°C, giving a very viscous substance which can be moulded by compression. Sheet polythene (1/16" & 1/8") is used in splint making and is moulded by bandaging.

At normal temperatures it is flexible, the degree of flexibility varying indirectly to its thickness. 1/16" sheet polythene can be easily bent whereas 3/16" is difficult to bend beyond a few degrees range unless the leverage is great. After heating and moulding polythene becomes rather less resilient and an encircling 1/16" polythene wrist splint will maintain the hand dorsiflexed without strengthening, though it is the usual practice to strengthen the volar aspect of the splint with a 1" wide strip of 1/16" polythene bringing its ventral thickness to 1/8". This latter thickness will resist a moderate amount of flexion spasm - for instance in spastic hemiplegia - but if a severe degree of spasm is present the volar aspect will require a 1/8" strip to bring the ventral thickness up to 3/16". Alternatively in such a case the whole splint could be made from 1/8" sheet which in encircling form provides considerable strength and resistance to bending. It may be noted that an encircling limb splint fixed in place with straps is virtually a tube and thus acquires the increased rigidity imparted to materials cast in tubular form.

By using strengthening strips of suitable shape and thickness it is always possible to strengthen a splint or orthopaedic appliance to make it sufficiently rigid in any desired position. There is no limit to the thickness and therefore the degree of strength and rigidity. The strip(s) is simply laid on the main section and heated with it. During heating the two coalesce.

Polythene is extraordinarily durable and if a splint be distorted with all one's strength it will not break, and if set asided after distortion it slowly returns to its original shape - within a few minutes.

A flesh coloured polythene is used. Cost, 13/2½ per Lb.

Polythene is physiologically inert and can indeed be used safely inside the body tissues - as in various forms of arthroplasty.

It is washable with soap and water or with any cleansing fluid.

Polythene is translucent to ultra violet and x-ray frequencies.

It is one of the lighter plastics having a specific gravity of 0.93 (Scales, in Nangle, 1951). The material required for a wrist splint weighs between two - four ounces.

Polythene shrinks a little when heated and cooled so that when transferring the patient's measurements to the polythene sheet it is advisable to add an extra ½" per foot to allow for this.

POLYURETHANE.

This material is a recent addition (1952) to the plastic series. German in origin, its composition is still secret, but urethane is believed to be an essential part of its structure. It is elastic in quality and porous in composition. In its sheet form it stretches freely but tears if the stretching force is excessive. However, I have never known it to tear while moulding a splint and in fact when it is adherent to the polythene, as it is during moulding, (see 'Preparing the Plastics') it is virtually impossible for this to happen. Again, when it is in the form of an adherent lining to the polythene in a finished splint it will withstand considerable wear and tear.

In this country it is manufactured in three densities, (a) light - in which the pores are large and the material soft and spongy in consistency, (b) medium - where the pores are smaller and (c) dense - where the pores are small and the consistence is firmer than in the two previous types. All three grades are about equal in elasticity and therefore in their malleable property, but the dense type is the best heat insulator and it is therefore used in making the splints.

About 50% of the air cells are in continuity throughout the material and a free flow of air is therefore allowed through the plastic. This has the advantage in splint making of allowing evaporation of sweat from the skin. The dry air in the pores of the material makes it a very efficient heat insulator and this property is the key to the technique of applying polythene directly to the patient's limb. Polyurethane of 3/16" thickness is used and it forms a heat barrier between the skin and the hot polythene, the patient feeling only a comfortable warmth, though the polythene is at a temperature of 120°C. to 140°C. Many rheumatoids compare it to the heat of a wax bath. I have never had a complaint of overheating.

Polyurethane is light in weight - the material for a volar wrist splint (Page) weighing only ½oz. It is washable with soap and water or any cleansing fluid. It is physiologically inert. It is perfectly translucent to X-rays. It is cheap in cost - 10/9d. per lb.

HEATING APPARATUS.

Any form of closed oven which directs its heat from above downwards and provides evenly distributed heat over the floor of the oven will be adequate, provided that it attains a temperature within the range of 120 - 140°C. If in constant use the temperature will gradually build up to exceed the limit of 140°C. unless some form of control is incorporated. A thermostat is the ideal method but a simpler and less expensive method is to have a switch on the outside of the oven which can shut off part of the interior heating element when the temperature is found to be rising above 140°C. A laboratory thermometer can be kept inside the oven and checked visually from time to time.

The above arrangement was found satisfactory in the original oven. This oven was made from a disused heat cradle, the lamp and fittings being removed and a sheet of polished aluminium fitted under the dome. Below the aluminium sheet, three parallel metal rods were fixed and the elements from an obsolete wax bath were strung along them. The connecting wires were all asbestos covered and led to the outside of the oven and into a switch panel which had three switches - one for each bar of the element. The switch panel was separated from the oven by an air gap of 1" to prevent overheating of the rubber lead from the panel to the 15 amp wall plug. The open ends of the cradle were blocked with sheets of ½" asbestos - one of the ends being provided with a flap for inserting and removing the plastics. The floor was also covered with ½" asbestos.

This oven was used constantly for seven months without trouble and was discarded in favour of a larger oven only when the area of the plastics required for braces and for long leg splints was found to be too great for it. A larger oven was made by the hospital engineer and was similar in principle and design to the original.

PREPARING THE PLASTICS.

The technique of making the splints is fairly simple and with practice they can be made quickly and safely by non medical Staff, such as Technicians, Physiotherapists, Nursing Staff, etc.

The oven is switched on and while it is heating to the required temperature the patient's measurements are taken, marked in ink on the sheet of polythene, and the resulting design cut out. Polythene of 1/16" thickness is easily cut with a pair of small scissors and 1/8" can be cut by the same method, or more easily with a knife such as that used by leather goods craftsmen. Polythene of 3/16" thickness is seldom required, but when it is, it too is cut with a knife.

Next, a piece of polyurethane of similar shape but ½" - ¾" larger all round is cut from the polyurethane sheet with scissors. This is placed on the asbestos sheet used as a carrying tray and the polythene section is placed on top of it. It will be seen that there is thus a margin of polyurethane protruding evenly on all sides from under the polythene (see photograph, Page 217). The purpose of this overlap is to protect the skin from heat radiation from the edges of the hot polythene which would occur during moulding if both pieces were of equal size.

The temperature of the oven is observed and when it reaches 120 C. the flap of the oven is raised and the tray carrying the plastics is pushed inside. The flap is then lowered.

The time taken for the polythene to soften and become malleable is in direct relationship to its thickness. 1/16" thickness softens in 8 - 10 minutes and 1/8" thickness softens in 15 - 20 minutes, and so on. Polythene indicates its malleable state by turning transluscent. Once this occurs it is ready to mould but it is essential to allow a further 10 - 15 minutes to elapse so that the softened polythene may "soak into" the pores of the underlying polyurethane. If this is done the polyurethane will form a firmly attached lining to the cooled and finished splint. If it is not, the polyurethane will be only lightly held to the polythene and will soon become detached - and will require to be glued back on. The attachment of the polyurethane to the polythene is entirely mechanical - by means of superficial infiltration of its pores by the heat softened polythene. Neither plastic possesses any true adhesive properties.

During the period of heating in the oven the polyurethane is not softened or altered in any way, acquiring only a temporary rise in temperature which falls to a comfortable warmth within seconds of its being removed from the oven.

When the time for the above processes has elapsed the tray carrying the plastics is pulled out of the oven and a piece of thick stockinette of rather larger size than the polythene is laid on the top of the soft polythene and gently pressed onto its softened surface. It adheres lightly to it. The stockinette must not be stretched on the surface before being pressed down. The adherent underlying polyurethane, though it is elastic, does interfere somewhat with the malleability of the polythene, and if tension is put on the stockinette the polythene is sandwiched between two materials which are less malleable than itself and this interferes with accurate moulding.

The stockinette protects the operators hands from the hot polythene and permits manipulation of the plastics without discomfort. The patient is of course protected by the polyurethane which is between the skin and the polythene.

MOULDING THE APPLIANCE TO THE PATIENT.

The next step is for the operator to lift the materials from the tray, check the temperature by laying the polyurethane against his forearm to make quite sure it is only comfortably warm, and then place it on the patient's limb or body and bandage it in place with moderate tension. A 3" crepe bandage is the most suitable type.

After removal from the heat of the oven polythene (unlike "Perspex") retains its malleable state for several minutes. Time is therefore available for exact positioning of the materials on the patient and for the bandaging process. Once the plastics are thus fixed in place it is best to avoid manual moulding. It is usually unnecessary. Sometimes, however, an intermittent pressure with the fingers is permissible and useful as, of instance, when moulding the plastics into the hollow of the palm of the hand where pressure from the bandage can not act directly. The palm of the hand is in fact the only place where manual moulding is advisable.

The length of time the plastics should be allowed to cool and set on the limb varies directly with the thickness of the polythene. Upper limb splints are usually made from 1/16" polythene with 1/16" strengthening strips, and these may be removed in three or four minutes without risk of losing their shape. Lower limb splints are more often made from 1/8" polythene without strengthening strips and this thickness is usually best left in situ for seven or eight minutes. Spinal supports and braces may be of ¼" thickness or more in certain areas of the appliance and must be left in position for a proportionally longer time.

The bandage is then unwrapped and any undesirable excess is marked with ink on the polythene after stripping the stockinette sufficiently to expose it. The encircling splint is then 'sprung' from the limb. Being resilient it regains its shape after removal. It is then left aside to cool to room temperature before being finished.

It will be seen from the above that although the total time employed in taking measurement, marking out on the sheet of polythene, cutting, heating and application may occupy from 30 minutes for a wrist splint to 1½ hours or more for a spinal brace, the actual time during which the patient's presence is required is seldom more than 10 - 15 minutes. The usual procedure was to take the measurements of the patient's limb or body in the O.P.D. or Ward and have the plastics prepared ready for a certain appropriate time at which they were moulded on the patient. He was then free to go after the few minutes required for the plastics to cool on the limb. If required urgently another half hour was needed for cooling and finishing.

FINISHING THE APPLIANCE.

If required for only a few weeks limb splints require no finishing. Since these splints completely encircle the limb a few turns of bandage are all that is required to give the small amount of additional support required to offset their resilience.

However, many cases of arthritis and neurological disease require appliances for a very long period of time and in such cases it was our practice to provide them with straps and buckles, or straps and press-studs, and also to punch ventilation holes. The latter would not be required in the porous polyurethane but are required in the polythene if maximum comfort is to be achieved. Polythene is not porous and without ventilation holes these splints tend to be rather warm in hot weather, though their warmth is a comfort, particularly to arthritics, in colder weather. A leather punch is adequate to punch holes in small splints but with larger appliances and braces it is necessary to have a foot operated punch with an 18" 'throat'. This piece of equipment is relatively inexpensive (£16 - £17) and can punch out the holes very rapidly. These holes should ideally be 1/16" diameter, though 1/8" is permissible. (Larger than this, they allow the skin to prolapse through them, particularly if there is much pressure of the limb against the splint, as for instance the palm of the hand in the case of a cock-up wrist splint worn by a hemiplegic patient with spasticity.) By using interchangeable dies it can also fix on straps, buckles and press-studs. The straps are attached to the splint by bifurcated tubular steel rivets in the following way:- holes are punched through the plastics and the strap, and the male and female sections of the rivets are brought together through the holes and riveted together by counter pressure between appropriately shaped dies. The buckles or press-studs are attached to the straps in a similar manner.

<u>Note</u>.

In the following description of the splints a few of the photographs are duplicates of those in the case reports. This was thought advisable as a matter of convenience for the reader.

KNEE SPLINT.

Splint from lateral aspect.

Splint from above. This patient has chronic rheumatoid arthritis. (Exton-Smith, 1956).

In dealing with this splint it is proposed to describe the method of preparing the plastics and of moulding them to the patient in some detail, so that when describing the other types of appliances the basic technique need not be given each time. The knee splint has been chosen as both its design and technique are simple. (It will be noted that there is some repitition of data already described, but this can hardly be avoided in giving a detailed description of the technique.)

MATERIALS.

Polythene ⅛". Polyurethane 3/16".
Polythene comes from the Makers in sheets of 3ft. square. Polyurethane comes in sheets of 3 or 6ft. square.

PATIENT'S MEASUREMENTS.

1. Circumference of limb at junction of middle and upper 1/3's of the thigh.
2. Circumference of limb at junction of middle and lower one thirds of the leg.
3. Distance between these points.

PREPARING THE PLASTICS AND DIAGRAM OF DESIGN.

The patient's measurements plus about 1½" all round, are marked on the polythene sheets as shown in Diagram 1. Marking is done with pen or chalk. The marked section is cut out of the polythene with a leather goods knife. It is then laid on the sheet of polyurethane and a dotted line is marked out in ink, ½" - ¾" away from its borders. The polythene section is then put aside and the polyurethane cut out with scissors along the ink marks.

In this manner two sections are provided, (i) a polythene section which is 1½" larger all round than the patient's measurements (this is to allow an overlap and to allow also for the shrinkage of some ½" - 1" which occurs when a polythene sheet of these dimensions is heated and cooled); - and (ii) a polyurethane section which is ½" - ¾" larger all round than the polythene section.

The polythene is laid on top of the polyurethane so that the latter protrudes evenly all round and in this relationship they are laid on the tray and put into the oven. (Diagram 3).

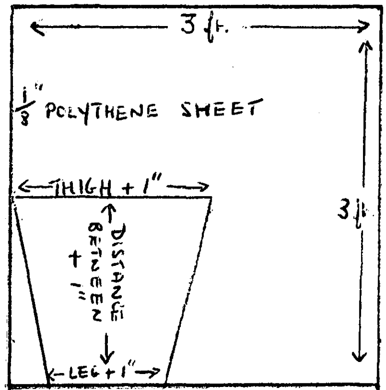


DIAGRAM I

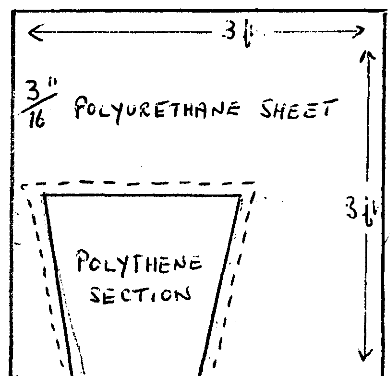


DIAGRAM II

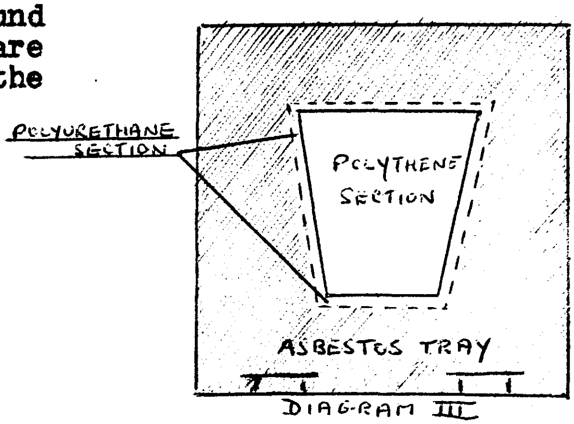


DIAGRAM III

MOULDING.

When the plastics are ready for moulding they are removed from the oven, covered with stockinette and wrapped round the limb in the appropriate position. To allow freedom of manipulation during the moulding, the patient's foot is suspended in a sling so that the leg is clear of the bed - making an angle of some 40° - 45° with the bed. A Guthrie-Smith sling is useful for this purpose. If a sling is not available the leg can be similarly elevated by an assistant holding the foot. The materials are wrapped in such a way that the free borders overlap along the lateral aspect.

This first stage of wrapping the materials is always most important. Having just been taken from the heat the polythene is at its most malleable and a firm wrap round by pulling on the free edges of the stockinette moulds it very accurately to the part. At this stage it will mould well, even to the double curve presented by a knee contracted to 35 - 40° of flexion. To achieve the best result it is desirable to have a 3" overlap of stockinette on each side so that a firm grip can be obtained for wrapping without touching the plastics. (See Diagram 4).

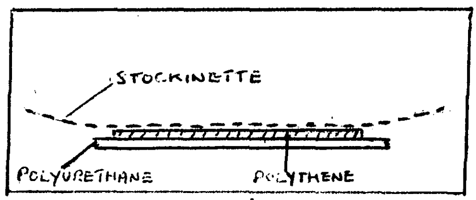


DIAGRAM 4.

Having obtained a close mould in this way the materials are held in situ while an assistant winds a 3" crepe bandage round them with slight tension. They are left, thus bandaged, to cool and harden, for 10 minutes. At the end of this time pressure with the fingers will confirm that the polythene is hard. The bandage is then unwrapped and the hard but resilient mould can be 'sprung' from the limb.

It is usually wise, howdver, before removing the splint to check that the free broders are overlapping reasonably evenly. An inexperienced operator may find, for instance, that there is a large overlap at thigh leval and a gap at calf level through the plastics having been wrapped carelessly and then bandaged in an uneven alignment as regards the free lateral borders. If this is the case it is best to detect it while the splint is on the patient so that the exact amount of excess can be marked out for later removal. Nothing can be done about the gap but at least this can be made even all the way up and down, and if a leather tongue is fitted during finishing the skin will not be pinched when the splint is put on. This pinching of the skin between the hrd borders of the polythene was a somewhat troublesome feature during the early development of this splint, and is the reason why it was decided to add 1" - 2" extra breadth when transferring the patient's measurements to the polythene, allowing the borders to overlap so that pinching is avoided and there is no need to waste time and materials on a leather tongue.

If the moulding and the overlap are satisfactory a few ink marks are made along the line of the latter and the splint is taken off, (see Diagram 5) and set aside to cool to room temperature. The advantage of making these marks is that they show exactly where the borders will meet when the splint is put on the limb and this will determine the position of the buckles and the length of the straps. These are fitted after the splint has cooled to room temperature. This may take an hour or so, and if these marks are not made the patient would have to wait in the Department for a fitting.

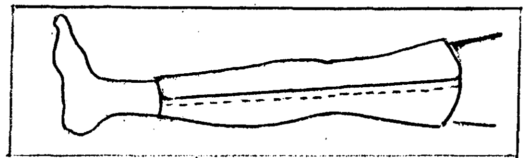


DIAGRAM 5.

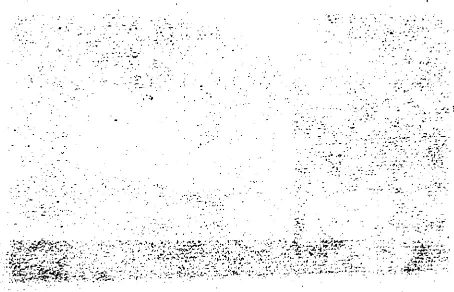
FINISHING.

The splint, when cooled to room temperature, is ready for wear if required for a short time. It retains enough resiliency to be pulled apart for 'slipping' over the limb. A few turns of bandage will hold it in place.

In cases of chronic joint disease, however, a splint is often required for an indefinite period, and it is therefore worth while carrying out a few more procedures to obtain the maximum comfort and efficiency. Ventilation holes (1/16" - 1/8") are punched out at 1" intervals. The polyurethane overlap of ½" - ¾" is trimmed back to ¼" or less all round. Sometimes it is better to turn the polyurethane overlap at the bottom and top of the splint back over the polythene and glue it on so that these borders are padded and therefore less likely to rub the skin. This extra procedure can be avoided if a padded border is planned in advance, by turning the top and bottom overlapping edges back and pressing firmly onto the hot polythene as soon as the plastics are removed from the oven, and before they are moulded to the patient. They "adhere" well and will usually stay firmly fixed when the splint cools.

Three or four straps and buckles (or press-studs) are provided at intervals along the free borders. As described above, the splint is moulded so that these borders meet along the lateral aspect of the leg and thigh so that the straps and buckles are on the outside and do not chafe the other leg. Having the opening at the side also makes the splint a stronger opposing force to flexion movement than if it were at the front or back. It is also more comfortable. Straps and buckles are easy for the patient to fasten and unfasten, and are much less bother than wrapping and unwrapping a bandage. Press-studs are even less trouble and are sometimes essential for rheumatoid patients with deformed fingers.

The fully finished splint, therefore, has ventilation holes, is provided with buckles and straps and, if necessary, has padded upper and lower borders. The weight of such a knee splint for an adult is 18ozs. and the cost of the materials 14/-. (approx.).
(The weight and cost of materials given here is for an adult's appliance completed with straps and buckles. This will apply to all appliances described.).



VOLAR WRIST SPLINT.

Ventral view of the splint.

Dorsal view.
Press-studs have been used instead of buckles, as they are easier for a rheumatoid patient to fix.

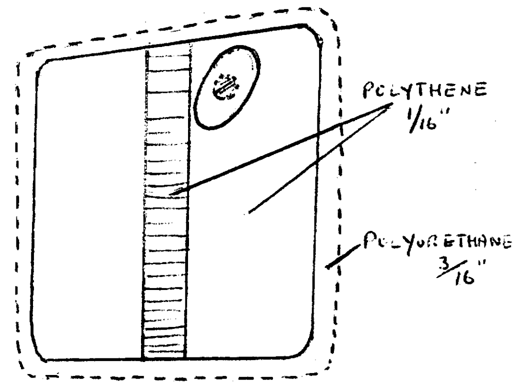
MATERIALS.
Polythene 1/16". Polyurethane 3/16".

MEASUREMENTS.

1. Circumference of forearm, 1" proximal to mid point.
2. Circumference of hand ½" proximal to M.P. joints.
3. Distance between these points.

PREPARING THE PLASTICS AND DIAGRAM OF DESIGN.

The materials are cut and laid out as shown in the diagram. Since 1/16" polythene is used in this case and is rather resilient, and extra 1" wide strip of polythene is cut and laid on top as illustrated. This will provide extra strength along the volar aspect of the splint. During heating in the oven it will coalesce so completely with the main polythene section that it will be barely visible, (see ventral view of splint on previous page).



Thumb-holes are cut in both plastics. In the polythene it is of roughly the same size and shape as the patient's thenar eminence and set at a similar angle. In the polyurethane the thumb hole should not exceed ½" - ¾" and is thus smaller than that in the polythene. The rationale of this is that when the patient's thumb is pushed through the holes during moulding the elastic polyurethane forms a 'sleeve' round the base of the thumb and so protects it from heat from the edges of the polythene thumb hole, which lies at a lower level round the thenar eminence.

MOULDING.

The patient sits with his hand supinated and dorsiflexed to 20 -30° and his thumb in the semi-opposed position. His thumb is inserted through the thumb-hole in the plastics and these are drawn down over the thenar eminence and wrapped rather firmly round the hand and wrist, so that the free borders meet (or better still, slightly overlap) on the dorsum. Holding them thus with one hand a crepe bandage is wound round them. The operator requires no assistance in most cases as the patient can usually co-operate by keeping his hand dorsiflexed, either voluntarily or with his other hand, but occasionally, as for instance in very spastic hemiplegia, it is better to have an assistant holding the hand dorsiflexed while the plastics are moulded and bandaged in place. Once this has been done the operator can himself hold the hand in the correct position for the 4 - 5 minutes required for cooling and hardening of the polythene. It is permissible to apply intermittent pressure with his thumb into the hollow of the hand while the polythene is soft since this concavity tends to escape the moulding pressure of the bandage.

After unwrapping the bandage from the 'set' plastics the usual ink marks are made (as for the knee splint) along the junction of the free borders on the dorsum. The splint is then 'sprung' and put aside to cool to room temperature before finishing.

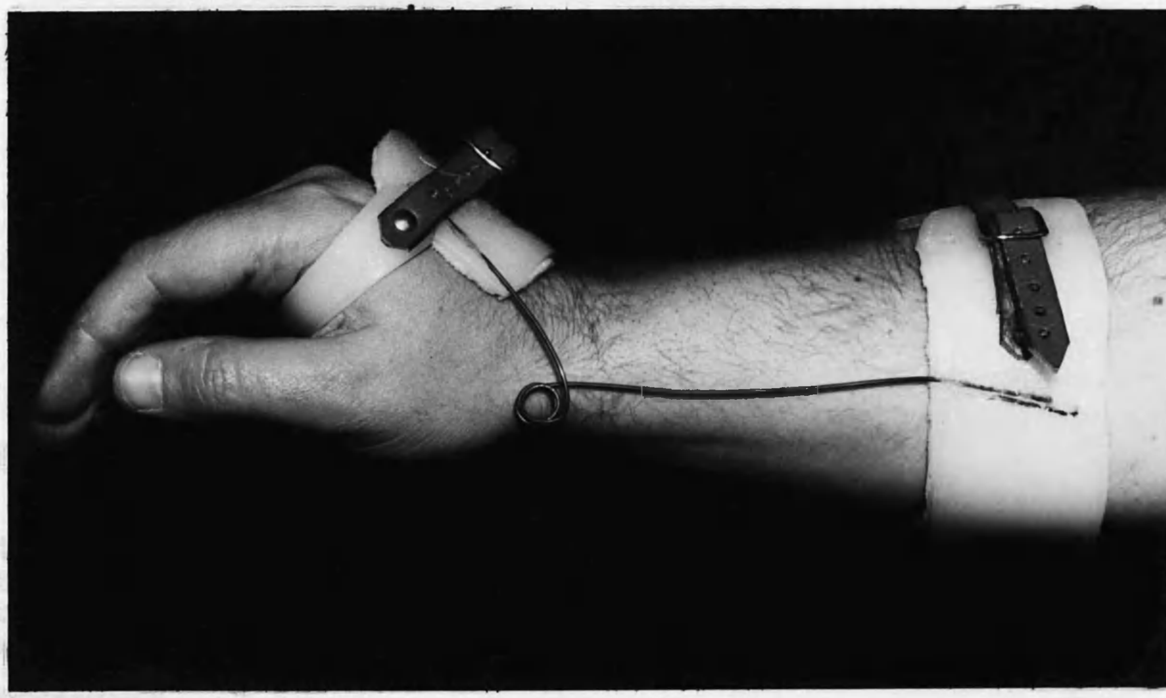
FINISHING.

The polyurethane overlap is trimmed off from the borders. Ventilation holes are punched. Two straps and buckles, or straps and press-studs are provided - one an inch distal to the wrist joint and the other an inch distal to the proximal end of the appliance.

An adult wrist splint weighs 2½ - 3½ozs. and costs 2/1d. - 2/10d.

A child's splint weighs 1½ - 2ozs. and costs 1/4d. - 1/8½d.

"LIVELY" COCK-UP WRIST SPLINT.



Prototype "Lively" Wrist Splint.

MATERIALS.

Polythene 1/8". Polyurethane 3/16".

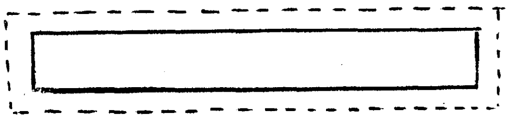
MEASUREMENTS.

1. Circumference of forearm 1" proximal to mid point.
2. Circumference of hand ½" proximal to M.P. joints.
3. Distance between these points.

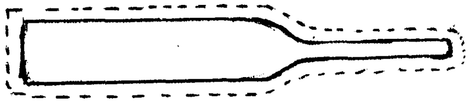
The forearm band is 2" wide.
The hand band is 2" wide over the dorsum and ¼" - ½" wide over the palm.

PREPARING THE PLASTICS AND DIAGRAM OF DESIGN.

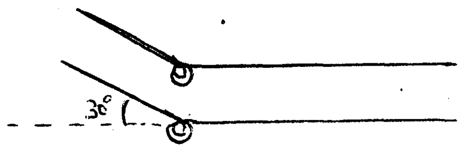
These are composed in the relationship shown in the diagrams. This splint is based on the Bunell hand splint (Bunell 1946, 1950) but adapted to the technique of direct application to the patient and using plastics in place of leather and metal.



......Forearm Band.



......Hand Band.



......16 gauge spring steel wire.

MOULDING.

Two bands of the plastics are cut and moulded to the patient in the usual way. That part of the hand band which will pass across the palm of the hand is made narrow ($\frac{1}{4}$2 - $\frac{1}{2}$") so as to allow objects to be gripped with a minimum of interference from the splint.

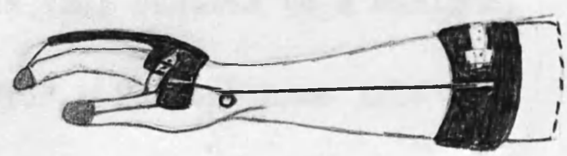
FINISHING.

When cooled, each moulded band is provided with a strap and buckle. They are then joined together on each side of the forearm and hand by 16 gauge spring steel wire previously measured and coiled as shown in the diagram above. The coils in the wire give it a spring, the degree of which is determined by the number of coils. Two are usually sufficient. These springs are situated in line with the wrist joint, one on either side, and do not therefore interfere with flexion - extension movement. (I have found that if the spring is situated on either the dorsum or flexure of the joint there is restriction of this range, the machanics of these arrangements being such that flexion tends to displace the forearm band proximally and the hand band distally because of the shortened distance between these points. The wires are, of course, rigid along the plane of the forearm so that the bands have to displace.)

The wires are very simply attached to the bands. They are heated to a dull red and then pressed into the polythene, this melts and the wire embeds itself. (See photograph on previous page).

The weight of this splint is 2ozs., and the cost 1/8d.

This type of splint is mainly of value in the treatment of radial paralysis. It allows the hand to be used more freely by stabilising it in the gripping position by bringing it back to this position after voluntary flexion. It also prevents overstretching of the paralysed wrist extensors. No finger extension mechanism is shown in the photograph, but this splint was an experimental one to determine whether or not it was possible to make lively splints with the P.P. plastics. It was moulded on my own hand and wrist and I wore it throughout a whole day to test it. I found it to be light, comfortable and efficient. Later a finger extension mechanism was added. The hand band was detached and a differently shaped piece was moulded and re-attached. The dorsal section was similar to that in the photograph but extended over the dorsum of the fingers just distal to the proximal I.P. joint, the fingers being slightly flexed at the M.P. and I.P. joints during moulding. The proximal half of the dorsal part of the band was extended to overly to the M.P. joint of the thumb. "Glove tips" and rubber bands were attached to the distal edge of the band to provide the small extensor force required for fingers and thumb. (see diagram).



The situation of the band and the small extensor force employed were such as to prevent hyperextension at the M.P. and I.P. joints. My experience with this splint was such that I believe it to be capable of development into an appliance comparable to that described by Bunell and Capener. It can be made at a fraction of the cost and much more quickly. A technician or Physiotherapist, experienced in working with these plastics, could make them. The Bunell and Capener splints require high technical skill and special equipment.

The development of "lively" splints using P.P. plastics was not carried further because of pressure of other work and because only one case of radial paralysis appeared in the Department. This patient (Case 308) was treated with a static cock-up splint and exercises and recovery occurred before work on the "lively" splint was complete.

DORSAL WRIST SPLINT.

This photograph illustrates how, in this type of splint, there is only a narrow band crossing the palm. Interference with gripping objects is thus reduced to a minimum.

MATERIALS.

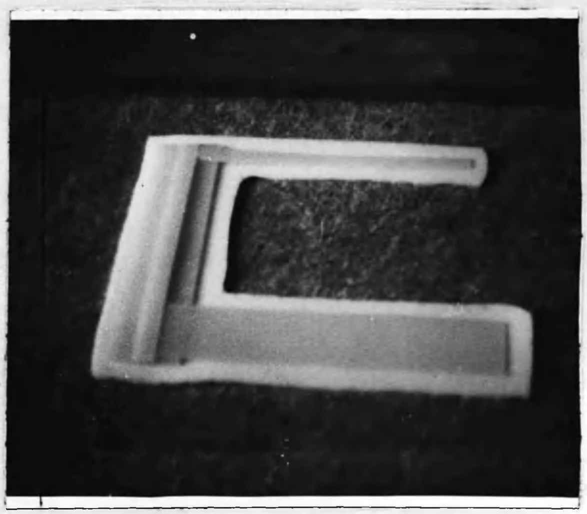
Polythene 1/8" and 1/16". Polyurethane 3/16".

MEASUREMENTS.

1. Circumference of forearm at mid point or slightly proximal to this, plus $1\frac{1}{2}$".
2. Circumference of hand $\frac{1}{2}$" proximal to M.P. joints, plus $1\frac{1}{2}$".
3. Distance between these points.

PREPARATION OF PLASTICS AND PHOTOGRAPH OF DESIGN.

The dorsal strip ($\frac{1}{8}$") must be almost rigid and so an extra ($\frac{1}{8}$") strengthening strip ($\frac{1}{2}$" wide) is laid along on top. The fixating bands round the forearm need not be rigid so 1/16" polythene is used.
Polythene does not stretch so the palmar band can be made of 1/16" polythene. This is quite strong enough to support the hand and interferes less with gripping than a $\frac{1}{8}$" band.



MOULDING.

The patient holds the hand dorsiflexed with his good hand. The dorsal strip is laid along the dorsum, and the forearm and hand bands are wrapped round to overlap it, the measurements being such as to allow of 1" - 1½" overlap. The plastics are then bandaged in position. A period of at least 12 minutes must be allowed for cooling as the dorsal strip is ¼" thick down its centre and takes this time to cool and set sufficiently for removal.

The bandage is then unwrapped, the mould checked and marked, and the splint is then removed.

FINISHING.

The polyurethane overlap is cut off. Ventilation holes are unnecessary in this splint as it is very open in construction.

The large overlap allowed for when taking the measurements brings the free borders of the encircling bands back over the centre part of ¼" thickness and onto the ⅛" thick side of the dorsal band, (see photograph on previous page). The reason for this is that it can then be fixed by press-studs which are stamped through the polythene itself. The bifurcated press-studs are rather short in length and can be brought together through polythene of up to ⅛" thickness, but no thicker. By this manoevre of design straps are rendered unnecessary and so a little time and material is saved. (This technique can be adapted to any splint).

The weight is 2½ozs. and the cost 2/1d.

VENTRAL WRIST SPLINT

WITH EXTENSION TO PREVENT ULNAR DEVIATION OF FINGERS.

Photograph of dorsal view of splint, fitted to a patient with rheumatoid arthritis. The wrist joint was painful and swollen. The M.P. joints were distended and ulnar deviation of the fingers was commencing.

MATERIALS.

Polythene 1/16". Polyurethane 3/16".

MEASUREMENTS.

1. Circumference of forearm 1" proximal to mid point.
2. Circumference of hand ½" proximal to M.P. joints.
3. Distance between points 1 & 2.
4. Distance from 5th M.P. joint to tip of 5th finger.
5. Circumference of 5th. finger (or of 4th & 5th fingers).

PREPARATION OF PLASTICS AND PHOTOGRAPH OF DESIGN.

The measurements plus ½" all round are marked on the polythene and the plastics are laid out in the usual way (see photograph opposite. Note that the strengthening strip has been omitted - this was an oversight.)

MOULDING.

This is carried out in the same way as has been described for the ventral wrist splint, the only extra being that the extension piece is bandaged round the 5th. (or 4th & 5th) finger. The finger is slightly flexed at its M.P. and I.P. joints.

FINISHING.

This includes trimming, punching holes and fixing straps and press-studs. The moulded extension piece is usually left as it is since it is unusual for the little finger to slip out. A small strap to encircle the finger and fixed by a press-stud may, however, be added as an extra precaution.

The weight of this appliance is about 4ozs. and the cost 3/2½d.

HAND SPLINT FOR PREVENTING

ULNAR DEVIATION OF FINGERS.



Photographs.

The patient had rheumatoid arthritis (two years duration) with early ulnar deviation. This could be fully corrected passively and the hand splint is shown maintaining full correction whilst leaving the wrist and three fingers free for use. (Case 265).

MATERIALS.

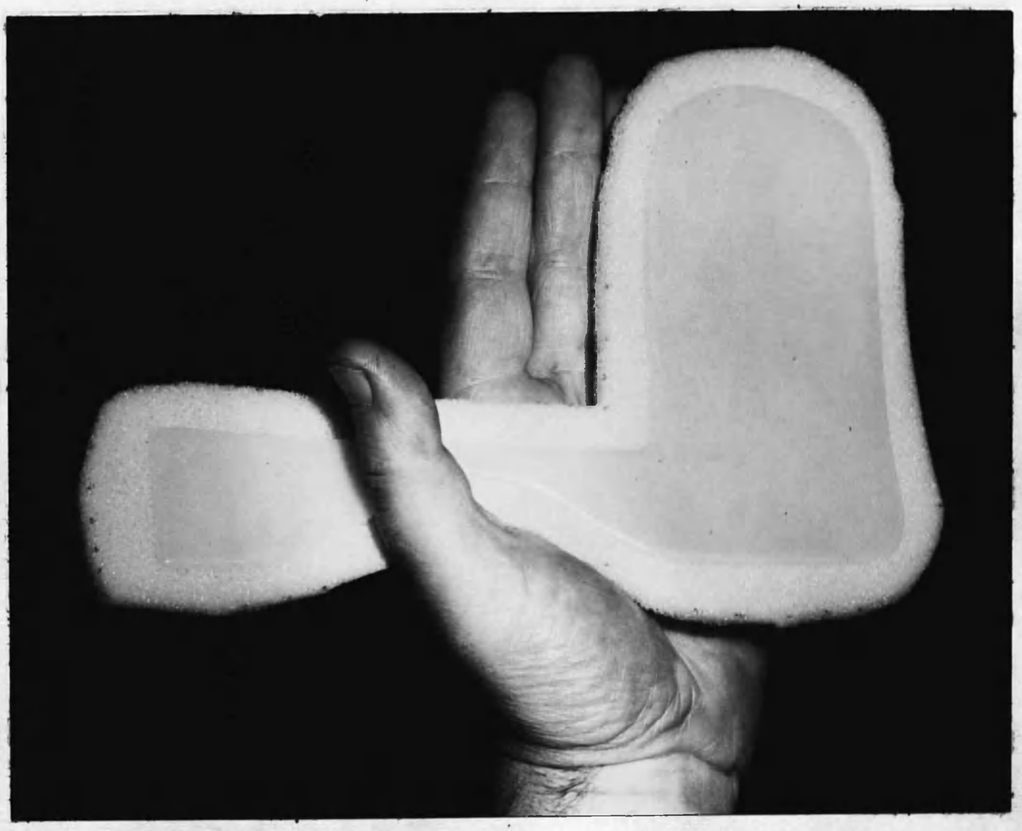
Polythene 1/16". Polyurethane 3/16".

MEASUREMENTS.

1. Circumference of hand ½" proximal to M.P. joints, plus 1".
2. Distance from level at 1. to the tip of the little finger.
3. Distance from tip of little finger to base of hypothenar eminence.
4. Circumference of 4th and 5th fingers.

PREPARING THE PLASTICS AND PHOTOGRAPH OF DESIGN.

The patient's measurements are transferred to the polythene and the appropriate shape is cut out. The polyurethane is then cut - a little larger all round as usual. (In the photograph overleaf it will be seen that the polythene is "adherent" to the polyurethane. This was achieved by heating them for the appropriate period in the oven and then cooling. This was done to



make the design, and its position on the hand, clear for photographing).

MOULDING.

The plastics are then heated, wrapped round the hand and bandaged into position for 4 - 5 minutes. The bandage is then removed and the mould checked. The extra 1"' added to the patient's measurements round the hand results in the overlapping of the band - shown on the left of the above photograph - ovef that part of the plastics shwon on the right of the photograph. This allows them to be fixed together by a press-stud in the plastics. (see Photograph)

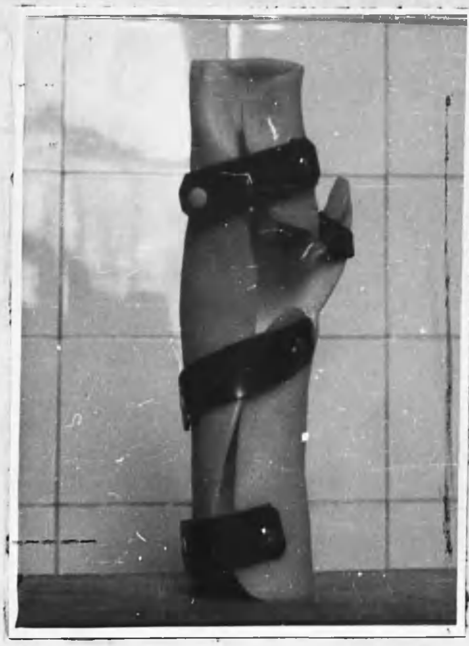
FINISHING.

The polyurethane overlap is trimmed off as usual and a press-stud is provided as in the photograph, No. Ventilation holes are not really necessary but they may be punched if desired.

The weight of this splint is 1oz. and the cost ninepence.

WRIST AND FINGER SPLINT FOR USE IN SPASTIC PARESIS.

TYPE A.



Photographs.

Above. Show front and back views of the splint.

Opposite. The splint being worn by its owner, a patient with spastic left hemiparesis.

MATERIALS.

Polythene 1/16" or 1/8".
Polyurethane 3/16".

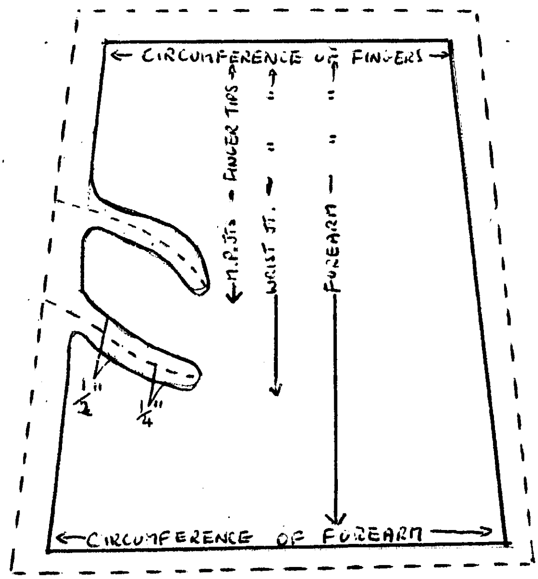
MEASUREMENTS.

1. Distance from finger tips to 1" proximal to mid point of forearm.
2. Distance from finger tips to wrist joint.
3. Distance from finger tips to M.P. joints.
4. Circumference of fingers at proximal I.P. joints.
5. Circumference of wrist.
6. Circumference of forearm 1" proximal to its mid point.
7. Length of thumb from M.P. joint to its tip.
8. Hemi-circumference of thumb.

PREPARING THE PLASTICS AND DIAGRAM OF DESIGN.

The measurements are marked on the polythene and the resulting design is shown opposite. The cut outs in the polythene which will enable the thumb part to be moulded must be ½" wide so that when the underlying polyurethane is divided, as shown by dotted lines, there will be an overlap of ¼" of polyurethane covering each edge of the polythene.

FOR LEFT SIDE.



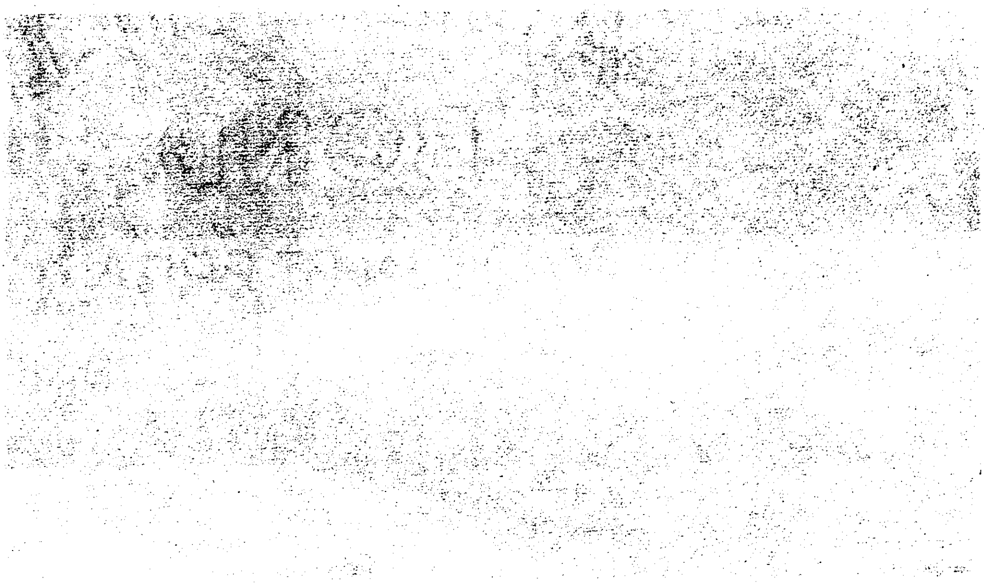
MOULDING.

The flexion spasm of fingers and wrist make this a rather difficult splint to mould. The most successful method was to first allay the spasm by passive manipulation of the flexed fingers and wrist into the desired position of 30° - 40° dorsiflexion at the wrist joint and almost full extension of the fingers. The usual type of case dealt with presented clasp-knife rigidity and by repeated stretching of the spastic flexors for a few minutes the spasm abated greatly and remained abated long enough for the plastics to be wrapped round and bandaged in position. It is usually necessary to have an assistant holding the hand and fingers dorsiflexed and the thumb extended by gripping the finger tips. Moulding is easier if the hand is held supinated as far as possible. Once the warm materials are in position the heat tends to further allay the spasm and it is usually a fairly simple matter for the operator to maintain the desired position for the 8 - 10 minutes required for cooling and setting.

FINISHING.

Three straps and press-studs are provided in the position shown in the photograph. The straps should be 1" wide to allow a wide area of pressure. This is particularly necessary over the dorsum of the fingers as they have a strong tendency to flex inside the splint unless strong counter-pressure is exerted. The soft polyurethane lining is sufficient to prevent excoriation of the skin over the dorsum of the fingers even where the flexion force is strong. A strap and press-stud is also fixed to exert a similar counter force to flexion of the thumb.

The weight of this splint is 6ozs. and the cost 4/9d.



ELBOW SPLINT.

This shows a patient with rheumatoid arthritic changes in the elbow joint. There was gross bony destruction and the ulnar nerve was compressed by any movement of the joint outside a very limited range. Severe pain resulted. (Case 30).

This shows the elbow immobilised in the splint.

MATERIALS.

Polythene 1/16". Polyurethane 3/16".
1/16" polythene strengthening strip.

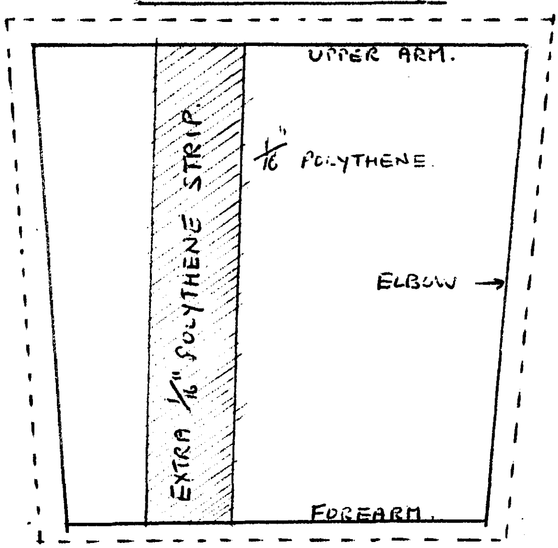
MEASUREMENTS.

1. Circumference of upper arm 1" proximal to its mid point.
2. Circumference of forearm 1" distal to its mid point.
3. Distance between these points.

PREPARING THE PLASTICS AND DIAGRAM OF DESIGN.

The plastics are cut to the above measurements plus 1" all round in the usual manner. The resulting shape is shown in the diagram. The strengthening strip is 1½" wide and it will be seen that it is placed to one side of the splint. The purpose of this is to bring the strengthened area of the splint down the ventral surface of the limb and yet allow the opening to be along its lateral border. Having the opening in this position avoids chafing skin or clothes and adds to the antero-posterior strength of the appliance - where it is usually most needed.

RIGHT SIDED SPLINT



MOULDING.

The strengthened area is laid down the ventral aspect of the arm and the larger area (shown on the right of the above diagram) is wrapped round the medial border and back over the posterior surface until it overlaps the border lying on the lateral aspect. It is then bandaged into position. After 4 - 5 minutes it can be removed for finishing.

FINISHING.

Three straps and press-studs are fitted in the position shown in the photograph.

Weight 3½ozs. Cost 2/10d.

LONG LEG AND FOOT SPLINT.

(No photograph available).

MATERIALS.

Polythene 1/8". Polyurethane 3/16".

(For children 1/16" polythene, plus a 1/16" strengthening strip, and 3/16" polyurethane.)

MEASUREMENTS.

1. Circumference of thigh at junction of upper and middle one thirds.
2. Circumference of knee.
3. Circumference of calf at its thickest point.
4. Circumference of ankle round malleoli.
5. Circumference of ball of foot.
6. Distance between 1. and tip of large toe - measured along the posterior surface of the leg and along the sole of the foot.
7. Distance between 1. and middle of lateral malleolus.
8. Distance between 1. and middle of knee.
9. Distance between lateral malleolus and tip of the big toe - measured along posterior sufface of ankle and heel, and along the sole of the foot.

The tape measure should, in all cases, be held closely into the curves of the leg and foot to obtain the correct surface measurements.

PREPARING THE PLASTICS AND DIAGRAM OF DESIGN.

The measurements are marked on the polythene. The marks are joined together by ink or chalk lines and the resulting design is shown in the diagram opposite. It will be seen that the pattern narrows sharply just below the level of the malleoli and then widens out smoothly to the level marked 'circumference of ball of foot'. Thus the narrow area (nor more than 2" wide) overlies the heel. By keeping this area narrow the borders shown joined together by dotted

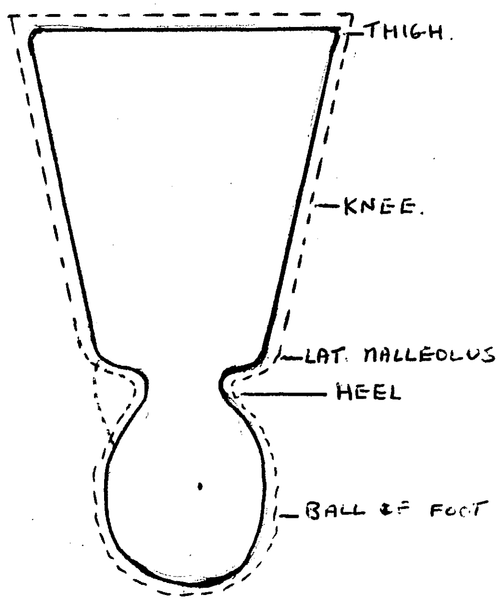


Diagram 1.

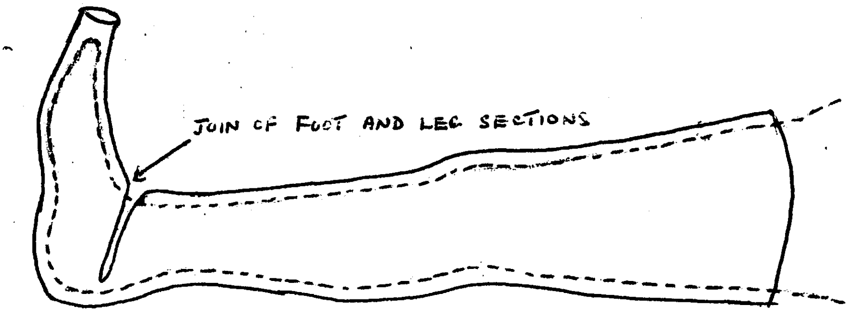


Diagram 11.

lines and arrows in Diagram 1. come together when the plastics are wrapped round the foot and ankle with the foot held in the fully dorsiflexed position. (See Diagram 11.)

If the area overlying the heel is made wider than 1½" - 2" wrinkling of the plastics in that area will occur during moulding.

MOULDING.

The leg is suspended at an angle of some 45° by a sling round the heel - as described when dealing with the knee splint. In this case however there must be no interference with moulding round the foot and ankle and therefore the sling is made in a special way. One end of a 3" cotton bandage is wrapped round the heel and tied firmly over the dorsum of the foot, and the leg is suspended by tying the other end to a suspension hook. Thus there is only one narrow 'rope' of material running upwards from the foot (see Diagram 3) - and this is at the point where the borders of the plastics will meet and does not, therefore, obstruct moulding.

The opening in this splint is situated along the middle of the anterior border of thigh and leg, and along the dorsum of the foot. It would be theoretically better to have the opening along the lateral border

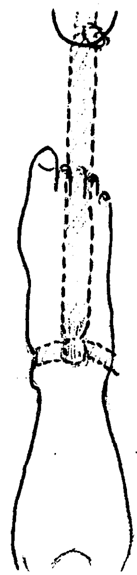


Diagram 3.

of the limb as in the knee splint but this would greatly complicate the design and the moulding. In practice no difficulties have arisen from having it at the front since this splint is mainly intended for use by non ambulant patients.

Moulding is carried out in the usual way. The knee is slightly flexed (5^o) and the foot fully dorsiflexed. An assistant is required to mould the foot and ankle sections while the operator wraps round the upper part of the splint and bandages it into place. The bandaging is then carried on round the ankle and foot after checking that the moulding to these parts is accurate. Because of the large area of plastics to be moulded it behoves the operator and his assistant to be quick with their work as after a lapse of about 3 minutes the polythene begins to lose its malleability. This is particularly relevant when making a child's splint where 1/16" thick polythene is used, as the thinner plastic cools more quickly.

The moulded splint can be 'sprung' after some 10 minutes and is then set aside to cool. It is usually wise to prop up the foot piece with a pillow so that it maintains its full 90^o dorsiflexion until the splint has cooled down to room temperature.

FINISHING.

Three or four straps and press-studs are fitted at intervals from 1" below the upper border to 1" above the malleoli. The press-studs are set on the lateral side of the splint to avoid chafing the other leg. Ventilation holes are punched.

Polythene of 1/8" thickness is not rigid enough to keep the foot dorsiflexed to 90^o and two side straps must be fixed from the foot piece to the part of the splint encircling the ankle. (See Diagram 4).

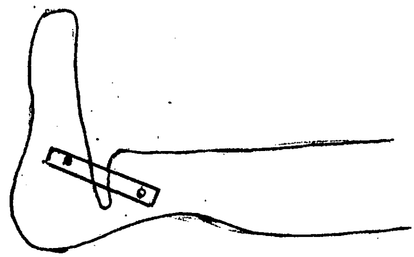


Diagram 4.

It may be pointed out, however, that the resiliency of the polythene is an advantage where the purpose of the splint is not to maintain an already adequate dorsiflexion but to correct a plantar flexion contracture. In this case two adjustable straps and buckles are fitted and these can be progressively tightened thus gradually obtaining more dorsiflexion, the resilient polythene following the gain in range. A rigid splint would have the disadvantage of requiring to be remoulded at each gain in dorsiflexion and clearly these gains would have to be obtained by other procedures, whereas the polythene splint with adjustable straps will itself obtain correction in many cases.

As described when discussing the knee splint the polyurethane overlap round the borders may, with advantage, be turned back over the polythene and glued on. This tends to make it a little more comfortable and is an added safeguard against the skin being rubbed, especially under the upper border. However, the overlap of polyurethane is usually, in itself, a sufficient protection against the hard polythene rim without its being turned back and glued. (See Diagram 5.)

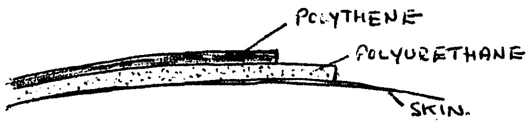


Diagram 5.

Weight of appliance - 30ozs. Cost 22/-.

SHORT LEG AND FOOT SPLINT.

Legs and feet of a child of 4½ years suffering from cerebral palsy. The left foot was most affected and there was extreme spasm of the plantar flexors. The invertors, too, were moderately spastic.

Shows maximum correction (75 - 80) being maintained by the splint. By adjustment of the crossed, diagonally placed straps the inversion spasm could also be corrected and the foot maintained in the plantigrade position. (Case 50).

MATERIALS.

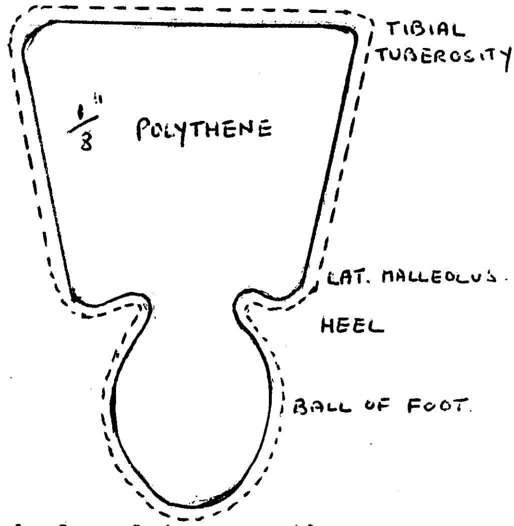
Polythene 1/8". Polyurethane 3/16".

MEASUREMENTS.

These are taken as has been described for the long leg and foot splint, but the upper border in this case is the tibial tuberosity.

PREPARING THE PLASTICS AND DIAGRAM OF DESIGN.

The measurements are marked on the polythene and the resulting design cut out. This is shown in the diagram opposite. (It will be seen that it is similar to the below knee section of the long leg and foot splint.)



MOULDING.

This too presents no differences to the method described for the longer splint.

FINISHING.

Ventilation holes are punched and two or three straps and press-studs (or buckles) are fitted as shown in the photograph. (It will be seen from the photograph that an extra band has been riveted onto the proximal end of this splint. This was done because the splint had, in error, been made too short to provide a good area of "grip", against the fixity of which the foot could be strongly dorsiflexed.)

As in the long leg and foot splint the diagonal straps may be permanently fixed to maintain a good dorsiflexion, or may be made adjustable to obtain a better dorsiflexion - as in the case photographed. (This particular splint was designed to be worn while walking and therefore as much of the splint as could be removed from the foot and ankle without reducing the mechanical advantage was cut out so that a sandal could be worn over the splint.)

Weight of adult appliance 14ozs. Cost 11/-.

HEEL-SORE SPLINT.

This photograph shows the splint fitted to a bedridden patient with a pressure sore on the heel. (Case 39). The design of the splint is such that all pressure is removed from the heel and transferred to the calf muscles whose larger surface area and softness is able to take pressure without skin breakdown. It will also be seen from the photograph that there is a free flow of air round the ulcer. The foot is held fully dorsiflexed by the diagonal straps so that the heel cannot fall down into the splint. The patient could exercise the calf muscles strongly by pressing the ball of the foot against the foot-piece of the splint. She did this every hour to offset venous stagnation and danger of thrombosis in the deep veins.

MATERIALS.

Polythene 1/16". Polyurethane 3/16".

1/8" Polythene strengthening strip.

MEASUREMENTS.

Similar to the short leg and foot splint but in this case the narrow section overlying the heel is made 2" longer to allow for the convexity under the heel in the finished appliance. (See "Moulding".)

PREPARING THE PLASTICS AND DIAGRAM OF DESIGN.

Diagram 1.

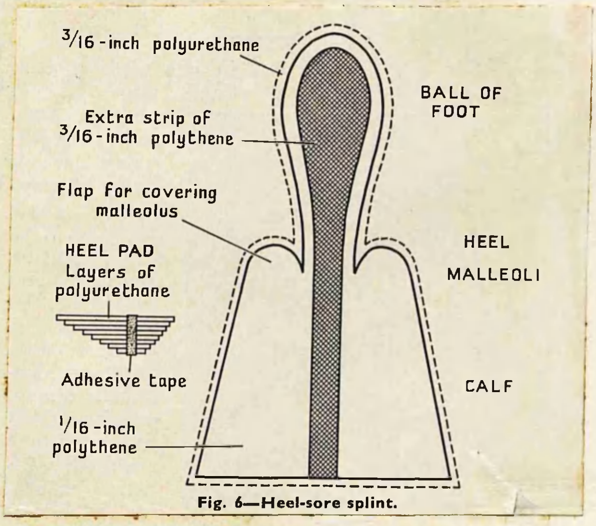


Fig. 6—Heel-sore splint.

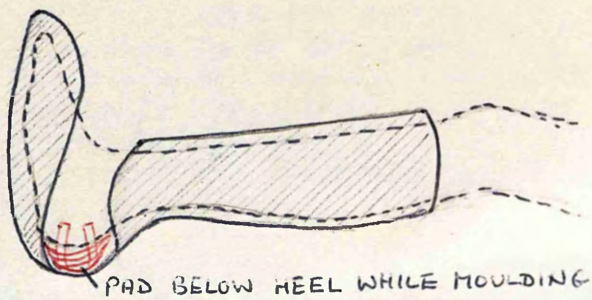
The materials are marked and cut out in the usual way and the design is shown in the diagram. It is particularly important to have deep malleolar flaps (see diagram) so that the patient's malleoli are well covered in the finished appliance, (see photograph). The reason for this precaution is that the bedridden patient for whom these splints are intended may well wish to change position at times and lie of their side. In such circumstances the soft polyurethane lining of the flaps will protect the malleoli. If the flaps are omitted or do not adequately cover the malleoli a pressure sore on the malleolus is liable to result from the edge of the polythene being pressed into the skin by the weight of the leg. (Case 38).

When only one splint is to be used a layer of 3/16" polyurethane is glued onto the medial half of the splint as a safeguard against the skin of the other leg chafing against the hard polythene.

MOULDING.

Diagram 11.

This is carried out in similar fashion to the short leg and foot splint, but with one extra procedure. This procedure is the taping of a pad of polyurethane (see Diagram 11) over the heel and distal part of the Achilles tendon. The effect of this is to create a permanent convexity below the heel



when the splint is cooled and set. In this the heel will lie free of pressure as previously described. It will be seen from diagram 11 and from the photograph that the plastics are moulded so that they extend a little beyond the tips of the toes. In this way pressure from the bedclothes on the toes is obviated.

FINISHING.

Ventilation holes are punched and straps and press-studs are provided as for the short leg and foot appliance.

Weight of this splint is 12ozs. Cost 9/6d.

CERVICAL SUPPORT.

This photograph shows the support in position on a patient who had gross destruction of the cervical spine from carcinomatous deposits (Case 37). She had severe root pain and the support was requested as an emergency. It was made and fitted within two hours of request. (This particular appliance is not quite typical in design because of the necessity of moulding on a deformed neck. For example the base on the chest is several inches lower than is usual.)

X

MATERIALS.

Polythene 1/8". Polyurethane 3/16".
1/8" polythene strengthening strips.

MEASUREMENTS.

Once a satisfactory design had been evolved (see below) the number of measurements required to be taken from the patient were reduced to a minimum. Such things as the width of the supporting strips and the shape and depth of the bases of the support over the chest and back were standardised and used in each case. These standard measurements are given in diagrams 3 & 4. The individual measurements are as follows:-

Anterior Section. (Diagram 1).

1. Distance between the angles of the rami of the mandibles.
2. Distance between the mental protruberance and a line joining the angles of the rami as in 1.
3. Distance between the angles of the rami and a horizontal line through the lower border of the manubrium sterni.
4. Length of a horizontal line across the chest, at the level of the lower border of the manubrium sterni, which extends 2" to each side of the width of the base of the neck.

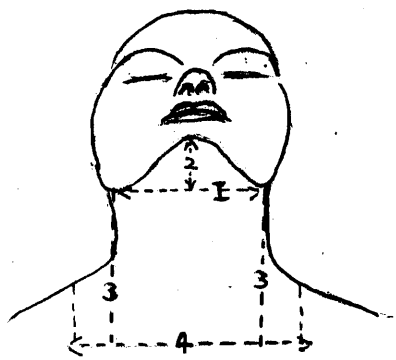


Diagram 1.

Posterior Section. (Diagram 2).

1. Distance between the ears measured over the occiput.
2. Distance between the line formed by (1) and the spine of the 1st. dorsal vertebra.
3. A horizontal line of the same length as "Anterior Section 4" measured across the back at the level of the 1st. dorsal vertebra.

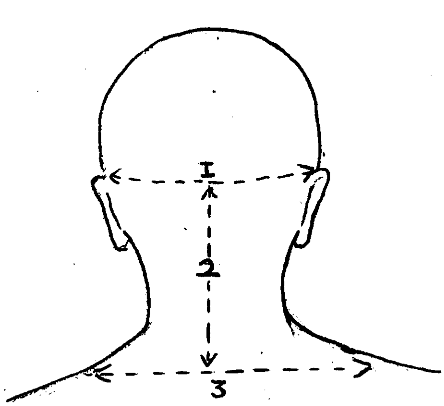


Diagram 2

PREPARING THE PLASTICS AND DIAGRAM OF DESIGN.

The measurements are marked on the polythene and joined together. Sharp angles are avoided and the resulting design is shown in Diagrams 3 &4. These represent the anterior and posterior sections respectively and shows the latter with the shoulder straps 'bonded' to it ready for moulding.

It will be seen from the diagrams that the strengthening strips are 1/8" thickness. Occasionally, if the head is heavy, these strips are better made of 3/16" polythene or even ¼".

The standardised width measurements are given in the diagrams as 1½" for the two vertical supporting strips of the anterior section and 2" for the one supporting strip of the posterior section. The depth of both front and back bases is standardised at 3". This is also a good average depth for the occipital part of the posterior section. The shoulder straps are 1½" wide.

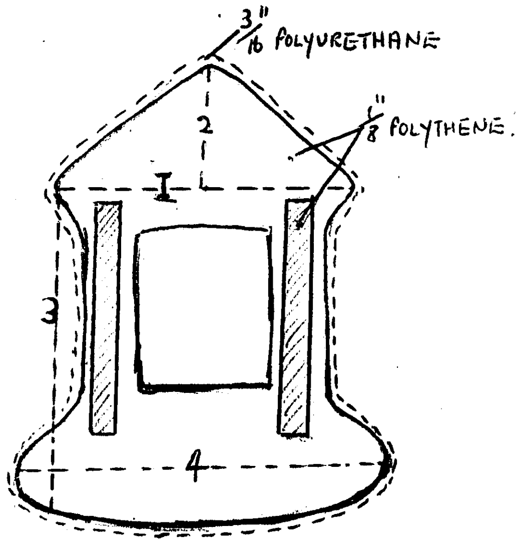


Diagram 3.

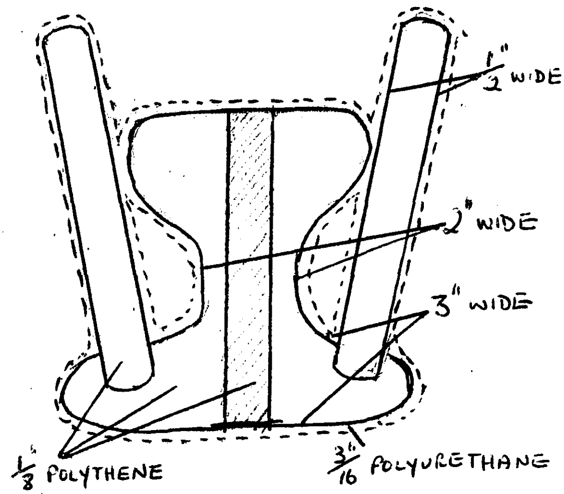


Diagram 4.

MOULDING.

Photograph 2.

This photograph shows the anterior section bandaged in place. The original technique was to mould front and back sections separately (as in the photograph) but later it was found quicker and more satisfactory to mould both simultaneously. (see overleaf.)

MOULDING (continued).

The patient sits on a chair with his head held (actively or passively) in the correct position - neither flexed nor extended, and looking straight to the front. For moulding the plastics the help of an assistant is desirable.

The anterior section is removed from the oven and covered with stockinette as usual. (The stockinette is previously cut in a similar shape to the plastics and is rather larger all round so that it completely covers them without being stretched). The section is then applied to the patient in the correct position and two or three turns of bandage over the vertex and round the neck mould it in place. As soon as this has been done the posterior section with its attached shoulder straps is taken out of the oven, covered in stockinette and applied to the patient. The bandage holding the anterior section is then carried on round the neck and occiput over the posterior section until both sections are moulded in correct relationship by the same bandage. The shoulder straps are laid over the shoulders and placed so as to overlap the base of the front section at the same time as the posterior section is applied and while they are, therefore, in their most malleable state. They do not need to be included in the bandaging process, the operator merely checking that they are in good position.

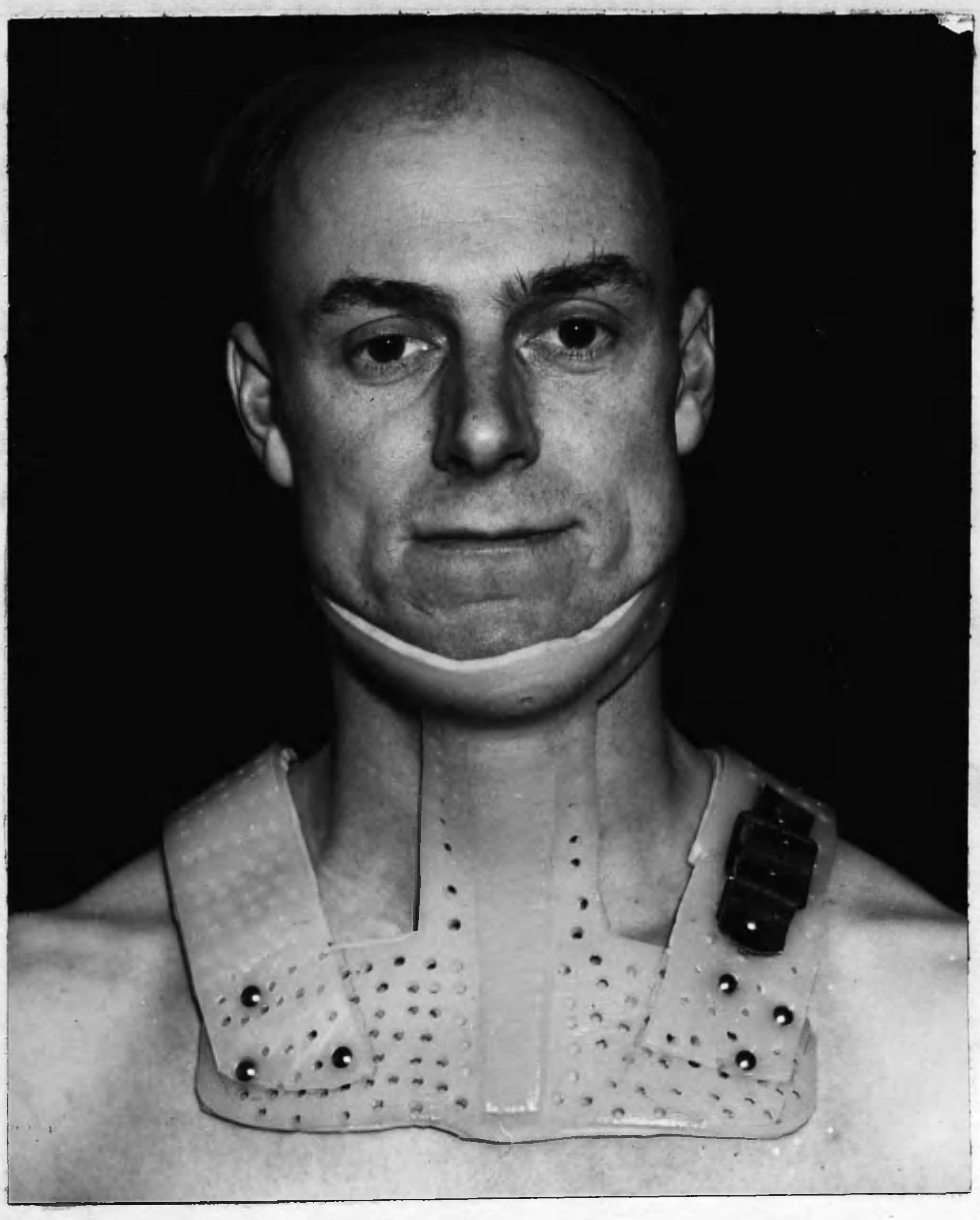
The patient sits with his head still for 15 minutes, after which time the plastics can be removed for finishing. This period of time may appear rather long for the patient to keep still but there are two factors which help him. One is that the warmth of the plastics is very soothing to the painful condition of the patient's neck and is virtually a pleasant heat treatment. The other is that after 6 - 7 minutes the plastics set sufficiently hard to take some of the weight of the head so that the patient can relax a little.

After unwrapping the bandage, and while the plastics are still closely moulded to the patient, the overlaps of the shoulder straps on the base of the anterior section are outlined in ink so that when riveting them together later they will be in their correct relationship. This avoids having the patient up for a fitting.

FINISHING.

By the method of preparing the plastics and moulding described above, the appliance is removed from the patient in two moulded sections, an anterior and a posterior, the latter having the moulded shoulder straps attached.

Finishing consists of riveting the free ends of the shoulder straps to the base of the anterior section. When thus joined, the left shoulder strap is divided at its mid point and the divided sections joined together again by a strap and buckle (or press-studs). The early examples of cervical supports were left thus, with only one strap and buckle, and the appliance was put on by pulling the divided strap apart and slipping the appliance on sideways from right to left. The strap and buckle was then fastened. (see photograph below).



Photograph 3.

FINISHING (continued).

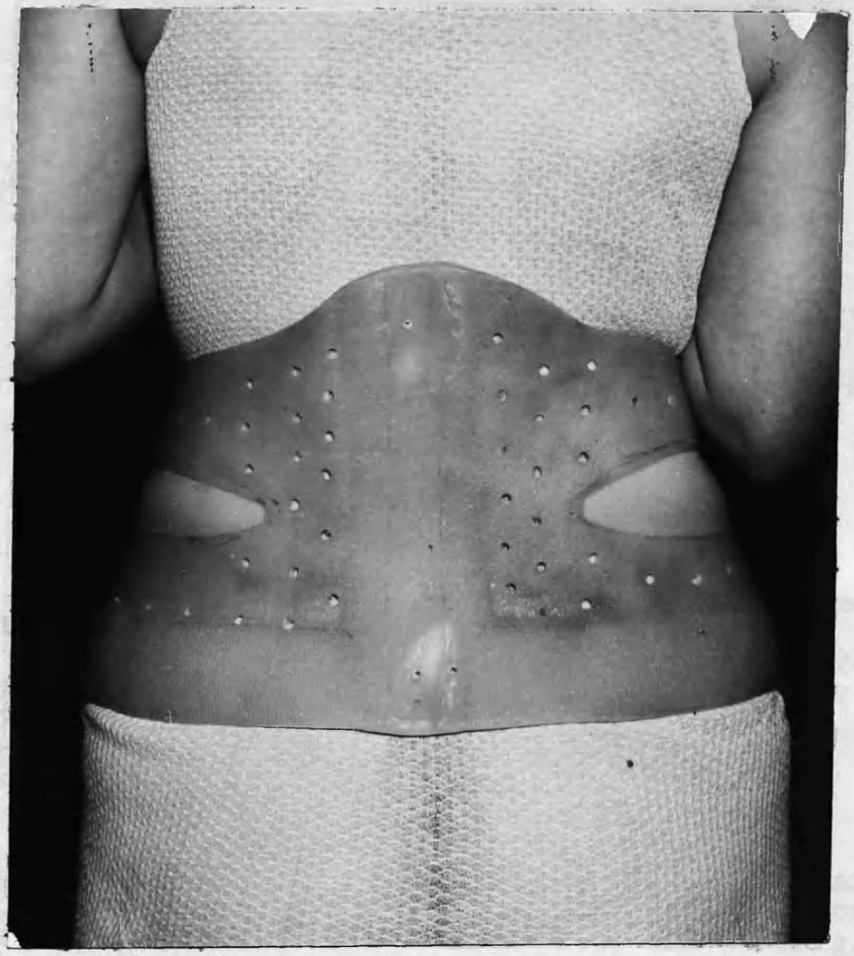
The appliance finished in this way was found adequate to prevent any flexion movement of the head, but rather too much rotatory and extension range was permitted, (about 1" of each). In order to make the appliance more rigid, and reduce these movements to a minimum, later examples were further provided with two straps and press-studs which joined the chin piece to the occiput piece on each side (see Photograph 1). The method of putting on the support remains the same but in addition the patient adjusts the two extra straps. Both the early and later type of support can be easily applied and removed by the patient without assistance.

The earlier type of appliance shown in Photograph 3 had one central supporting strip in the mid-line. One or two patients with prominent thyroid cartilages found swallowing a little embarrassed by the central strip. Later designs, therefore, make use of two supporting strips placed laterally, (see photograph 1).

Ventilation holes are punched out as usual though they are not strictly necessary in view of the open design of the support.

The weight of the appliance varies from 5ozs. in the case of a child (Case 18) to 12ozs. for an adult. male (Case 35). The cost of the materials therefore varies from 4/-. to 9/6d.

LUMBAR-ABDOMINAL SUPPORT.



This photograph shows the appliance in position on the patient. This was one of the first supports made and had a lace-up opening at the front. Later it was found better to have the opening at the side and the design was altered to achieve this. (see below).

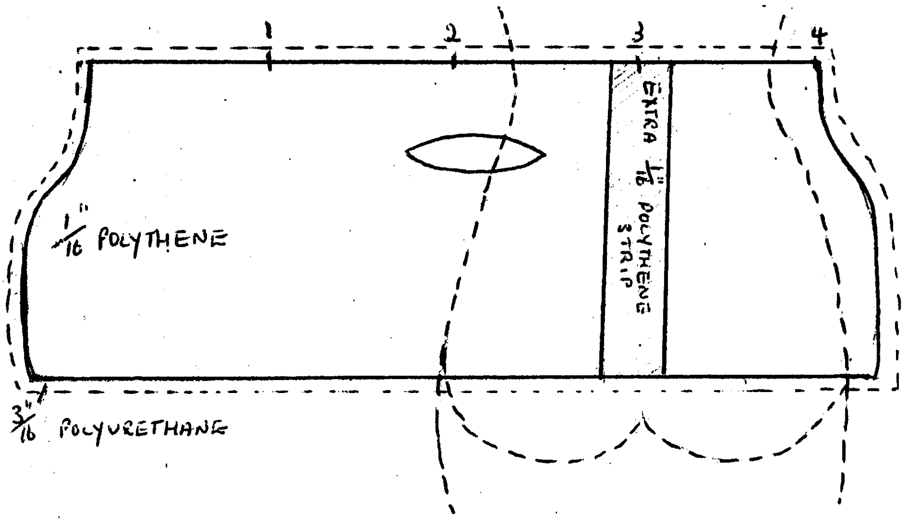
MATERIALS.

Polythene 1/16". Polyurethane 3/16".
Polythene strip, 1/16".

MEASUREMENTS.

1. Circumference of pelvis just above the level of the greater trochanter.
2. Circumference of the body 2" above the waist.
3. Distance between 1. & 2.

PREPARING THE PLASTICS AND DIAGRAM OF DESIGN.



These measurements are marked on the polythene and then joined up by curved lines as shown in the diagram above. The curve of the lines is necessary so that the free borders will meet evenly along the lateral aspect of the pelvis. Straight lines would result in an uneven gap at the junction owing to the double curve presented by this part of the body.

The top line of the diagram is divided into four equal parts. A strengthening strip 2" wide is laid vertically at point 3, and an elliptical "window" is cut 2" below point 2. The "window" is 2" deep and 4" long. The position in which the plastics will be applied to the body is illustrated by representing a posterior view of the patient's lumbar spine and buttocks drawn in dotted lines. It will be clear from this that when the softened plastics are wrapped round the free borders will meet along the right side of the waist and pelvis.

The "window" at waist level on the closed side of the support is essential to avoid wrinkling of the polythene which is not sufficiently malleable to accommodate itself to he sharp double curve presented by this part of the body.

If there is a sacro-iliac element in the patient's backache it is an advantage to strengthen the lower border of the design with a 1½" wide strip of 1/16" polythene (see photograph). This gives additional support of the "pelvic hoop" type.

MOULDING.

The patient stands upright with hands clasped behind his neck. If his abdomen is protruberent it is firmly bandaged before moulding commences. The operator positions the plastics on the patient's body as illustrated in the diagram on the previous page, and then wraps them firmly round and bandages them in place. The help of an assistant is of value for this procedure so that the operator can make sure that the vertical strengthening strip stays in its proper place overlying the lumbar spine and sacrum, while the assistant wraps the materials round and applies the bandage. The patient can then lower his arms but remains standing in optimum postural position for 8 - 10 minutes, while the polythene sets.

The bandage is then unwrapped, the moulding is checked and marked at the opening as usual. The cast is then 'sprung' and set carefully aside to cool to room temperature.

FINISHING.

The straps and buckles are fixed at intervals along the lateral opening. Ventilation holes are punched.

The weight of the appliance is usually between 12ozs. - 16ozs., and the cost of the materials is therefore between 9/6d. - 12/6d.

LUMBAR SPINAL SUPPORT.

Foreword.

I have used the term "Lumbar Spinal Support" to indicate an appliance which is larger and stronger than the Lumbar-abdominal support, and which does restrict the range of movement of the lumbar spine to a significant extent.

This photograph shows a three-quarters view of an example of this type of appliance. It may be noted that, when well moulded to the patient, polythene closely follows the curves of the body; this photograph showing that even the small depression of the umbilicus has been reproduced in the mould.

MATERIALS.

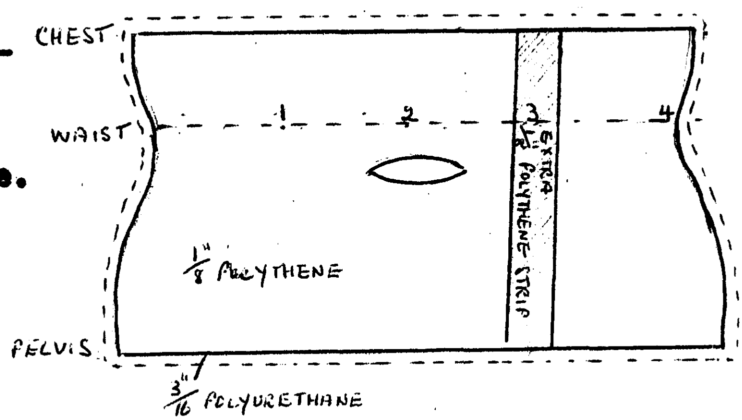
Polythene 1/8". Polyurethane 3/16".

MEASUREMENTS.

1. Circumference of pelvis just above the level of the greater trochanter.
2. Circumference of chest at the level of the lower angle of the scapulae.
3. Circumference of the waist.
4. Distance between the level of (1) and the "waist".

PREPARING THE PLASTICS AND DIAGRAM OF DESIGN.

The measurements are marked on the polythene sheet and are joined together to give the design shown in the diagram opposite. It will be seen that it is similar to that for the lumbar-abdominal support with the addition of the chest measurements.



MOULDING.

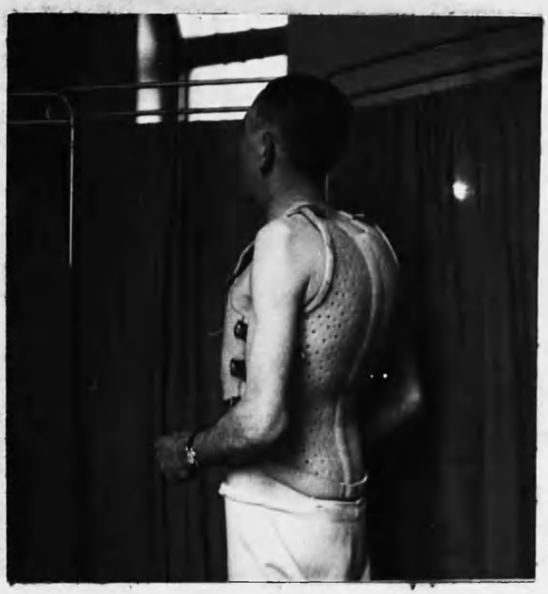
This is carried out in similar fashion to that described for the previous appliance. The plastics should however be left in situ for about 15 minutes to allow adequate setting of the thicker polythene.

FINISHING.

Four 1" straps and buckles (or press-studs) are fitted in the positions shown in the photograph, and ventilation holes are made.

The weight is approximately 2 - 2½lbs. Cost of the materials 25/- to 30/-.

SPINAL BRACE.



These photographs show two views of a brace made for a patient with chronic dorsal and upper lumbar backache caused by a long standing kyphosis of the dorsal spine with accompanying degeneration of the intervertebral discs.

MATERIALS.

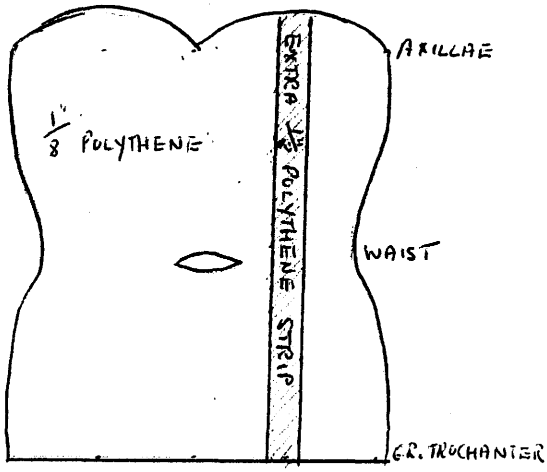
Polythene 1/8".
Polyurethane 3/16".
Polythene 1/8", strengthening strip.

MEASUREMENTS.

1. The circumferences of the body, from the level of the greater trochanter to the level of the axillae, are taken at 3" intervals.
2. Distances between these two levels.

PREPARING THE PLASTICS AND DIAGRAM OF DESIGN.

The measurements are marked on the polythene sheet. They are joined by curving lines and the resulting design is shown opposite. The strengthening strip and window are placed in the usual positions. It will be seen from the diagram that the parts which will mould over the upper chest and back are curved upwards. In this way they will come above the level of the axillae in the finished brace and so provide a little more support. (see photograph).



MOULDING.

The patient stands with arms abducted and the materials are wrapped round in the usual way and bandaged. The patient then immediately lowers his arms so that the contours of the chest and back take up the position they will be in when the finished support is worn. After 20 minutes the bandages are unwrapped. The mould is checked, marked and taken off.

FINISHING.

Ventilation holes are very necessary in this large, enclosing appliance and must be punched out at 1" intervals.

Two shoulder straps are fitted as shown in the photographs and should be 1½" wide where they come over the shoulders and narrowed to 1" where they approach the buckles. It is best to glue a strip of 3/16" polyurethane to the undersurface of the straps in order to make them more comfortable and to lessen the risk of skin abrasion.

Four straps and buckles (1" wide) are fitted along the lateral opening.

The appliance is put on by pulling it open and slipping over the body from left to right. The patient can apply and remove it unaided.

Weight 3lbs. Cost 37/-.

SACRAL BED-SORE JACKET.

MATERIALS.

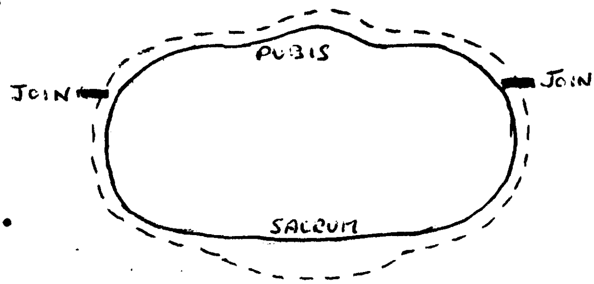
Polythene 3/16". Polyurethane ½" & 3/16".

MEASUREMENTS.

1. Circumference of waist.
2. Circumference of pelvis just above greater trochanters.
3. Distance between these circumferences.
4. Shape and size of bed-sore.

PREPARING THE PLASTICS AND DIAGRAM OF DESIGN.

The jacket is designed to be moulded in two sections. Patients requiring such an appliance are usually unable to stand and so the two sections are cut for moulding separately, the patient first lying prone and then supine. Thus, the above measurements are divided into front and back sections. An extra 1" is added to the width of each section to allow for an overlap. The back section is designed to come 2" farther towards the front than the hemi-circumference. This results in the design shown in the diagram opposite. The rationale of this is that if the patient turns on his side he will not by lying on the join.



CROSS SECTION OF PELVIS

(APPLIANCE REPRESENTED BY BROKEN LINE)

Diagram 1.

The front section is made of 1/16" polythene and 3/16" polyurethane, and the posterior section is made of 3/16" polythene and ½" polyurethane.

A pad of polyurethane 1" thick is built up from 3/16" polyurethane sections in pyramidal shape (see diagram 2). This pad is made roughly the same shape as the ulcer but 1" larger.

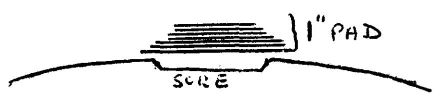


Diagram 2.

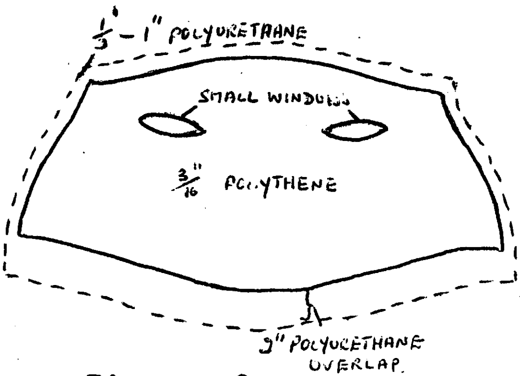


Diagram 3.

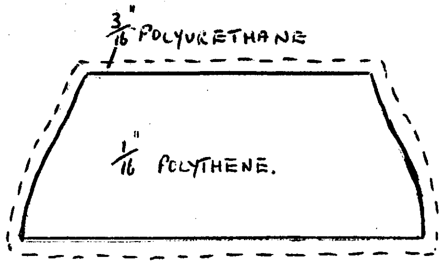


Diagram 4.

MOULDING.

The patient is made comfortable in the prone position. The ulcer is covered with one layer of lint and the polyurethane pad is laid on top so that it overlaps the ulcer evenly all round. It is taped in place with one or two strips of adhesive. The posterior section is then removed from the oven and laid over the lower back and buttocks in the correct position. It is difficult to bandage it in place and sandbags have been found satisfactory for moulding. After 15 minutes the sandbags are removed and it is seen that the underlying pad of polyurethane has caused a smooth convexity in the plastics over the region of the sore. The skin at the lateral borders of this section is ink marked, and the section is then removed and set aside to cool.

The patient is then turned to lie on his back and the anterior section is moulded over the pubis and lower abdomen so that its lateral edges overlap the ink marks made previously at the edges of the posterior section before it was removed. The amount of this overlap is noted. In this way it is ensured that the front and back sections can be rivèted in correct relationship.

Since the front section is of thin 1/16" polythene it takes only 4 - 5 minutes to cool and set.

FINISHING.

The lateral borders of the two sections are riveted together. A 1" wide strip is cut out down the middle of the anterior section and four straps and

<u>FINISHING</u> (continued).

buckles are fitted. This gap is cut out in order to allow a measure of adjustment. Ventilation holes are punched out.

It will be seen from the diagrams that a 2" overlap of polyurethane has been allowed below the lower border of the posterior section. This is turned back over the lower border of the jacket and glued onto the outer surface of the polythene. It was found most important to do this in order to protect the patient's skin from danger of trauma from the hard lower border of the polythene.

If the patient is incontinent a layer of oiled silk should be glued over the polyurethane lining of the posterior section.

Weight 2lbs. Cost 25/-.

PLASTIC BED.

MATERIALS.

Polythene ⅛" (or 3/16").
Polyurethane ¼".

MEASUREMENTS.

(1) From the hairline on forehead to tips of toes - measured along the posterior surface of the body.

(2) Circumference of head.

(3) Circumference of neck at level of 6th cervical vertebra.

(4) Circumference of chest at level of axillae.

(5) Circumference of shoulders.

(6) Circumference of waist.

(7) Circumference of pelvis at level of greater trochanters.

(8) Circumference of each thigh just below gluteal fold.

(9) Circumference of each knee.

(10). Circumference of each calf at thickest point.

(11) Circumference of each ankle round malleoli.

(12) Circumference of each foot round ball of foot.

(13) Distances between each of these circumferences.

All these circumferences are then halved in order to obtain the required hemi-circumferential measurements.

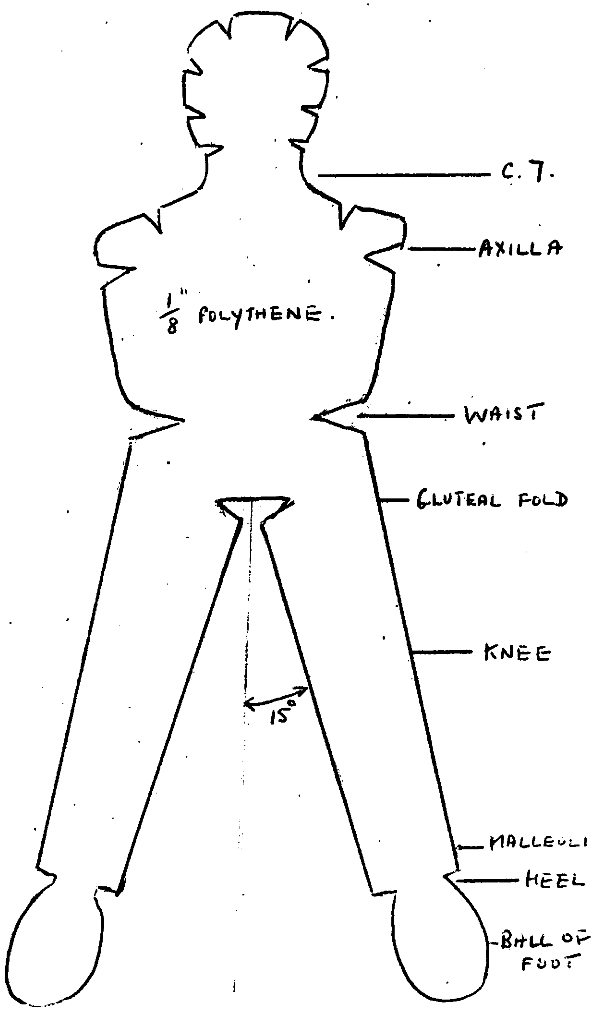
Photograph shows a patient with acute poly-arthritis resting in the appliance. (Case 19).

PREPARING THE PLASTICS AND DIAGRAM OF DESIGN.

It will be seen from the photograph that this bed was made in three sections. This was due to the fact that the floor space of the oven was only 40" x 30" and the plastics had been obtained in sheets of only 3.sq.ft. This gave rise to severl difficulties which would not have arisen if suitable materials and equipment had been available. To avoid complicating the diagram of design by dividing it into three sections - as was necessary in practice - it will be shown as one section. (The moulding and finishing will also be described as if one section were used).

It will be noted that no provision has been made for the arms except for short sections to support the shoulders. The patient for whom this bed was intended already had wrist and ulnar deviation splints (see photograph) and thus only the elbows would be free of restraint. These joints were only slightly involved. It was therefore considered best to leave out arm rests. Only polythene of 1/8" was used throughout. No strengthening stirps were incorporated. (It will be seen from a study of the photograph that the bed really only maintains curves and does not take much weight, the heels, buttocks, shoulders and back of head parts of the appliance resting as they do on the floor. This appliance requires no great strength.

The measurements are marked on the polythene and the design cut out with a leather knife. It is then laid on ¼" polyurethane sheet, the latter being marked and cut out with scissors in the usual way. (It may be worth noting that ½" polyurethane was used in the first attempt to make a bed but this thickness was found too great to allow accurate moulding of these large sections.)



To permit moulding to the double curves presented by some parts of the body it was found necessary to cut out wedges from the borders of the polythene (see diagram on previous page.)

The lower limb sections were cut out to form an angle of 15° abduction on each side of the mid-line.

MOULDING.

The patient was made comfortable in the prone position on a firm plinth (adjustable length type) with his feet over the bottom end and his head over the top end. The shoulders were prevented from drooping forward by placing a small sandbag under each. By thus lying prone on a firm support full extension of hips and knees was obtained and the lumbar and dorsal curves of the spine were held in correct position. An assistant held the head so that the cervical spine was in its best functional position - neither flexed nor extended. By keeping the feet over the bottom end of the plinth 90° dorsiflexion could be obtained during moulding.

The plastics were removed from the oven and covered with a layer of stockinette. The operator and an assistant then laid them on the patient's back and without waste of time laid the sandbags on top so that their weight provided a moulding force. The head and neck part was bandaged in place and likewise the parts covering the feet and ankles.

After 20 minutes the moulded plastics were removed and carfully laid aside to cool to room temperature.

NOTE. For the sake of clarity the above description of the moulding is described as if it had been done in one section instead of in three sections as it actually was. This raises the question of whether, in fact, a full sized plastic design would remain malleable long enough for the sandbags and bandages to be applied. From my experience with this bed I would say that if 1/8" polythene was used the operator and his assistant would have to have experience and observe good team-work. It could then be done. If 3/16" polythene was used it would be much easier because of the appreciably longer duration of malleability of the thicker material.

FINISHING.

Wide straps and press-studs were fitted to keep the knees extended during sleep. The position in which these were fitted - as shwn in the photograph - was found to be unsatisfactory. After the bed had been made the knees became acutely involved and the straps caused pressure over the distended supra-patellar pouches. They were therefore moved up to mid-thigh and a further pair of straps were fitted 4" below the knee.

Ventilation holes should be punched out at 1" intervals.

Weight 5½lbs.
Cost of materials £3. 7s. 0d.

CASE REPORTS OF PATIENTS IN THE MANAGEMENT OF WHOSE DISEASE POLYTHENE-POLYURETHANE APPLIANCES WERE USED.

CASE No. 20.

Age. 9 years.

Sex. Female.

Case History.

This little girl was admitted on the 8.12.54. Her left knee was swollen and painful and held in 90° of flexion. No active movement was attempted, and passive extension or flexion caused pain and distress. The right knee and one or two joints of the fingers and toes were mildly affected. This was a known case of juvenile rheumatoid arthritis, having been treated at the Hospital for Sick Children, Great Ormond Street, in 1952 for this complaint. There had been no symptoms during the intervening period.

A plastic knee splint was made by the method described. During application the knee could be straightened to only 30° flexion. After the splint had been worn at this angle for a few days all painful spasm disappeared. This same splint was then reheated and applied again with the knee in 5° - 10° of flexion. The other knee was also splinted.

There was a progressive improvement with splinting and physiotherapy and on her discharge on the 17.3.55, the patient was walking normally with a full range of painless movememt in the knee-joints. When last seen as an Out-Patient on the 7.6.55 her condition had been maintained. No drugs were used in this case.

CASE No.21.

Age. 11 years.

Sex. Male.

Complaint. Juvenile rheumatoid arthritis.

Case History.

He was admitted on the 31.10.55 complaining of pain in the left knee joint of one week's duration. The joint was warm and contained a moderate amount of effusion. The other joints were judged to be normal. E.S.R. was 70mms. in the 1st. hour. Temperature 100°F. X-ray of the knee joint showed nothing abnormal. Pain and swelling remained localised to this joint and a diagnosis of juvenile rheumatoid arthritis was made. He was treated with aspirin and bed rest.

I first saw him on the 18.11.55, when the left knee presented signs similar to those found on admission. The right knee and left ankle joints also gave evidence of minimal involvement at this examination. The circumference of the left knee was 12¾". The left thigh showed ¾" wasting. A splint was fitted which held the knee flexed 5° - 10°. The Nursing Staff were instructed to let him wear it constantly except when receiving physiotherapy, (active and passive movements).

By the 7.12.55 he had no spontaneous pain in the knee and a full painless passive range was obtainable. There was still a small amount of effusion but the circumference of the joint was reduced to 12¼". The right knee and left ankle still showed minimal signs. E.S.R. was 20mms. in the 1st. hour. He was shown how to do static quadricep exercises while wearing the splint and instructed to do them hourly. (The thigh still showed ¾" wasting.) No weight bearing was allowed.

He was discharged home on the 7.1.56. By this time the E.S.R. was 7mms. in the 1st. hour and all signs of activity had gone. The circumference of the left knee was 12" and equaled that of the right. The left thigh was ½" wasted. He had worn the splint constantly up to this date. He was instructed to continue doing so until further notice.

On the 21.1.56 both legs were quite normal. He was told to wear the splint by day and leave it off at night. On the 9.2.56 he was instructed to leave the splint off one hour longer each day until after 16 days he finally discarded it. When seen on the 24.2.56 permission was given to go back to school on the 26.2.56. The E.S.R. was 7mms. in the 1st hour and all joints were normal. When last seen on the 19.4.56 the musculo-skeletal system was still free of signs and X-rays of both knee joints were quite normal.

There is no doubt that regression of his symptoms and signs while wearing the splint was due to a natural remission, though the quick relief of spontaneous pain in the left knee after being fitted with the splint may have been mainly a result of the local rest afforded by the appliance. I have outlined the management of this case in some detail to illustrate what I believe is one of the major advantages of the polythene-polyurethane knee splint in acute rheumatoid arthritis. That is that when pain has disappeared from the knee joint it is much safer, for a few weeks, to allow walking only with the joint immobilised and so prevent the shearing strain of normal walking on the still abnormal cartilages. These lightweight plastic splints are tolerable for this purpose as has beem demonstrated in the above case.

CASE No.22.

Age. 20 years.

Sex. Male.

Occupation. University Student.

Complaint. Rheumatoid arthritis.

Case History.

This young man was admitted to hospital on the 2.7.54 with acute polyarthritis. He had had two previous episodes of joint pain in the previous four years but these were much less severe than at the time of admission to hospital.

The right ankle joint was swollen and hot and showed abnormal lateral movement. The left ankle showed similar, though much less marked, signs. The right wrist and fingers were also quite severely involved. Nearly all the other limb joints showed some evidence of involvement. The E.S.R. was 43mms. in the 1st. hour. He was treated with bed rest, calcium aspirin. Heat and exercises were also given. The condition settled under this regime and by the end of the month only the right ankle joint remained acutely involved. He could only hobble a few paces before the pain became so severe that he was forced to stop.

He was very anxious to get back to his classes, but he was clearly incapable of travelling because of his ankle. A plastic appliance was suggested by his Physician - one that would immobilise the joint. A splint was made (⅛" polythene) similar to the "short leg and foot splint" (Page230), but extending only as far as the middle of the calf. The weak area - between the foot and ankle sections - was bridged by riveting on strengthening strips (⅛" polythene), medially and laterally. The finished article was put on by pulling apart and slipping over the foot and leg. When strapped up it held the ankle very firmly, allowing very little movement of the joint. The foot was held dorsiflexed to 90°. A leather sandal was altered so that it would fit over the splint. The latter weighed 16½ozs.

He found walking in the splint very much less painful that without it. He was discharged on the 4.10.54.

I next saw him on the 24.11.54 and he gave the history that for the past three weeks he had been managing to get to and fro his classes while wearing the splint. He had also been using it at night as he found that it reduced pain. His ankle joint showed a little less activity that when I had last seen it. There was no evidence of the tendancy towards eversion deformity it had shown prior to splinting.

I did not see this patient again and can give no information as to his subsequent progress. I have included him in the series because he was the only patient of mine to be supplied with an ankle splint. I hope too, that the above record will help to demonstrate the adaptibility of these plastic splints to the needs of individual patients.

CASE No. 23.

Age. 34 years.

Sex. Female.

Occupation. Housewife.

Clinical Account.

She had suffered intermittent attacks of mild polyarthritis over the two years previous to coming under my observation. Her only complaint then was of pain in her wrist joints causing inability to do her housework.

When first seen on the 18.2.55 her E.S.R. was 40mms. in the 1st. hour. She had an almost full range of movement of both wrist joints but there was pain at the extremes of movement. They were warm and slightly swollen. Grips were poor. Ventral type wrist splints were made and fitted on the above date.

On the 13.4.55 she reported that she had been wearing the splints day and night and that she was able to do her housework without the severe aching in the wrist joints which had previously resulted from such activity. E.S.R. was 50mms. in the 1st. hour.

By the 7.11.55 she had pain in many joints but her wrist joints were relatively pain free as long as she wore the appliances. Attempts to use her hands without them invariably caused pain and she therefore kept them on more or less constantly. E.S.R. was 60mms. in the 1st. hour. Her left knee was painful, warm and a little distended. A left knee splint was therefore provided on this date. She was also put on Butazolidine, 0.2 Gms.,b.d. to be taken after food and with half an ounce of Mist. mag. trisil. co.

On the 2.1.56 she reported that her multiple joint pains had been much less while on Butazolidine. She still wore her wrist splints and had found that the knee splint had relieved pain at night. Examination revealed a full painless range at both wrist joints. There was a small amount of fluid in both knees accompanied by warmth and a little restriction of movement by pain. A splint was made for the right knee joint. 1.5ccs. of Hydrocortisone were injected into the left knee joint. Butazolidine was stopped as she had recently begun to complain of indigestion following administration of these tablets. She had had no gastric symptoms prior to taking this drug.

29.2.56. - The left knee had improved for 1 - 2 weeks following the Hydrocortisone. She had been sleeping well, wearing both knee splints. She still complained of intermittent aching in many joints. The right knee joint was injected with 2.0ccs. of Hydrocortisone.

14.3.56.

The right knee had improved since injection and had remained improved. Still wearing knee splint at night and wrist splints by day.

28.3.56.

Some pain had returned in both knees. On examination there was warmth and a small degree of effusion. The range of movement was within a few degrees of normality though there was some pain at the extremes. She had a full painless range at both wrist joints. The grips were firm. No evidence of activity in the wrist joints or carpi, but there were slight changes evident in the M.P. and I.P. joints. Both knees were again injected with 2.0 cc's of Hydrocortisone.

25.4.56.

Knee pain had improved for three weeks following Hydrocortisone and then became worse again than before. She had found the splint still "a great relief". Full range both knees. No effusion. Wrists show a full painless range. E.S.R. was 50mms. in the 1st. hour.

No clear clinical evidence of the value of local joint rest, extending in the case of the wrist joints for over a year, emerges from the above account. The patient herself, however, was quite clear on the fact that they had been a great help in relieving her pain at all times. On the contrary it may be noted that intra-articular Hydrocortisone relieved pain for only some two weeks on each occasion, though the degree of relief was marked during each of these times. Butazolidine was also effective for two months but had to be discontinued because of the gastric symptoms produced by its use.

CASE No.24.

(continued overleaf)........

(continued)..... **CASE No. 24**

Age. 57 years.

Sex. Female.

Occupation. Hospital Catering Officer.

Case History.

When first seen on the 17.3.55 she had been suffering from rheumatoid arthritis for two years. The wrist and finger joints showed most activity and she had difficulty in carrying out her duties. The M.P. joints of both hands were distended, but there was no tendency to ulnar deviation of the fingers. Between the above date and the 18.1.56 she was treated with a series of Hydrocortisone injections into these joints. The most distended and painful were injected at each session. An excellent response followed on every occasion; pain was much reduced and diminution of the joint swellings could be observed within a week of injection. These good results, however, never persisted for longer than three weeks, and usually far less. Pain and effusion thereafter returned to their previous state.

On the 18.1.56 it was noted that, when she attempted to make a fist, the fingers sometimes deviated towards the ulnar side. This was particularly evident in the right hand. It was important that she continued at work and a range of splints was therefore made; a pair of wrist and finger splints (Photograph 6) for night wear: wrist splints (Photographs 1. & 2.), and hand splints (Photographs 2,3 &4) for wear during the day. Much of her work consisted of book-keeping and I think the photographs show that writing is permitted when wearing either the wrist or the hand splints. In this way she could continue working without the danger of deformities developing.

She wore these appliances constantly and on the 25.4.56 she was able to report that she had found the splints comfortable to wear and that her pain had been much easier. Examination showed that the M.P. joints were still as active as before but no ulnar deviation had developed. Wrist movement remained almost normal in range and was pain-free except at the extremes.

CASE No. 25.

Age. 34 years.

Sex. Male.

Occupation. Part-time watch repairer.

Clinical Account.

This patient had juvenile rheumatoid arthritis at the age of five years and between then and the age of seventeen years he had several severe episodes. These left him severely crippled so that he could walk only with elbow crutches following arthrodesis of both knees in extension. The hands and wrists were also badly affected. From the age of seventeen onwards the disease had remained quiescent and when I first saw him on the 5.8.54 there were no signs of activity.

At that time he was self-employed as a watch repairer and worked in his own home. He had just enough mobility of the fingers to do this sort of work. The right hand was the better. The range of movement in the right wrist joint was 40° flexion - 65° flexion - 40°flexion. Passive extension was also limited to 45° flexion by fibrous contracture.

It was thought that if some further active extension could be obtained in his right wrist it might be of great help in his work. Both wrist, carpus and fingers were badly deformed and it was found very difficult to mould the splint, but it was eventually carried out satisfactorily, the wrist being held powerfully extended while the plastics set. When fitted on the 14.8.54 and the straps tightened it was seen to hold the wrist joint extended to the maximal possible degree.

He wore this appliance night and day except when actually engaged in his work - some 2 - 4 hours daily. By the 21.10.54 there was a slight gain in active and passive extension - to 30° flexion. This gain was presumably due to stretch of the fibrous tissue as he used his hand; the splint being static could not, of course, exert any active extensor force. The splint was heated out until flat and remoulded to hold the wrist joint fully extended to the new angle of 30° flexion. (Photograph on previous page).

He continued to wear the splint as before and by the 17.2.55 a further 10° had been gained so that active and passive extension could be obtained to 20° flexion. By this time the lining of the splint was frayed and discoloured. It was therefore scraped off and the polythene heated out flat. A new lining of polyurethane was fixed by heating the two together, and for the third time the splint was moulded to the hand and wrist. The hand was held maximally extended. On this occasion a Polythene-polyurethane pad of some 1" square was made separately. This was placed over the dorsum of the wrist to underly the distal strap of the splint. By tightening the strap over this pad quite a considerable upward thrust was obtained by the part of the splint nestling in the palm - owing to the resilience of the polythene.

He wore this splint until the 7.7.55 and by that time passive extension of the wrist joint was possible to 0° - a further gain of 20°. Unfortunately the wrist extensor muscles could not make use of this extra gain, no doubt due to their long period of stretch with consequent irreversible lengthening. It was intended that he be shown to the Orthopaedic Surgeon for his opinion as to a tendon shortening operation but the patient did not keep his appointment and was lost sight of.

This case was one of the first cases to be splinted and was instructive from several points of view. First was the gross deformity of hand and wrist which made moulding a difficult procedure, but with care it was found possible to produce a good mould of the part. The photograph on the previous page shows the splint moulded for the second time (21.10.54). The A.P. view does not bring out well the complexity of the mould but I think enough can be seen to show some of the subtlety of the shape. (During this second moulding protection of the skin from the edges of the polythene, by then exposed, was achieved by taping a loose piece of 3/16" polyurethane over the hand and wrist prior to moulding.) The second lesson learnt was that these splints could be tolerated for considerable periods of time (in this case 11 months) without complaint. The third, that it was possible to use the same materials on two or three occasions by heating out flat and remoulding to the new angle - as described.

CASE NO. 26.

Age. 42 years.

Sex. Female.

Occupation. Housewife.

Clinical Account.

This patient had suffered from rheumatoid arthritis for 14 years. During this time she had had many courses of physiotherapy and on several occasions had been supplied with Plaster of Paris splints for hands and knees. She gave the history that she had never worn any of these for more than two or three weeks because of their weight and discomfort.

When first seen on the 13.9.54 she presented with limitation of movement of the wrist and finger joints, more marked on the right side. The fingers of both hands showed fibrous contractures of the M.P. joints which were held in 60° - 15° flexion (5th - 2nd fingers) and in 45° deviation to the ulnar side. The fingers of the left hand were 75% correctible passively and those of the right hand 50%. The grips were weak. She had no constant pain in the wrists but they ached after attempts at housework. The left knee seemed almost normal but the right knee was swollen and warm; painless range 90° - 25°.

Right and left ventral type wrist splints, and a right knee splint, were fitted on the 20.9.54. She was instructed to remove them for three 10 minute periods daily for active and passive exercises. She tolerated them well and gave the history that she wore them more or less constantly. She could do housework better with her wrists stabilised by the splints, and could lift heavy objects, such as kettles, without dropping them as she had often done previously. The right knee splint was particularly helpful at night, reducing pain and allowing better sleep.

By the beginning of January 1955 the wrist splint with an extension piece for preventing ulnar deviation had been devised and a left sided one was fitted on the 19.1.55. It held the fingers almost fully corrected and it was hoped that by prolonged wear a permanent improvement might result. By the 20.4.55 the fingers of the left hand were freely correctible - fully as far as ulnar deviation was concerned and to 10° - 15° of flexion at the M.P. joints. Active correction howevere remained impossible and on release the fingers fell each to their original position. She still wore her wrist splints by day and the knee splint at night - and sometimes also by day as she could walk with less pain while wearing it.

On the 29.1.55 she reported that she had, a few days previously, gone out shopping on her own while wearing the knee splint. She had been out for 2½ hours. This was the first time she had been out of the house unaided for 3 years. The knee had ached a little on return home. On examination the knee was warm and showed a little effusion. E.S.R. was 35 mms. in the 1st. hour. Her condition continued to improve slowly. The wrist joints became less painful and she could leave off her splints during the day without ill effect. It was decided to try a new type of hand splint to hold the fingers of the left hand in their correct position, (see photograph). These still fell into their original position on removal of the wrist and finger splints, thought they were now perfectly "loose" to passive movement. E.S.R. was 25mms. in the 1st. hour.

Between the 20.10.55 and the 14.12.55 she had three injections of Hydrocortisone into the right knee joint in an attempt to clear up the resisual slight activity which was preventing her from discarding the knee splint. These injections had no effect at all, either objectively or subjectively. She therefore continued to wear the knee splint each night and sometimes during the day.

By the 8.2.56 signs of activity had disappeared from the right knee joint. There was no heat or fluid and it had a painless range of $100^{\circ} - 10^{\circ}$. No abnormal movement was detected. She was instructed to leave off the splint whenever she could, provided that the pain did not recur.

On the 11.4.56 she gave the history that she had worn none of the splints for three weeks. On examination neither knee showed signs of activity and both had a painless range of $100^{\circ} - 10^{\circ}$. She could walk well without aids. The wrist joints appeared inactive and she had no complaint of pain. By this date she had constantly worn splints which had held the fingers of the left hand almost fully corrected for fifteen months. It was disappointing that there was absolutely no improvement in the degree of ulnar deviation deformity when the correcting force (the splint) was removed. She could not actively improve their position in the slightest, even though full passive correction could be obtained with a very light pressure. I have been unable to find any published report of the effect of such a prolonged correction of ulnar deviation of the fingers in chronic rheumatoid arthritis, but it would seem from the facts of this case that such a deformity, once allowed to become fixed by soft tissue contracture cannot be corrected by means of an appliance. It is interesting to compare the lack of results in this case with the excellent prophylactic effects of this type of splint in early cases of rheumatoid arthritis with M.P. joint distension and a commencing tendancy to deviation. (Case 19).

Between September and December 1954 this patient received heat and exercises for her knees. From then onwards she received no treatment apart from codeine and splinting, (and the three unproductive hydrocortisone injections). I think it might fairly be said that the wrist splints improved her work capacity throughout the period of observation, and that the knee splint reduced pain and prevented further flexion deformity of the right knee until she obtained a natural remission towards the end of the course of treatment.

CASE No. 27.

Age. 48 years.

Sex. Female.

Occupation. Housewife.

Clinical Account.

Following intermittent episodes of joint pain for three years she developed an acute polyarthritis in May 1952. She was admitted to hospital on the 20.5.52 where she was treated with Cortisone. At that time the fingers, wrist, knee and ankle joints were swollen and hot. The E.S.R. was 71mms. in the 1st. hour. Her condition responded well to Cortisone but when it was stopped on the 12.6.52 she had an exaccerbation of symptoms and signs. She was then put on "Myocrisin" but this was stopped after one week because of leukopoenia. From then on she received only aspirin.

She was treated as an Out-Patient from the time of discharge (13.6.52) and Butazolidin was added to her aspirin therapy. The former helped greatly in reducing pain and her general health improved. After fourteen months treatment with this drug it was stopped because of an episode of acute abdominal pain lasting four days. The pain ceased after stopping the Butazolidin. From this time (February 1954) onwards her main disability was caused by pain in the hands and wrists, this being increased by using her hands. Range of movement at wrist joints :-

Right:-	Flexion	60°	Extension	40°
Left:-	Flexion	70°	Extension	25°

On the 17.11.54 ventral wrist splints were made for both wrists and it was hoped that these would stabilise her wrists and so reduce pain. This hope was realised and the patient wore them each day. During the next seven months she remained well with only mild intermitten pain in various joints. She continued to take aspirin.

On the 29.6.55 I noticed that the metacarpo-phalangeal joints of both hands were a little swollen and that a tendancy to ulnar deviation of the fingers was commencing. A pair of wrist and finger splints for prevention of deviation were made and she was instructed to wear them each night and during the day also when she was not actively engaged in housework. The E.S.R. at this time was 57mms. in the 1st. hour. She also complained of some increase of pain in many joints and Butazolidine therapy was therefore recommenced, 0.2 Gms. b.d. Her joint pains improved though the disease remained active; the E.S.R. on the 14.9.55 was 72mms. in the 1st. hour. No ulnar deviation had developed.

On the 26.10.55 the W.B.C's dropped to 1,500 and Butazolidine was stopped. Fortunately activity was by then less evident in her joints and no great incsease in pain resulted. She continued to wear both pairs of splints as directed and on the 21.12.55 it was found on examination that ulnar deviation had been entirely prevented. The range of movement at the wrist joints was good:-

Right:-	Flexion 75°	Extension 50°
Left:-	Flexion 70°	Extension 40°

Abduction, adduction, supination and pronation showed a normal range. The E.S.R. was 31mms. in the 1st. hour. The W.B.C's were 4,600, and she was put back on Butazolidine 0.2 Gms.,b.d. as she still had some pain.

On the 2.1.56 the E.S.R. was 80mms. in the 1st. hour but the joints showed little activity. On the 29.2.56 the E.S.R. was 93mms. in the 1st. hour and she had a sore throat. The W.B.C's were 2,100. Butazolidine was again stopped.

Her general condition improved soon after and on the date of my last examination of the patient (4.4.56) her general health was good and her joints were not troublesome. She was taking only aspirin. There was no ulnar deviation of the fingers and the ange of wrist joint movement remained equally good to the findings on the 21.12.55. The lining of the splints required renewal.

From the time she was fitted with splints on the 17.11.54 until the last examination on the above date she had received only one months treatment with physiotherapeutic methods (wax and exercises to hands and wrists) in February 1955.

To summarise the above account - a patient with active joint disease whose wrist joints were stabilised in a good position for one year and five months maintained an excellent range of joint movement. The same pair of splints were used every day and at the end of the period of observation had suffered no damage, and were still serviceable though the polyurethane lining was somewhat deteriorated and a fresh ling had to be put in both wrist splints. Ulnar deviation which had just begun to develop on the 29.6.55 was abated by a pair of splints designed to prevent this (Page 217) and over the axt ten months they were successful in controlling this tendancy in spite of continued activity in the metacarpo-phalangeal joints. Whereas the wrist joints might conceivably have maintained their mobility by other methods of treatment I feel sure from experience of cases developing deviation of the fingers that this deformity would have occurred without the constant correcting force of the appliances. (See also Cases 19, 24)

Her pain responded well to Butazolidine but this drug had to be stopped on several occasions because of either gastric syptoms or leukopoenia. Cortisone had been effective in the acute stage of her illness in 1952 but a rebound phenomena on stopping it had offset the benefit obtained.

CASE No. 28.

Age. 55 years.

Sex. Female.

Occupation. Housewife.

Clinical Account.

She had suffered from rheumatoid arthritis for 14 years and by September 1954 had severe, multiple joint destruction. Her main disabilities were pain in the wrists and fingers and in both knees. She could walk only a few yards with the aid of two sticks. Pain troubled her mainly at night. She was fitted with ventral wrist splints and splints for both knees on the 8.9.54.

She wore these appliances for the next eighteen months - wrist and knee splints at night and the wrist splints only by day. At the end of that time she gave the history that her previously severe pain had been much lessened while wearing them and that the stability imparted to her wrist had enabled her to use her hands more during the day without the development of pain. No objective clinical improvement was noted.

During the period of observation three attempts were made to put her on Butazolidin. The first two were discontinued because she said it made her feel ill. On the third attempt (beginning on the 7.11.55) she tolerated it better and derived considerable ease. It was stopped on the 7.2.56 as a routine W.B.C. count revealed a leukopoenia.

When I last saw her on the 28.3.56 the splints were still in excellent condition, though the polyurethane lining had discoloured with usage to a dun colour - but was otherwise satisfactory. She had found them comfortable enough to wear all four splints each night thoughout the eighteen months of observation, and the wrist splints also during the day.

CASE No. 29.

Age. 58 years.

Sex. Female.

Occupation. Housewife.

Clinical Account.

This patient had had increasingly severe rheumatoid arthritis for ten years. When first seen (14.9.54) her hands and wrists were particularly troublesome. Both wrist joints and carpi were moderately swollen and felt warm to the touch. The range of active movement in the right wrist was:- extension 0°, flexion 25°. In the left wrist it was:- extension 5° and flexion 20°. Supination and pronation were restricted to a 60° - 80° arc. The M.P. and I.P. joints of the fingers were less acutely involved and the grips were fair. The knees were also painful and extension in both was limited to 35°. The E.S.R. was 45mms. in the 1st. hour.

On the 23.9.54 ventral wrist splints were made. She wore them more or less constantly and found them of most help in bed at night and when doing housework, pain being diminished in both circumstances.

Some three months later, despite continueing activity in most joints, and a persistently raised E.S.R - 60mms. in the 1st. hour, the range of active movement at the wrist joints had improved to 10° extension and 40° flexion on the left and 30° extension and 35° flexion on the right. She had received no other local treatment for these joints during that time.

By the 6.6.55 there was a further gain of 15° - 20° in flexion at both wrist joints, extensor range remaining unaltered. On the 5.10.55 she was able to report that her wrists gave her very little trouble and that she could leave off the splints for considerable periods without recurrence of pain. The E.S.R. on that date was 66mms. in the 1st. hour. Her knees were becoming increasingly painful and a pair of polythene-polyurethane knee splints were made on the 9.11.55 by the Physiotherapy Staff.

From then on she wore her knee splints each night with some relief of pain. Her wrist splints she wore when pain was troublesome in those joints.

At the time of my last examination (3.4.56) she had worn the wrist splints for one year and six months. The knee splints she had worn for some five months. These appliances had sustained no damage during that period of time and the moulds remained the same as when first made. The linings, as usually occurs, required replacing in the wrist splints at the end of nine months. Tat of the knee appliances was still in reasonably good order after five months.

During the period of observation she received only codeine co. in the way of drugs. She had several courses of heat and exercises for her knees but the wrists received no treatment apart from the splints. I think it is probable that the improvement in joint range at the wrists was a result of the local rest of these inflamed joints by means of these appliances. The patient herself was in no doubt that they had greatly relieved her pain.

CASE No. 30.

Age. 68 years.

Sex. Female.

Occupation. Housewife.

Clinical Account.

She had suffered from rheumatoid arthritis for 18 years. By 1955 there was gross destruction of many joints. She had a Judet arthroplasty of the left hip in 1954 and a compression arthrodesis of the right knee in the same year.

When I first saw her on the 21.9.55 her main complaint was of severe and constant pain in both elbows and of pain and paraesthesia in the left ulnar nerve distribution. On examination both elbow joints were found to be distended with effusion (see photograph). The range of active movement in the right was between 110° and 50° and in the left between 100° and 45°. Passive flexion or extension beyond these loci produced severe pain. There was a great deal of abnormal lateral movement in both joints. Despite the symptoms of left ulnar nerve involvement there was no clinical evidence of localised wasting in the muscles innervated by that nerve. The E.S.R. was 55mms. in the 1st. hour

Between the 21.9.55 and the 24.4.56 she had a series of aspirations of both elbow joints (not always very productive) with replacement by 2.0 cc's of Hydrocortisone. Five such procedures were carried out on the left elbow and four on the right. On no occasion did she obtain much relief of pain, the longest period of relief was 3 days and this seemed mainly due to the fact that on that occasion a considerable quantity of gelatinous effusion (20 ccs.) was withdrawn. The effusion withdrawn was always thick tenacious material and usually only some 5.0ccs. was obtained. It appeared that the joint cavity was loculated. Injections of Hydrocortisone seemed to make no difference subjectively and no objective improvement in joint range or reduction in size of the effusion was noted.

Pain in the elbows was particularly troublesome at night and, in the hope of reducing it, a pair of elbow splints were made on the 1.11.55. (see photograph). She wore these every night and part of the day for the ensuing seven months of observation. She claimed that they were of great help and allowed her to have a good night's rest.

On the 16.12.55 a left knee splint was made of strengthened 1/16" polythene and 3/16" polyurethane. This weighed 12ozs. and she found it light and comfortable to wear. It was quite strong enough to prevent movement of the knee joint outside its painless range.

When last seen on the 24.4.56 all these appliances were in good order and required no attention. (Photograph of appliances on Page 224.)

During the period of observation Butazolidine therapy was tried on two occasions. On both, she developed an allergic rash and stomatitis within ten days of administration of this drug and cessation of treatment was necessary. Calcium aspirin was therefore used. She received no physiotherapy while under my care.

CASE No. 31.

Age. 69 years.

Sex. Female.

Occupation. Housewife.

Clinical Account.

She presented as a case of chronic rheumatoid arthritis of 14 years duration when first seen on the 21.9.54. Her right shoulder, right knee and both wrists were the most troublesome joints at that time. There was swelling and heat in both wrist joints, with pain on movement. The grips were weak. The M.P. and I.P. joints showed some activity and there was a 30° ulnar deviation of the fingers accompanied by some 25° - 30° flexion deformity at the medial three M.P. joints. The ulnar deviation component was almost fully correctible passively. The right knee showed a moderate amount of effusion and was warm to the touch, movement being restricted by pain to 80° - 15° - 80°. Walking was painful.

A pair of ventral wrist splints and a right knee splint were made on the 21.9.54. Two months later she reported that her wrist joints were much less painful since wearing the splints, and also that her right knee was less troublesome at night. She had tried walking with the splint on but though it relieved pain in the knee it had caused her hip joint to ache. She attributed this, probably correctly, to the increased strain on the hip while walking with an extended knee.

She continued to wear these appliances with subjective benefit until June 1955 when I decided to try the effect of the more recently evolved splint for prevention of ulnar deviation of the fingers. These were fitted at the beginning of that month. She was instructed to wear them at night always and during the day whenever possible.

She continued to wear all her splints until the end of April 1956. By that time she had worn her wrist splints, and knee splint, for one year and seven months. The ulnar deviation splint she had used for eleven months. Although there was no marked improvement in joint range at either wrist or knee, no flexion deformity had been permitted in the former, and the latter had been maintained at 15°. (She could, in fact, extend both wrists some 20°).

The ulnar deviation had not improved at all in spite of the long period of correction and on removal of the splint the fingers slipped medially to their original position. The lack of improvement in this case, as in Case 26, suggests that once deviation has become established mechanical correction is of no avail.

In this case, as in the others, it can be said of the splints that the patient was pleased to wear them for a very long period of time, and found them beneficial. Apart from some attention to the lining the appliances did not deteriorate in any way.

Butazolidine, 0.2 Gms., b.d. was given to this patient throughout the time of observation. It was taken after meals and with Mist. mag. trisil. co. It produced no ill effects in her case - one of the few who tolerated it for such a prolonged period. There is no doubt that it relieved her pain since during one period of two weeks when it was suspended she experienced an exaccerbation.

CASE No. 32.

Age. 42 years.

Sex. Female.

Occupation. Press Operator in a factory.

Case History.

She complained of pain in the lumbar spine of three weeks duration when first seen on the 17.9.54. On examination movement of the part was free of pain and had a normal range. The left knee jerk was less easily obtained than the right. X-rays revealed narrowing of disc spaces L. 3 & 4, and L.4 & 5. This was associated with osteophytosis and was clearly of long standing. No history of injury was obtainable.

She was ordered a course of short wave diathermy to the lumbar spine and extension exercises. By the 28.9.54 she reported that pain was much less. Treatment was suspended.

On the 19.10.54 she returned complaining of recurrence of the pain. There was some pain, this time, on full flexion of the spine. The left knee jerk was absent. It appeared that a prolapsed intervertebral disc was present causing local pressure and pressure on the anterior nerve root.

Early in November, 1954 a lumbar-abdominal support was made (see photograph on Page 242). She wore this constantly every day and found it a help in relieving her backache. The support did not in any way immobilise the part but it did tend to prevent movement outside the painless range.

The ache remained tolerable while she wore the appliance. In the early part of February, 1955, it was kept in the Department for a few days for attention to the lining, and she later gave the history that her backache had materially worsened during that time.

Soon after this (21.2.55) another appliance was made which it was hoped would allow less movement of the lumbar spine than her original one (see photograph on Page 245). She found it equally comfortable and after wearing it for a month or so she was able to report a further lessening of her pain.

She wore this second support for nine months. At the end of that time she still complained of a certain amount of pain and she was referred to the Neuro-Surgeon who recommended spinal fusion. This procedure was undertaken and I lost sight of her.

Altogether she wore the first and second supports for a period of just over a year. She found them light and comfortable to wear. They did not break or deteriorate in any way in spite of her wearing them to her work each day. It could not be said that they caused any permanent improvement but they undoubtedly relieved her pain.

CASE No. 33.

Age. 43 years.

Sex. Female.

Case History.

When seen on the 15.3.55 she had had more or less constant pain in the cervical spine with radiation to the left shoulder and arm for several years. Little relief had been obtained from physiotherapy. X-rays showed a narrowed disc space between C.4 & 5 and on left lateral flexion of the head pain radiated down the left upper limb. A diagnosis of prolapsed disc with root irritation was made.

A cervical collar was made on the 15.3.55 and fitted two days later. When seen on the 21.4.55 she gave the history that her pain had greatly abated. She complained however of painful pressure from the edge of the chin piece of the support. A further layer of lining was glued on.

By the 27.5.55 she had much less neck pain but she was still wearing the support more or less constantly by day.

On the 13.7.55 she was able to leave the appliance off for a day on occasions, but pain usually returned by the end of the day.

On the 11.10.55 she gave the history that she had stopped wearing the collar a month previously as pain had gone from her neck. It had not so far returned.

She had therefore worn the appliance for six months, gradually leaving it off towards the end of that period, and finally discarding it. She had found it comfortable to wear at all times and she had been able to do her work with much less pain. This work consisted of heavy duties as a domestic. She did not again attend the Clinic and presumably her neck pain remained in abeyance - or was controlled by further use of the collar.

CASE No. 34.

Age. 48 years.

Sex. Male.

Occupation. Storekeeper.

Case History.

When seen on the 10.11.54 he complained of pain in the lumbar spine of five months duration. This pain had followed a fall on the buttocks. On examination he was seen to have a gross dorsal kyphosis with compensatory lumbar lordosis. There was little restriction of movement in the lumbar spine but he experienced pain on flexion. X-ray showed no evidence of bony injury. The dorsal vertebrae were wedge shaped but there was only mild osteophytosis. The disc space between L.1 and L.2 appeared narrowed.

A Fisher type brace was ordered and this was fitted on the 3.12.54. Over the next few months he complained constantly about this appliance. He found it very uncomfortable. He wore it to work but found that on its removal at night his back ached more than it had done previously. On examination it appeared to fit well. The Fitter saw the patient with me and suggested minor alterations. These were carried out but after a further period of wear the patient refused to wear it any longer.

On the 5.4.55 I attempted to make him a full length plastic brace and this was successfully accomplished. It moulded very well to his pronounced deformity - better than I had anticipated. It was fitted a week later. He found it light and comfortable.

When next seen on the 9.5.55 he reported that it was a great help. He was able to work in it with comfort. (His work included carrying 2cwt. bags of flour). By the end of June he had only a slight ache in the lumbar spine.

From then until the last time I saw him, on the 20.4.56, he wore it off and on depending on whether or not his back ached. The appliance was then still in good order (see photograph taken on that date) and required no attention. The polyurethane lining was somewhat deteriorated but did not yet require replacement.

CASE. No. 35.

Age. 43.

Sex. Male.

Case History.

Pain in the lumbar spine began in November 1955. In December his haemoglobin was found to be 57% and he was admitted to the Italian Hospital, London, for transfusion. While there, pain in the cervical spine made its appearance and this was followed by pain referred down the right arm. In January 1956 he developed pain in the left hip and left shoulder.

He was transferred to the Whittington Hospital on the 30.1.56. X-ray there showed destruction of the bodies of the 1st. and 2nd lumbar vertebrae and this was considered to be due to secondary carcinomatous deposits. A series of investigations pointed to the stomach as being the site of the primary growth.

He continued to have pain in the above sites, the most severe being in the cervical region and in the right arm. X-ray of cervical spine showed destruction of several of the vertebrae. Pain in the left thigh was also severe. I was requested to see the patient on the 10.3.56 to assess the likelihood of relief from a plastic cervical support. The patient was found in severe pain which, according to the Ward Sister, had not responded well to morphia, pethidine and other analgesics unless given very frequently. He sat propped up, his head held quite still and he gave the history that any movement of the head outside a very limited range caused excruciating pain in his neck and down the right arm.

He was given a further ¼gr. of morphia and taken by stretcher to the ward where the equipment for making plastic appliances was housed. His measurements were taken, and the plastics cut and put in the oven. When the materials were ready for moulding his head was carefully held in good position by an assistant while I moulded the plastics. He complained of no pain during this manoeuvre. When moulded, cooling was carried out quickly by putting the moulds in a free flow of air by the window. They were then riveted together and the necessary straps and press-studs added as quickly as possible. The appliance was fitted to the patient and he was instructed in how to adjust the strap. He was then returned to the ward. The whole operation was completed in just under two hours.

On enquiring the next day he said that he had had the collar taken off during the night as he could not sleep in it. It had been put back on in the morning and he had since adjusted the strap until a comfortable fit was obtained. By the time I saw him he was quite enamoured with it and had found that he could relax his neck muscles without pain developing.

He slept with the collar on that night and pain remained abset in the neck and arm. From that day on he never took the appliance off except when he was washed and shaved each morning. He remained free of cervical and root pain throughout the course of his illness until his demise in June 1956.

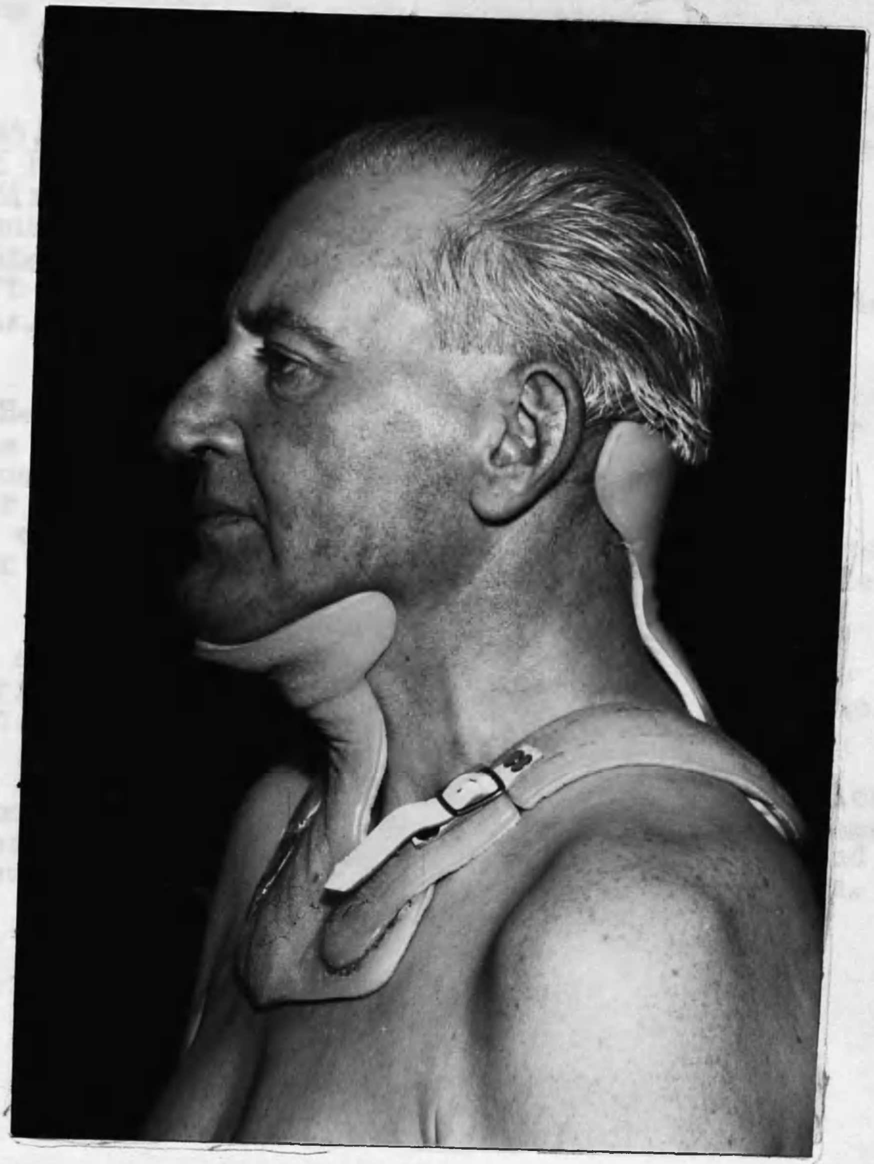
Pain in other sites remained troublesome, the most severe being in the left thigh. It was thought that this was most probably root pain from the destructive lesions in the lumbar vertebrae. A polythene-polyurethane shell was made on the 29.3.56, extending from the shoulders to the gluteal folds. The upper end of this appliance came to just below the base of the cervical support. The mould was made with the morphinised patient lying in the prone position. He made no complaint of pain during this operation.

It was hoped that this moulded plastic shell would, by maintaining the spine in correct curvature, ease his pain.

Fracture boards were placed under his mattress to obtain a firm base of support. He lay in this appliance during the greater part of each day for a fortnight, and at the end of that time he was still unsure whether or not it was helping him. From the report by the Ward Sister it appeared to me that it had not been of any real benefit and it was discarded. The fact that it had not relieved pain raised doubts as to the cause of the pain in his thigh and an X-ray of this area was taken. A large deposit in the shaft of the left femur, just below the level of the greater trochanter, was revealed. It appeared from the film that a pathological fracture was imminent and it was thought that the part should be supported in some way. A medical colleague was found who had similar measurements to the patient and a hemicircumferential plastic shell was made which included both buttocks and the left thigh as far as the knee.

This appliance was fitted beneath the patient and was found to support the limb satisfactorily. Pain in the region was relieved much more than it had been by the other shell. It was particularly helpful in allowing his to sleep. Previously, after an injection of morphia had relieved his pain and he was dropping off to sleep a sudden sharp pang in the left hip region would bring him back to conciousness. This was probably due to relaxation of protective muscle spasm. When wearing his 'spica' he could get off to sleep much better, the thigh being held immobile by this new appliance. He continued to wear it with benefit until the time of his death.

CASE No. 36.



Age. 60 years.

Sex. Male.

Case History.

In November 1954 he developed an acute polyarthritis which affected mainly his wrists and cervical spine. The E.S.R. was 57mms. in the 1st. hour. He was treated with aspirin and rest. By the end of December the acute phase appeared to be passing, at least in the limb joints. His neck remained very painful.

A plastic collar was made and fitted on the 23.12.54. (This was the first one I made. This supported his neck very well. He could talk and eat while wearing it.

He wore the appliance most days and sometimes at night, finding considerable relief of pain. By the 10.3.55 he was able to leave it off several hours per day. His other joints had fluctuated in degree of involvement during the preceeding months but were, by this date, fairly comfortable with the exception of the left ankle and left shoulder. The E.S.R. had fallen to 20mms. in the 1st. hour.

On the 22.4.55 his condition was much the same. He still wore the collar sometimes and shoulder pain was troublesome. He did not again attend the Clinic until the 13.1.56. He had been back to work - labourer - in the intervening period. On the latter date he complained of constant pain in the lumbar spine. His neck and limb joints were only occasionally troublesome.

He was admitted for investigation on the 27.1.56 and discharged on the 9.3.56. His lumbar pain had improved with rest. No diagnosis as to the aetiology had been made.

He was re-admitted on the 23.3.56 in a critical condition and died on the 31.5.56. At autopsy carcinoma of the pancreas was found with secondaries in liver and peritoneum. The skeleton was not examined post-mortem.

CASE No. 37.

Age. 67 years.

Sex. Female.

Case History.

She had been well until six weeks prior to admission on the 23.8.55 for investigation of pain in the lumbar and dorsal spine. X-rays revealed secondary carcinomatous deposits in D.11 and L.2. Further investigations pointed to the stomach as the site of the primary growth.

On the 13.10.55 she began to complain of pain in the cervical region and X-rays showed multiple deposits in this part of the spine. By the 20.10.55 the pain was severe and she had in addition episodes of pain radiation down the right arm. I was requested to see her with a view to making her a cervical support. On examination it was found that movement of the neck outside a limited range caused severe pain and it was thought that a collar would be of service. On the same day an appliance was made by a similar routine to that described when dealing with Case 36. It was made and fitted within two hours.

After a day's experiment with the adjustable strap she found a suitable adjustment and from then onwards the support afforded by the collar was of great relief to her. Both cervical and root pain disappeared entirely and she was able to sleep much better. Pain from other less mobile sites was relieved by morphia.

I saw her almost daily until she was discharged home to the care of her family on the 26.11.55, and during that month she had only occasional pain in the cervical region. This always followed removal of the collar while her face and neck were washed.

On the 5.1.55 I saw her at the O.P.D. where she had been sent because of recurrence of neck and root pain. On examination I found that the head had settled in rather too much forward flexion, and also there was some lateral inclination. The weight of the head was by this time almost entirely supported by the collar, the cervical vertebrae having been almost completely destroyed by the cancerous growths. It appeared that the front supporting strips of the support were not sufficiently strong for this task. The collar was removed and while a Colleague supported her head these strips were strengthened by riveting on an extra ⅛" strip on each side - these having first been softened by heat and moulded to the appliance. Extra polyurethane padding was glued in place and the collar was re-fitted. The patient's head was once again held in good position and the pain, which had developed during the 20 minutes required for this strenghening procedure, slowly abated.

I did not see this patient again but on the 23.3.56 I received a letter from her son to say that his mother had died a week previously but that she had had no pain in the neck or arm since the collar was altered on the 5th of January. She had worn it constantly until the time of her death.

CASE No. 38.

Age. 69 years.

Sex. Male.

Complaints. Right hemiplegia. Pressure sore of right heel.

Case History.

This patient was admitted on the 3.2.55 having had a cerebral vascular accident, leading to complete right hemiplegia on the previous day. Then days later a blister, containing altered blood had appeared on his right heel. It continued to enlarge and an inflamed area developed around it, despite nursing attention.

I conceived the idea of making a splint which would relieve the part from pressure. (See Page 232).

This appliance was successfully made and fitted on the 18.2.55. It held the heel suspended in a free flow of air (see photograph). No dressing was applied and all other treatment for the sore was stopped. Within a week a hard black crust had formed and the surrounding zone of erythema had disappeared. He continued to wear the splint and after a further two weeks the scab had separated revealing a clean area underneath, with only a small central area of superficial skin breakdown.

By this time a small area of skin abrasion had occurred beneath the lower border of that part of the splint abutting on the lateral malleolus. Further development was avoided by padding the area with polyurethane. It was seen that this sort of thing would reduce the value of these splints, and its repitition in other cases was avoided by designing the splint so that flaps of the plastics would cover the malleoli, (see photograph of Case 39).

The skin abrasion over the heel, left by separation of the crust, healed within a few days, and the skin returned almost to normal. Unfortunately, the patient, who had never fully regained conciousness, died on the 23.3.55, following an extension of his cerebral lesion.

It was remarkable how quickly this incipient heel sore responded to simple relief of pressure and exposure to the air. No pressure areas developed in the skin over the calf of the leg where the pressure, previously applied to the heel, was transferred by the splint. This was presumably because of the wider area of distribution of pressure and the absence of superficial bone structure beneath the skin.

CASE No. 39.

Age. 73 years.

Sex. Female.

Complaints.

Peritonitis and bilateral heel sores.

Case History.

She was admitted on the 1.9.55 with peritonitis of unknown aetiology. Surgical intervention was considered unsafe and treatment was confined to the appropriate medical methods.

By the 29.9.55 her general condition was much better but she had developed pressure areas on both heels which were progressing in spite of nursing attention and treatment by the Physiotherapy Staff, with local ultra-violet light and massage. On this date the state of her heels was as follows:-
Left heel; 2" diameter black blister situated posterio-medially. The centre was fluctuant and appeared ready to breakdown.
Right heel; $1\frac{1}{2}$" diameter black blister situated posterio-laterally. Firmer to palpation than that on the left. Both blisters were surrounded by a $\frac{1}{2}$" wide

Patient wearing splints two days after being fitted.

ring of erythema. They were tender to touch, especially at the periphery.

Heel sore splints were made and fitted on the 1.10.55. All other local treatment was stopped - in order to assess the value of these appliances. The patient found them comfortable and made no complaints throughout the five weeks they were used.

It seemed possible that the splints might increase the danger of thrombosis. She was warned of this, and instructed to make a habit of pressing her feet against the foot pieces of the splints every few minutes during the day. I may be over - emphasising the danger of thrombosis since, after all, if the calves were not resting on the splints they would be resting on the bed; and a point in favour of the splints is that by bringing the foot pieces above the toes the weight of the blankets is taken off, not only the toes but off the legs as well, so that the legs are freed of the weight of the blankets - by a sort of tent-pole mechanism. The patient was allowed to be on her back or on her side as she wished since in both positions the sores were kept off the bed, but she was encouraged to be on her back for most of the time.

Figures 2a, and 2b, (taken from a paper by Exton Smith, 1956) show the state of the left heel sore on the 10th. and 20th. day after fitting the splints.

Fig. 2. (*a*) The application of a plastic splint in the treatment of a pressure sore of the heel.

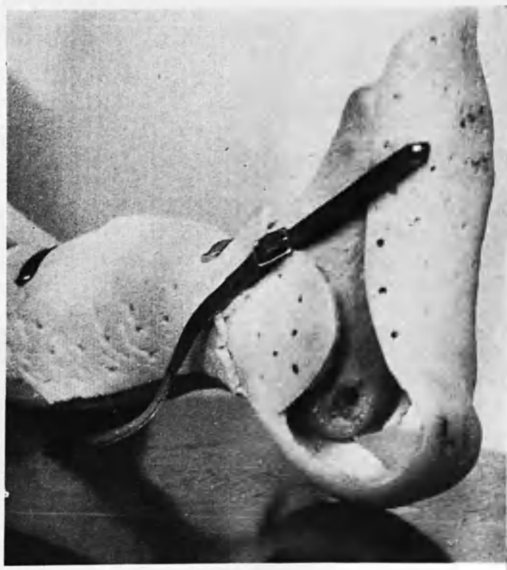


Fig. 2. (*b*) Improvement after 10 days. The sore was completely healed after 5 weeks.

It will be seen that by the 10th day (Figure 2a) the blister had resolved into a black crust. This separated ten days later, leaving a clean shallow ulcer of ¾" diameter - see figure 2b.

It required a further two weeks to achieve complete healing. During the last two weeks of the five weeks course of treatment by splinting the patient was allowed to sit out of bed, and by the end of the course, when the heels were quite normal, she was able to start walking straight away.

Following the fitting of the appliances no other treatment whatsoever was used. No dressings were applied, the heels being left exposed to the air.

CASE No. 40.

Age. 72 years.

Sex. Female.

Complaints. Diabetic gangrene. Pressure sore of right heel.

Case History.

This patient was admitted on the 17.6.55 with diabetic gangrene of the second and third toes of the left foot. The peripheral pulses could not be felt in either foot. Attention was directed towards the affected toes, an electric fan causing a good circulation over the foot which was kept elevated on a pillow. After two weeks of such treatment the condition of the toes was much better but a pressure area had developed over the right heel. The left heel showed no such changes.

The circulation was in a precarious state and I was requested to supply a heel sore splint to prevent further pressure on the affected heel. Because of the poor blood supply to the part application of the warm plastics had to be done with great care. In addition to the usual 3/16" polyurethane - attached after heating to the polythene - the foot and leg were covered with another layer of similar thickness. This was taped round the parts prior to moulding. The plastics were left on the limb for the minimum time required to harden (five minutes). No ill effects resulted from the above process.

At the time the splint was fitted the skin over the back of the heel showed a blister filled with thin watery fluid and there was some erythema surrounding it, tender to touch. This blister burst the following day and a shallow, sloughing ulcer appeared in its place.

The patient continued to wear the appliance, the ulcer being covered with two layers of gauze. No other local treatment was given.

The progress of the ulcer was rather disappointing. After two weeks there was little change from its original state. It was decided that splinting should continue but, in addition, the ulcer should be cleaned twice daily with Eusol swabs followed by dry dressings. Little improvement resulted from the new regime for the next ten days, but thereafter healing commenced and was complete after a further four weeks. The whole course of treatment occupied nearly eight weeks.

CASE No. 41.

Age. 6 years.

Sex. Male.

Complaint. Lower motor neurone paralysis of the left arm.

Case History.

This little boy had contracted poliomyelitis at the age of one year. On recogery ther was residual paralysis of the left shoulder girdle and left arm. Since the age of two years he had sustained four fractures of the left humerus. All had been caused by trauma. Three had occurred during 1955, in February, May and June; no doubt owing to the increased exposure to injury since going to school.

When first seen on the 21.7.55 X-ray showed a recent transverse fracture of the shaft of the humerus at the junction of the middle and upper one thirds. The fragments were in excellent position. The ulna, radius, humerus and scapula were markedly osteoporotic. There was no radiological evidence of the previous fractures.

He had been seen by an Orthopaedic Surgeon who had advised simple rest of the arm in a sling in view of the good position,but in view of the likelihood of displacement of the fragments I had been asked to see him with a view to making some sort of protective plastic appliance.

A suitable design was evolved and the resulting appliance is shown in photographs 1. & 2. on the previous page. This was fitted on the 29.7.55. It was made of ⅛" polythene and 3/16" polyurethane, and weighed 8ozs.

He wore this "shield" each day for the next two months and his mother gave the history that he had found it comfortable and had, in fact, become quite attached to it. He could put it on and remove it unaided. She had noted no pressure areas in the skin. At this attendance the part was X-rayed while wearing the appliance. Being translucent to X-rays a good film was obtained and it was seen that firm union had occurred in excellent position.

(The ensuing history of this appliance was that the child was loathe to have it taken away, perhaps feeling that he could indulge in more horse-play with less risk. The mother, also, was apprehensive of further fractures and when I last saw him on the 3.1.56 he was still wearing it. Examination of passive shoulder movements at that time revealed no tendency towards contracture, but the parent was advised to put the joint through a full passive range night and morning and to get in touch if any restriction was noted.)

A month later, on the 21.10.55 a more exact assessment of the limb was carried out. In brief this revealed complete absence of any movement at the shoulder and elbow. The wrist extensors showed no flicker of activity. Of the wrist flexors the flexor carpi ulnaris was quite strong (4) but the flexor carpi radialis was paralysed. The extensors of the fingers showed the following power:- thumb (3), forefinger(2), middle and ring fingers (0), little finger (1). Finger flexion was much better, the medial four fingers showing good power (4), but there was no flexion, adduction or opposition of the thumb.

By giving him playthings it was seen that poor use was being made of his finger flexion because of the inability to extend his wrist. A dorsal type cock-up wrist splint was made on the 21.10.55 which held his wrist wxtended to 20° . This splint weighed $1\frac{1}{2}$ozs.

An attempt was also made, at this time, to make an appliance which would allow fixation of the elbow at right angles. This consisted of two plastic bands, one round the forearm and one round the upper arm. These could be tightened or loosened. They were joined by two straps and buckles, one on the medial and one on the lateral aspect. These allowed a change in the angle of the elbow by adjustment of the straps - from 90° to 45°. This appliance weighed 3ozs.

The wrist splint proved to be of great help and he wore it throughout the period of observation, each day. His mother gave the history that he could use his hand much better while wearing it. It caused no skin pressire. Being fixed on with pressestuds, the child soon learned to put it on and remove it unaided.

The elbow appliance was less successful. Apparently it worked very well and did not cause any skin abrasions or discomfort but it was not of great practical value. The only time the patient required to have his elbow at a right angle for any length of time was when he was sitting at table. In this circumstance he simply lifted his left hand onto the table with his right and it lay there in the required position. At other times, when the elbow was held flexed by the splint, the limb tended to get in the way and was therefore liable to suffer trauma. The main complaint, however, was that he had to take his "shield" off when wearing it and he did not like being parted from this old friend. Thus the elbow splint was discarded. Perhaps at an older age a similar sort of plastic appliance will be of more value.

CASE No. 42.

Age. 36 years.

Sex. Male.

Occupation. Bricklayer.

Complaint. Disseminated sclerosis.

Case History.

His symptoms began in 1942 with ataxia and difficulty in walking. He remained at work, in spite of increasing disability until 1952. When first seen on the 7.10.55 he was confined to a wheel chair. He had very little active movement at hips, knees and ankles, being able to move each joint through ranges which varied from 0° - 45° (power 2-3). His upper limbs were much less affected. He was incontinent of urine. Apart from his inability to walk his main complaint was of flexion spasms of both legs, particularly when in bed. These were sometimes painful. The right leg was most often involved.

It is not intended to present a detailed analysis of this case, since his progress with splinting was not closely observed. The case is, however, included because he did obtain certain benefits which I feel were attributable to his appliances.

Both knees were splinted in extension on the 7.10.55, and he was instructed to wear them each night and also during the day when possible. He could put the splints on and remove them unaided.

He was re-examined on the 30.11.55, 11.1.56, 20.1.56 and 23.4.56. At the last examination he gave the history that he had worn the splints each night during the preceeding six months. He had found them tolerable. He was very pleased with them as they had, to a large extent, abolished his nocturnal flexion spasms. He also found that when spasms occurred during the day he could re-extend both legs much more easily. Clinically, however, there was no appreciable change in active or passive movement found at any of the examinations made on the above dates.

Probably the best objective result obtained by these splints was that he could walk while wearing them. He required the support of two persons to do so, but he could nevertheless walk in a fashion, bearing his own weight. This gave him a great psychological fillip. Prior to splinting he had two long leg callipers, but his hip movement had been so weak that, for over a year, he had been unable to walk in them. They each weighed over 4lbs. against the 1½lbs. of the plastic appliances, and the lighter weight of the latter enabled him to make use of his weak hip movement.

As regards the splints; during the first two months of wear straps were broken from the right splint on three occasions owing to the force of flexion spasms. The lining of this splint also required to be increased in depth over the patellar and round the upper and lower borders as skin pressure areas developed under these places. As the spasms diminished in number and intensity during the third month such evidence diminished and finally disappeared.

CASE No. 43.

Age. 37 years.

Sex. Female.

Complaint. Disseminated sclerosis.

Case History.

The diagnosis of disseminated sclerosis had first been made five years previously and since that time there had been a steady deterioration in her condition. When seen on the 27.9.55 she was confined to a wheel chair. There was a normal range of movement at both shoulders and elbows but power was reduced (3). The condition of her hands was her main concern. She was able to sew and knit but was having increasing difficulty in doing so. Recently on waking in the morning her hands had been tightly clenched and it was half and hour before they loosened.

Examination of hands and wrists revealed the following clinical findings:-

Wrists.

Right. Dorsiflexion and flexion were both equally shlow and spastic but the movement was strong (4).

Left. As in the right but less strong (3).

Fingers.

Right. With the wrist dorsiflexed to 30°, the tip of the digits settled ¼" - 2" (5th - 2nd) from the proximal palmar crease with the thumb resting lightly against the forefinger. On command to extend the fingers from this position it required two seconds to initiate movement. She then separated the tips of the fingers an average of 3" from the palm. The thumb extended about 1" from the forefinger. On command to grip my two fingers there was no delay in starting movement and the power of the grip was good (4).

Left. With the wrist dorsiflexed to 30° the tips of the 5th, 4th and 3rd fingers rested lightly against the palm. The forefinger settled 1" from it. The thumb rested against the side of the forefinger. On command to extend the fingers there was a delay of four seconds before movement began. She then extended them an average of 2" from the palm. The thumb extended 1" from the forefinger. When instructed to grip there was no delay in initiating flexion but the grip was weak (3).

Full passive extension of both wrist and fingers met with only a slight (B) degree of resistance, rather more marked in the left.

It seemed, in view of the paresis and the presence of some spasticity that this patient would be instructive in assessing the value of stretching the more spastic muscles (i.e. the wrist and finger flexors) for a period of time. As the left hand was rather worse than the right it was chosen for the trial. The right hand was left unsplinted to act as a control for the left.

A ventral type wrist and finger splint (type A) was fitted on the 27.9.55 and the patient was instructed to wear it constantly.

She was next seen on the 27.10.55. She gave the history that she had worn the splint only at night since it interfered, during the day, with her knitting and other pastimes. She had foud it comfortable when wearing it at night. She gave the history that, on removal of the splint in the morning, the fingers stayed out quite straight. The fingers of the right hand were found clenched as usual. During the half hour which elapsed, while unclenching of the right hand occurred, the fingers of the left hand gradually flexed. Thus at the end of this time both hands were in the position which they had occupied, at a similar point of time, prior to splinting. She had not noticed any improvement in active extension of the fingers of the left hand during the rest of the day. Examination (at 5.0.p.m.) on this date showed no change from the original findings.

On examination a month later (at 4.0.p.m.) there was only one change compared to the initial findings, but this was of some significance. The fingers of the left hand settled 1" - 2½" from the palm and there was a definite decrease in resistance to passive extension of the fingers and wrist. Whereas they had originally presented more spasticity than on the right there was now appreciably less. The patient gave the history that the fingers of the left hand did not "curl up" so much as those of the right hand during the day. There was no improvement in active extension of the left wrist or fingers. The right hand and fingers showed a little less movement than they had shown originally. Active movement of the elbow and shoulder showed no change.

Night splinting was continued for a further two months. At the end of that time (24.1.56) no improvement in active extension of the fingers was noted though left flexion spasm remained reduced on comparison with the right hand. It seemed rather pointless to continue splinting and it was therefore stopped. Two interesting points arose from this case. Spasm of the flexors, though not at any time marked, was definitely reduced. Despite reduction of spasm there was no improvement in active extension.

CASE No. 44.

Age. 59 years.

Sex. Female.

Occupation Housewife.

Complaint. Radial Palsy.

Case History.

On the 26.8.55 she had a right radial mastectomy at another hospital. On recovery from the anaesthetic a right sided wrist drop was noted. Electro-diagnosis, later, showed that this was due to neurapraxia of the radial nerve. She was transferred to us on the 4.10.55.

Examination on that date showed paresis of the infraspinatus, deltoid, triceps and extensors of the wrist and fingers. The degree of paralysis varied, the wrist and finger extensors being most affected and showing only a flicker of active movement. When pronated, the hand lay flexed to 70° under the action of gravity.

For the next three weeks she was treated with daily sessions of interrupted galvanism and passive exercises. This line of treatment did not improve active extension of either wrist or fingers.

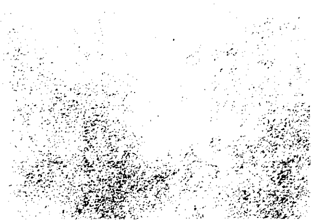
A dorsal type wrist splint was made on the 25.10.55 which held the wrist extended to 25°. It can, I think, be appreciated from examination on the photograph how little this splint interfered with gripping. The narrow supporting band does not get in the way. Weight was 2½ozs.

When next seen on the 4.11.55 there was some degree of active extension:- 70° flexion - 0° (3), 0° - 20°E.(3). By the 7.12.55 there was a marked improvement:- 75° flexion - 0° (4), 0° - 35° (3). It will be noted that she could, by then, extend the wrist past the angle at which it was held by the splint (25° extension). A photograph was taken on this date (see below) of the patient actively extending her wrist. Examination of the other paresed muscles showed that they too had made some recovery but not to the same extent as had the wrist extensors. The finger extensors also showed a little improvement, but as may be seen from the photograph this movement was still weak.

By the 3.2.56 there was a very good wrist dorsiflexion:- 70°flexion - 40°extension (4). Splinting was discontinued. The other muscle groups also showed further improvement.

It may be noted that by resting the extensors of the wrist and fingers they recovered quickly. No doubt, this improvement was coincidental with a natural recovery to some extent. Nevertheless, the fact that the other muscle groups did not show the same rapid pattern of recovery is some evidence that the splint expediated improvement - particularly as the wrist and finger extensors had shown the least amount of active movement initially.

Whatever its merits in stimulating recovery may have been, there is no doubt that while wearing this splint she was able to make good use of this hand - within the limitations imposed upon the limb by paresis of the other muscles. She found it comfortable to wear constantly throughout nine weeks. It caused no skin abrasions. No deterioration occurred.



CASE No. 45.

Age. 43 years.

Sex. Female.

Complaint. Right ulnar nerve palsy.

Occupation. Canteen worker.

Case History.

She sustained a partial right ulnar palsy following excessive use of a tin-opener at work. This instrument had caused a neurapraxia, probably by pressure on the nerve where it courses laterally to the pisiform bone. There was hyperextension at the M.P. joints of the 5th. & 4th. fingers accompanied by flexion of the I.P. joints.

A "wrist and ulnar deviation splint" was moulded in such a way that the 5th. & 4th M.P. joints were held flexed and the I.P. joints extended. The thumb, forefinger and middle finger were left free for use. These fingers were not involved by the paralysis.

She wore the splint for two months, by the end of which time there was full recovery of function. She had been able to continue working while wearing this appliance.

CASE No. 46.

Age. 29 years.

Sex. Male.

Complaint. Friedreich's ataxia.

Case History.

The symptoms of his condition first began at the age of fourteen years. He had been investigated and treated at several London Hospitals since then. He had been under the care of a Physician at the Whittington Hospital for the last six years. During that time there had been a steady deterioration in his ability to stand and walk. For the previous two years he had been unable to walk at all - not even with maximum assistance. In December 1954 two Cuff-top calipers had been ordered for him in the hope that by bracing his knees, he would be able to make use of the small amount of hip movement still remaining. Boots were also made to help correct the severe pes equinovarus, combined with pes caves, deformities of his feet. The calipers weighed 3lbs. 15¾ozs. each, and the boots 1lb. 15ozs. each. He found this extra weight almost impossible to move and attempts at ambulation were soon after suspended.

A detailed neurological examination of this patient in September 1955 revealed that he still maintained a fair amount of power and range of flexion, abduction and adduction at both hip joints. Extension was very weak(2) but he could still fully extend the limbs. He could extend both knees to 15° - 20° against gravity (3). There was no dorsiflexion at either ankle but he had a fair power of plantar flexion (3). The upper limbs were exceedingly strong in all muscle groups and only moderate ataxia was present.

The question was whether or not he could make some attempt at walking with a pair of long leg and foot splints. The great strength of his arms made it a possibility that he might walk with crutches (under supervision) if the legs were braced.

Two such appliances were made. During moulding of the foot parts the plantar flexion-inversion component of the deformity of the feet were held as fully corrected as possible. When finished and fitted to the patient they held the knees fully extended and the feet in fairly good position. Strengthening strips were riveted between the foot and the ankle to strengthen the parts correcting inversion. Thin, roughened leather "cut-outs" were riveted onto the soles of the splints.

In virtue of the lightness of the appliances (average weight 2lbs. 4ozs. each) he was able to walk with the support of one Physiotherapist. He progressed by circumducting each foot in turn. Admittedly it was with a great struggle that he got along, and at first he could manage only a few yards, but it was most rewarding to see him on his feet again, under any circumstances. In time he learned to walk, under supervision, in a walking machine, but he did not, while under my observation, ever manage more than some 20 yards. I last saw him in May 1956 by which time he had been wearing his splints, while in the Department, for eight months. He could not use them at home as he had insufficient help there to allow safe usage.

This case, like Cases 41 & 49, illustrates one of the benefits of this type of appliance. Their low weight permits patients with very weak hip movements to walk with support for quite a long time after ambulation, with the usual type of metal calliper, has become impossible.

It may also be worth pointing out the financial aspect. The calipers and boots supplied to this patient cost £46, and this money could not, of course, be reclaimed when they were found to be valueless. The pair of plastic splints cost £2. 15s. in materials. Making them required three hours of my time and that of a Physiotherapiest, the value of which works out at a further £2. 15s. The splints therefore cost about £5. - nine times less than the other appliances.

CASE No. 47.

Age. 4 years. 10 months.

Sex. Male.

Complaint. Chronic residual left hemiparesis.

Case History.

At the age of 2yrs. 10months he developed encephalitis of unknown aetiology. He was unconcious for one month. On return of conciousness he was found to have a total left hemiplegia. Over the next year he learned to walk with the aid of a B.K. iron. His left arm recovered movement only at the shoulder and elbow, and this was very limited. During the following year his walking improved a little further but no improvement was noted in his upper limb despite constant re-educational therapy.

When first seen on the 7.10.55 movement in the left upper limb was confined to 90° abduction and flexion (3) at the shoulder and full flexion (3) of the elbow from its settling position of 60° . He could extend the elbow to 60°(3) but not beyond. There was no active movement in the wrist or fingers. There was slight to moderate spasticity on extension of the elbow from 60° to 0°. With the fingers held extended in line with the metacarpals passive extension of the hand and wrist was free of resistence from its settling position of 75° (see photograph on previous page) to 0°. From 0° -70° extension there was slight to moderate spasticity.

A splint was made on the 14.10.55 which held the wrist slightly extended (about 5°) and the fingers in line with the hand. He wore it night and day for seven weeks but at the end of that time there was still no active extension of the wrist or fingers.

On the 3.1.56 a new splint was made which held the wrist more extended (30°), the fingers being again fully extended. He wore it night and day, except for washing, for four weeks. Examination then revealed that there was no resistance to passive extension, of hand and fingers, up to the locus of 30° extension at which they had been maintained by the splint. There was, thus, a 30° gain in the range of normal tonus. No flicker of active extension was noted in either wrist or fingers. Just before this examination a place had been found for the child at a school for crippled children, and, as he went off there shortly afterwards I did not see him again.

This case showed no improvement whatsoever in active movement, though the wrist had been constantly extended for eleven weeks. It is included in the series for just that reason, as it underlines the conclusion, derived from the study of the series of hemiplegic cases, that where there is no active movement found at the initial examination of a part no return of voluntary movement will occur from maintainence of the joint in functional position even though release of spasticity results from doing so.

There is no doubt in my mind that he did wear the splint constantly. His mother was a most reliable person and she was very interested in this attempt to obtain some movement in the child's hand.

The only positive feature of this case was that it helped to show that these plastic appliances are tolerable for long periods, even by children.

CASE No. 48.

Age. 10 years.

Sex. Male.

Complaint. Tuberculous meningitis.

Case History.

This child, a mentally retarded schoolboy, was admitted on the 29.1.55 complaining of headaches and delirium. Clinical examination and special investigations led to the diagnosis of Tuberculous meningitis. On the 1.2.55 he became comatose. His level of conciousness improved within a few days but he remained stuporose until the 14.4.55. His mental state then improved. Quadriplegia was diagnosed on the 15.3.55 He had occasional convulsions over the next few months. His quadriplegia resolved into a right hemiplegia before he was discharged to an orthopaedic hospital on the 26.3.56.

I was called to see him on the 17.3.55 regarding the correction of the deformity of his limbs. At this date the condition was:-

Right leg. Hip flexed to 120°; the knee fully flexed. The foot plantar flexed. The muscles were very spastic and required about 10 minutes steady passive movement to obtain extension at the hip and knee. Reflexes were greatly exaggerated and a strong withdrawal reflex was present.

Left Leg. Similar to the right but spasticity less marked.

Right Arm. Shoulder adducted, elbow flexed to 25° and the forearm and hand pronated so strongly that the palm of the hand faced almost directly forward. The wrist was flexed and the fingers tightly clenched.

Left Arm. Showed signs of a moderate degree of spasticity and paresis, but not nearly so marked as on the right.

Long leg and foot splints were made for both legs and the right arm was also splinted (on the 24.3.55). The leg splints extended from the thigh to the toes and held the knees flexed to 10° with the feet dorsiflexed to 90.° The right arm splint was made with the elbow extended to 10° and the forearm and hand supinated as far as it was possible to overcome the extremely spastic pronators - i.e. to mid pronation. Thehand was included in the splint so that the wrist was dorsiflexed to some 20° and the fingers were extended. The moulding of these splints was exceptionally difficult because of the degree of spasticity and the inability of the child to co-operate.

He wore these splints ever day until discharged one year later. The period of the day during which he wore them varied from 24 hours to 8 hours. at different times.

On discharge his general condition was reasonably good - he was sitting in a wheel chair for several hours a day and taking some interest in his surroundings - playing with toys, etc. He would answer questions quite accurately. The condition of his limbs was as follows:- he preferred to keep his knees flexed to 90° both in bed and in the chair but passive extension to 10° flexion could be easily obtained. There was no deformity of the hands or arms on either side and a full passive range at all joints was obtainable. Owing to his mental state the amount of active movement of the limbs was impossible to ascertain, but there was more spontaneous movement on the left side.

The same set of splints was used throughout.

The upper parts of the leg splints became soaked with excreta quite frequently but being washable this presented no problem.

It would be untrue to say that this patient tolerated the splints well: quite the reverse. He protested vehemently each time they were put on. I believe, however, that he disliked, not the splints, but the passive extension of his very spastic legs which necessarily preceeded their fitting. Once on, his protests soon diminished.

There can be little doubt, on considering his original state, that the appliances prevented the occurence of gross flexion deformities.

CASE No. 49.

Age. 64 years.

Sex. Female.

Complaint. Paraplegia in flexion.

Case History.

She was admitted to hospital on the 21.2.55 with increasing weakness of the legs and incontinence of urine. Clinically the signs suggested a lesion compressing the spinal cord at T.4 level. At operation an intra-medullary neoplasm was found.

By the 22.7.55 knee extension was insufficiently strong to permit standing. Movement at hips and ankles was also weak. She was supplied with long leg callipers but it was found that hip movement was too weak to utilise these appliances.

On the 29.7.55 a pair of plastic knee splints were made (weight 1.1b. 2ozs.) and wearing these she was able to walk a distance of 100 yards with the help of one person. She wore these appliances for nine months and when last seen on the 25.4.56 she was still able to walk 60 yards before tiring. She was thus able to continue a semblance of activity for nine months (perhaps more) longer than she could have done if only the usual callipers had been available. She was very proud of her ability to keep walking and she remained hopeful of some improvement coming about. Thus, by keeping her ambulent the plastic appliances had a direct bearing on maintainance of her morale, and in this their main value lay.

CASE No. 50.

Age. 4½ years.

Sex. Female.

Complaint. Cerebral diplegia.

Case History.

This child suffered from Little's disease. Only the lower limbs were affected and of these the left was much worse than the right. The above photograph shows the child attempting to fully dorsiflex both feet. It will be seen that there is a severe plantar flexion deformity of the left foot, accompanied by some inversion. On passive dorsiflexion extreme spasticity of the flexors was felt. The foot could be dorsiflexed to only 75°, and this against great resistence.

She had been referred to us by Great Ormond St., Children's Hospital with a request to continue the passive manipulations and walking exercises which she had been receiving at that Institution for the previous two years. They had been unable to effect any improvement. They had also supplied her with a Dennis Browne calcaneus splint for the left foot, for wear at night, but their letter indicated that this appliance had not helped.

It appeared to me that no attempts at education in walking could hope to prosper unless the foot could be held dorsiflexed in some way, while the exercises were carried out. A splint was therefore designed which in its completed form (see photograph) held the foot in the maximum obtainable dorsiflexion. By providing crossed diagonal straps it was possible by suitable adjustment to correct the inversion component of her deformity. The foot of the splint was then cut away as much as was possible without reducing its control of her foot. By doing this it was possible to fit a sandal over the splint. The appliance was fitted on the 20.5.55.

Walking education was then commenced. For the first few paces it seemed that the problem had been solved but thereafter it was noted that the stimulus of walking increased spasm in the flexors and the heel was gradually levered up in the splint. Examination of the appliance showed that no further tightening of the band proximal to the bulge of the calf muscles could be safely attempted.

From then on, at each treatment session, she was allowed to walk until the heel came up and then the splint was readjusted and further walking encouraged. This was a rather tedious process for the Physiotherapists but as the months went by she began to make definite progress. This, I think, was due in part to the fact that she wore the splint for twelve hours each night and this led to a very gradual release of spasticity.

By the 18.10.55 the spasm was sufficiently reduced for passive dorsiflexion, to within a few degrees of a right angle, to be obtainable. On that date I noted for the first time a flicker of active dorsiflexion. At that date her mother gave the history that she found it much easier to get the splint on and that the foot was much "freer". The Physiotherapy Staff added their observation that her heel remained well down in the splint during walking practice. There was no change in active or passive movement at the other untreated joints.

On the 22.11.55 I discussed with her mother the possibility of the child wearing the splint for 24 hours per day; pointing out that a much quicker and more thorough release of spasm might be forthcoming if this could be arranged. The parent agreed to try and arrange this with the child's Schoolmistress.

I next saw her on the 28.11.55 and received the history that constant splinting had been carried out until the 26th. when the girl had had a convulsion. She had, apparently, had two previous episodes since birth. There did not appear to be any connection with the splint as the child had tolerated it very well and had made no complaints about it. It was thought best, however, to go back to her previous period of wear.

She was next seen on the 16.1.56 and on this occasion I witnessed an active dorsiflexion of the foot carried out as an isolated movement, the leg being firmly held. The amplitude of action was small (15^{o} to 20^{o}) but the movement was quite definite. Passive dorsiflexion was quite easily obtainable to a full 90^{o} on this occasion.

On the 3.2.56 a message was received saying that the little girl's mother had died suddenly. Her course of treatment was, of course, interupted by this tragedy.

When I next saw her on the 16.3.56 she had begun again to wear her appliance. Passive movement was still possible to 90^{o} , resistance being only moderate. No active movement was seen on this occasion.

Owing to various circumstances I did not see this little girl again. This was unfortunate, as she had made slow but steady progress during the eight months of treatment. It would have been most interesting to see if any permanent release of spasticity resulted from the prolonged stretch of the ankle plantar flexors. Temporary release certainly did occur. I doubt if much active dorsiflexion would have followed, but in view of the 20^{o} active movement seen on the 16.1.56 some useful activity might have been gained.

This was the only case of congenital cerebral palsy which I had under treatment with the stretch technique. Naturally no definite conclusions can be drawn from one case, but from a very close personal observation of the response in this child I should say that it is possible that muscle spasm in this condition may be so abated. Whether or not it would be permanent it is impossible to say.

See next page for further photographs.....

Above.

This shows the maximal degree of dorsiflexion obtainable by passive movement.

Opposite.

This shows the foot held dorsiflexed to fullest extent by the appliance.

CASE No. 51.

Age. 78 Years.

Sex. Female.

Case History.

Over the past four years she had suffered increasing disability from Parkinson's disease. When she was first seen on the 30.3.56 her neck was fixed in severe flexion deformity, and she could not raise her head from the position shown in the photograph (above left).

A cervical support was made with the head held in the maximum degree of extension which was obtainable (above right). She was very pleased with the appliance finding it comfortable to wear and enabling her to see what was going on in the ward.

Just before leaving my post at the Whittington Hospital I noticed a rather remarkable development in this case. I saw her sitting up in bed holding her head up without the appliance. This incident occurred a month after fitting the collar. On request, she flexed and extended her head several times. I was unable to follow up this patient's further progress, but it may be that in Parkinson's disease a somewhat similar mechanism to that shown in the hemiplegic series is capable of utilisation. It may, in fact, be easier in view of the more equally distributed spasticity in opposing muscle groups. It would not, of course, be of great value except at joints where extension was more often desireable than flexion - as in the cervical spine, and perhaps at the knee and wrist joints.

SOFT TISSUE LESIONS.

CASE No. 52.

Age. 42 years.

Sex. Male.

Occupation. Bakery worker.

Case History.

I saw this patient on the 19.12.54. He complained of pain in the right thenar eminence. The skin over this area was red and shiny and there was tenderness on light pressure. The patient said that it had developed after transfer to the department which specialised in making Christmas puddings. Apparently, one of the ingredients of the puddings came in tubes and from these tubes it had to be squeezed out - in the manner of toothpaste. These tubes, however, were large ones and contained material, which being viscus, required considerable pressure to expel it. For several days he had done little else except sit and squeeze these tubes. The diagnosis was clearly a traumatic dermatitis and myositis. He was loathe to give up the work as it was well-paid.

I therefore made him an appliance which I hope will henceforth be known as "Brennan's appliance for Christmas Pudding Makers". This consisted of a plaque of ⅛" polythene cut to the shape of his thenar eminence and moulded thereto. It was held in place by appropriately placed straps and buckles.

He telephoned after Christmas to say that he had been able to continue making puddings with a minimum of pain and with satisfactory financial reward.

CASE No. 53.

Age. 39yèars.

Sex. Female.

Occupation. Dispenser in a chemist's shop.

Case history.

This patient complained of chronic pain in the flexor aspect of the right wrist. It was most in evidence during working hours and it cleared up when she was on holiday. There was no history of injury. Close enquiry as to the nature of her work revealed that she spent the entire working day manipulating boxes and bottles with the affected hand.

On examination there was tenderness on pressure over the flexor retinaculum and for one inch of the wrist proximal to this structure. Firm flexion of the fingers caused pain in this area, and this was greatly increased if the wrist joint was held flexed while she gripped.

A diagnosis of tenosynovitis of the flexor tendons of the fingers and thumb was made. A cock-up wrist splint was made. This was a dorsal type appliance and the supporting palmar band was made ¼" wide in order to reduce interference with gripping to a minimum.

She wore the appliance while at her work and after a week pain began to diminish and finally, after a month, it was barely noticeable. The splint did not, of course, prevent movement of the flexor tendons, but it did rest the inflamed area of the wrist and at the same time kept it in the position in which movement of these tendons was allowed most freedom.