REVIEW
OF LITERATURE
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HISTORICAL ASPECT

Poliomyelitis is said to have occurred nearly 6000 years ago in the time of ancient Egyptians, the evidence for this, which is not yet fully proved, is in the withered and deformed limbs of certain Egyptian mummies (3700 B.C.). In 1580 - 1350 B.C. the priest Ruma was shown on a plaque with a withered leg and equinus foot which was probably poliomyelitis.

In 1559 a painting by Pieter Bruegel, showed a crippled beggar which might not necessarily be polio, though it probably did occur during this period in England. In 1789, there is first known description of poliomyelitis by Underwood.

Poliomyelitis was recognized as clinical entity in the first half of the 19th century. Outbreaks were reported by Sedgwick in England in 1834 and by Calmer in USA in 1843. Von Heine published his monograph describing the clinical aspects of the disease in Germany in 1840. First epidemic of poliomyelitis occurred in 1834 in the Island of St. Helena. Larger epidemics appeared at the end of the 19th century in Scandinavia and subsequently in North America, Australia and New Zealand. Sporadic outbreaks continued in Great Britain, with the first major epidemic in 1947. In the Scandinavian countries and in the United States large scale epidemics have occurred, but with the
immunization programmes using both the salk and sabin vaccines, no large scale epidemic has occurred recently. The pathological process in poliomyelitis with the involvement of the anterior horn cells of the spinal cord was first described by Duchenne in 1855.

INITIAL PARALYSIS

The most important and the most interesting feature of the disease is the muscle paralysis and its sequelae. In fact, the discovery of weakness or paralysis in one or more muscles may be the first certain sign that a patient is suffering from acute anterior poliomyelitis at all. The paralysis usually reaches its maximum severity within 48 hours though it may in some cases continue to increase or involve other limbs over the course of several days. Occasionally a second wave of paralysis may follow a week or more after the complete subsidence of the initial bout of paralysis, especially if the patient has been allowed to become ambulant too soon.

At the end of paralytic stage, a patient may have any combination of paralysis from weakness of one or two muscles in a limb, to complete quadriplegia. Fortunately for those who are extensively affected, the level of paralysis at this time is not directly related to the degree of recovery that may ultimately occur. For example, one limb, all of whose muscles are paralysed at the height of the acute illness may show a return of
activity in almost every muscle after 2 or 3 weeks, while
the equally affected opposite limb may remain completely
and permanently paralysed.

**MUSCLE RECOVERY**

End of the fourth week is a convenient time at which
to make a detailed assessment of the residual paralyses
and paralyses relevant to the future state of limbs. At
this stage patient has recovered from the effects of acute
illness as such and much or all of pain and tenderness
in muscles has subsided. This work was done by Sharrard
(1957). He studied the recovery of muscles in upper and
lower limbs. It was rapid between the end of the first
month and the end of the second.

After this the recovery rate steadily diminished
until at the twelfth month, for practical purposes
recovery ceased. A small further increase in power can
result in selected muscles if they are given intensive
muscle training up to the end of the second year, but it
is doubtful, except in particular instances, whether this
small amount of extra power is worth obtaining because it
often disappears again when the training routine ceases.
At the end of two years no further recovery in any individu-
dual muscle ever occurred provided that the patient had
been treated properly and that no deformity had arisen.

Sharrard (1957) further made it clear that these
results apply to the recovery of muscles and not to
functional recovery in a limb or in a patient as a whole which sometimes goes on for longer than two years although the strength of individual muscles does not increase.

These findings of Sharrard referred to paretic muscles i.e. muscles that are active however weak they may happen to be. The prognosis for recovery in completely paralysed muscles is quite different.

From the earliest days of disease, a certain proportion of muscles destined never to recover because they have completely lost their nerve supply. Others have retained a number of motor nerve cells, but are temporarily out of action.

Sharrard further showed that muscles that are paralysed at the end of the first month 68 percent never recover, while the remainder will begin to function again with time and treatment.

Among muscles that are still paralysed at the end of fourth month 90 percent remain paralysed permanently, and at the end of sixth month this figure is raised to 95 percent. The 5 percent that do show some recovery after this seldom achieve more than a flicker of contraction. Thus the fourth month marks the end of the period after which a completely paralysed muscle may be expected to recover any useful function.

The destruction of motor cells in the spinal cord has been shown to occur regionally and focally (Elliott, 1942 and Sharrard, 1953). A consequence of this is that one
can know about the complete loss of all the motor cells
supplying a muscle, if there is complete paralysis in
muscles supplied by the same and adjoining spinal cord
segments. Thus the presence of complete paralysis of
the quadriceps (L₂,₃,₄) and tibialis posterior (L₄,₅)
indicates that a tibialis anterior (L₄) which is also
completely paralysed is very unlikely to recover.

To sum up the whole process of recovery Sharrard
gives a very beautiful example. In his words - "It is
rather like the development of a negative in photography,
but on a much longer time scale. During the first month
the picture is quite unrecognisable; but between then
and the fourth month, the main outlines appear. At the
fourth month we can see what the picture is but it
requires yet more time before the image becomes quite
clear and the edges well defined. The picture is fully
developed by the twelfth month; the patient has reached
what is some times misnamed the chronic stage of poliomyelitis and each of his affected limbs shows a permanent
pattern of paralysis.

**DISTRIBUTION OF PERMANENT PARALYSIS**

Though a striking feature of the paralysis that may
result from an attack of poliomyelitis is its diversity,
the belief that some order exists in the apparently
irregular distribution of the permanent paralysis has been
expressed by several authors. Wickman (1913) stated that
"although a great variety of combination of paralyses
are found, certain types appear more often than others; in the leg the peroneal group and certain muscles of thigh— 
my experience the quadriceps femoris especially—tend to be implicated”.

At first sight the pattern seems to be different in every case and to be quite haphazard in its distribution 
but as Lovett (1915, 1917) and Legg (1929, 1937) described 
all is not quite as disorderly as it would seem to be.

Sharrard (1955) studied distribution of permanent 
paralysis in 149 patients. There were 2000 limb muscles 
that were either paralysed or paretic at the end of the 
period of recovery. He showed with the help of tables 
how frequently individual muscles were affected. The 
quadriceps, hip abductors and inner hemstrings were 
often affected, the leg muscles less often and the 
intrinsic muscles of the foot the least frequently 
affected. In the same group of patients the situation 
of muscles that had remained permanently paralysed was 
almost reversed. Tibialis anterior, tibialis posterior 
and the long flexors and extensors of the toes led in 
frequency, while the hip and thigh muscles were much 
less often paralysed. The intrinsic muscles of foot were, 
though, the least often paralysed as well as the least 
often affected.

Sharrard also determined the ratio of paralysis to 
paralysis by tables which showed the susceptibility of each 
muscle to paralysis. The tibiales and long flexors and
extensors of the toes were very susceptible, the adductors and glutens maximus the least. Tibialis anterior was seven times as likely to be paralysed as the hip adductors or flexors and twice as likely to be paralysed as the peronei. According to him these were absolute values of considerable significance and can not be explained by the mechanism of chance.

**AGE AND SEX DISTRIBUTION**

The characteristics of the disease have altered and poliomyelitis can no longer be regarded as truely infantile. The change in age group of patients is illustrated by statistics in the state of Massachusetts where in 1907 only seven percent of patients were over 15 years of age compared with 25 percent in 1947. Legg (1929) worked out age and sex incidence. According to him average age of patient was 5.4 years. The males predominated in all years except at four and five when the females predominated and at 10 when they were equal. Instances of more than one case in the same family occured 32 times in 755 families (4.2 percent). One family had four children affected.

Another study carried out by WHO in 1982 reveals - "All but four recipient cases were in patients under five years of age and 69 percent were in patients under one year of age. This age distribution was obviously related to immunisation schedules which in all countries required the immunization of infant in the first year of life".
REGIONAL DISTRIBUTION

Jahss and Samuel (1917) studied 400 cases of anterior poliomyelitis and emphasized about regional distribution, a large number of cranial nerve involvement and muscle distribution.

Of the entire series 78 percent showed some involvement of lower extremities and 38 percent showed involvement of only one limb. Of this 10 percent were of upper extremity and 28 percent of the lower. In 20 percent of cases there was some form of trunk paralysis showing that it had been quite a common occurrence. The right and the left sides of the body were equally attacked.

The extent of paralysis varied from a part of one leg to involvement of both legs, both arms, both sides of the abdomen and back and also the larynx.

In 13 percent of cases, the cranial nerves were involved. In six cases two different nerves were involved at the same time. The 5th nerve was affected, one time; the 6th nerve, one time; the 7th nerve, 38 times; the 10th nerve, four times and the 11th nerve, 13 times.

Lovett (1917) in his study of infantile paralysis concluded that most common involvement was of both legs, then one or the other leg, next in frequency all four extremities, then two legs and one arm, and then one arm. Next in frequency came a distribution of much importance - one arm and one leg - and here a hemiplegic arrangement
was distinctly more common than one arm and one leg on opposite sides.

In 948 patients over three years of age affected in 1916 epidemic, 72 percent were paralysed in the abdomen. According to Lovett these unique findings were undoubtedly because examination in every case was made as to this point. The examination for paralysis of the back was not as satisfactory or as accurate as most examination and slight degrees of weakness was apt to be overlooked. Back muscles involvement was 13.5 percent.

Neck paralysis has evidently been largely overlooked but frequently exists. In Lovett's study it was present in 11 percent of cases. The normal patient can lift the head against a small force when lying on the back. Weakness or paralysis of one or both sternomastoid muscles makes this impossible.

Legg (1929) noticed that the legs always show a much greater amount of involvement than the arms, with practically no difference between the right and left sides. Generally, too, the upper arm and the thigh show a greater amount of involvement. This however, did not hold true in regard to the severity of involvement. There was no great difference seen in the comparative severity of involvement of upper and lower arms. It was interesting that while the thigh shows a greater amount of involvement, the total paralysis in it is only 0.6 percent as compared to 7 percent in the leg.
PARTIAL VS TOTAL PARALYSIS

Lovett (1915) while commenting upon nature of the paralysis mentioned that partial paralysis was much more common than total. Of 1,452 muscles affected 416 were totally paralysed and 1,036 partly, that is, the relation of partial to total paralysis was as 2.5 to one. This ratio of partial to total paralysis varied in individual muscles.

A curious phenomenon was observed several times, where part of a muscle was paralysed and other part not. This was observed in deltoid muscle, where the anterior or posterior half might work independently of the other. Another muscle in which this was observed was pectoralis major, where the sternal and clavicular parts were separated by function.

The predominence of partial over total paralysis is of importance. According to Lovett, the reason for this would seem to lie in the grouping and relation of the nerve cells in the anterior cornua of the cord. These cells lie in longitudinal bundles, which are naturally largest in the cervical and lumbar enlargements.

He pointed out - "we must remember that the poison of infantile paralysis reaches the cord by means of the circulation and that the main blood supply is from the anterior spinal artery, horizontal branches from which enter the cord at each side at different levels, about
200 in number. The planes of destruction, therefore are likely to be transverse, while the lines of nerve centre association are longitudinal so that in the case of a muscle which derives its innervation from a group of nerve cells occupying several segments, a transverse lesion may well leave certain centres intact and some power may remain in the muscle.

This matter of partial paralysis is most important in the matter of treatment because in such muscles there remains some initiative and with it the power of developing more muscular volume and new association by repeated passages of impulses from brain to muscle.

**SEVERITY OF PARALYSIS**

According to Lovett's study, the muscles of the limbs nearest the trunk are more frequently affected than the distal ones; the left arm muscles are noticeably more frequently affected than the right. The leg muscles in the right and left leg are equally affected.

The facts of use or function are that the right arm is much more actively used than the left, not only more frequently, but also for more varied and complicated and finer movements. But the legs are equally used. It would therefore seem that muscles used actively, continuously and in a complicated way are more likely to escape than those less used, or used for simpler, less continuous work. Lovett presumed that the blood supply would be more
free around the spinal centres where the motor activity was greatest and most complicated and perhaps less free where the motion were less frequent and complicated. This would account for the predominance of left arm paralysis and the equal paralysis of both legs.

This also accords with the distribution of the paralysis in both arms and legs, which has been shown to be most frequent near the trunk. The demands on the hip and shoulder muscles are simple and less continuous than on the muscles of the lower leg and forearm or of the hand and foot. The latter are continuously active in small, fine complicated movements, whereas the larger muscles nearest the trunk deal with the coarser and less frequent movements. The relation between the activity of the proximal and distal parts of a limb are not unlike those of the left and right arms in their relative use. It seems probable from these facts and this grouping that on the whole muscle centres given to finer, complicated more frequent movements have a more active blood supply and are less likely to attack on their nerve centres by the virus of infantile paralysis than the centres of muscles functioning in heavier, less complicated and less frequent movements.

Lovett (1915) analyzed 58 cases and pointed out about paralysis of arm muscles. In cases in which the muscles of upper extremity are involved without paralysis
occurring at other parts of the body, it is more severe in this region than when the muscles of the legs are also involved. Arm paralysis which is strictly regional is more severe than arm paralysis which exists in combination with more general paralysis.

Lovett concluded from his study and said that the investigation of paralysis of the arm showed —
1. that the paralysis was most frequent at the shoulder and diminished in frequency from shoulder to the hand.
2. that the paralysis was severest in the shoulder and diminished as one went towards the hand.
3. that paralyses of the muscles of the left arm was very much more frequent than of the right arm.

With regard to paralyses of the muscles of lower limb the following facts were observed, which are of importance as contrasted with the similar observation in the arm: —
1. The paralysis was on the whole more frequent at the hip and diminished in frequency towards the foot; that is the individual muscles in the upper segment were more often affected than in the lower.
2. The paralysis was on the whole lightest in the hip, next lightest in the thigh and severest in the lower leg; that is, the proportion of total to partial paralysis increased as one went away from the hip towards the foot.
AFFECTION OF INDIVIDUAL MUSCLES

Lovett (1915) made tables to show the affection of individual muscles which shows that they were affected either partially or totally. The main facts are that the quadriceps, glutei and gastrocnemius lead in frequency and that paralysis of leg muscles is much more frequent than of arm muscles. Abdominal paralysis existed in more than half of all the cases and affection of the muscles of the spine in more than a quarter. The latter points have a distinct bearing on the occurrence of scoliosis and indicate that such affections are more common than had been supposed. The cases of abdominal paralysis were always symmetrical with two exceptions one right and one left. This paralysis may occur as the only paralysis in the entire muscular system. When associated with paralysis of other parts, the association is always with leg muscles.

Sharrard (1955) obtained tables for lower limbs as well as for upper limbs. In frequency of affection the deltoid muscle led, followed by triceps and pectoralis major. The least affected muscles were the long flexors of digits; the intrinsic muscles of the hand were in the intermediate position. In frequency of paralysis the deltoid muscle came second to the thenar muscles and was followed by interossei and the triceps; pectoralis major which was third in frequency of affection, now became
twelfth. On determining susceptibility to paralysis, the intrinsic muscles of the hand were the most susceptible followed by the muscles acting on the wrist. The deltoid muscle was only moderately susceptible and the least susceptible were trapezius and pectoralis major.

Sharrard studied 2464 affected muscles, of these 1,502 were paretic and 962 paralysed. The ratio of paresis to paralysis was 1.56 to one.

The numbers of pareses and paralyses of individual muscles, and the proportion of paresis to paralysis varied. The main facts were that the quadriceps and the hip abductors (Gluteus medius and minimus) led in frequency of affection and in numbers of pareses, but the muscles of the leg were the most frequently paralysed. Tibialis anterior, tibialis posterior and the long flexors and extensors of the toes showed low proportions of paresis to paralysis, while the hip flexors and hip adductors showed a high proportion.

The order of the muscles shown in tables by Sharrard confirmed the findings of Lovett (1915) that the muscles nearest the trunk are more frequently affected than the distal ones. He observed "the demands on the hip and shoulder muscles are simple and less continuous than on the muscles of the lower leg and forearm or of the hand or foot. The latter are continuously active in small, fine and complicated movements".
It is tempting on this basis to assume that a casual relationship exists between differences in the size and function of individual muscles and their frequency of affection.

When, however, the same muscles are arranged in order of frequency of paralysis, the picture is completely different. The largest number of paralyses are found in the distal muscles, which also agrees with Lovett’s findings. To explain them he states - "the severity of the paralysis is proportionate to the weight to be met by the muscles at different levels, not because this factor influences in any way the original affection of the nerve cells but because it may retard the recovery of those muscles working against the greatest weight."

But this hypothesis fails to explain several important discrepancies. There is very low incidence of paralysis in the intrinsic foot muscles which by Lovett’s reasoning, should be the most frequently paralysed of all muscles in the lower limb. The number of paralysed inner hamstring muscles - differs from the number of paralysed biceps femoris muscles, though it should be about the same. Further, the rate of recovery in proximal and distal muscles has been shown to be the same for all muscles in the lower limb instead of showing any differences needed to account for the complete dissimilarity between the order of the muscles
in tables (Sharrard 1955).

As Skinnj (1949) observed in a similar study there is no quality of the muscles such as size, function, position in the limb or phylogenetic development that can satisfactorily explain the frequent affection of some muscles and the high proportion of paralysis in others.

Not much work has been done in India on this particular subject. Punetar and Patel (1977) however, studied the pattern of residual paralysis in poliomyelitis of lower limbs in Ahmedabad. According to them it was found that while the quadriceps, hip extensors and tibialis anterior were most frequently affected, the flexor hallucis longus and flexor digitorum longus were involved least frequently.

On the other hand, in the paralytic group tibialis anterior, quadriceps and tibialis posterior were most commonly affected and the tensor fascia femoris involved least commonly.

The segmental distribution of muscles affected and muscles paralysed show that while lumbar two and three were most frequently affected, lumbar four was most commonly involved in complete paralysis. While commenting the susceptibility of a particular muscle to paralysis they told that tibialis anterior, tibialis posterior and quadriceps were very susceptible, while abductors of hip
and tensor fascia femoris were the least.

Infantile poliomyelitic paralysis has been regarded as a haphazard affection of muscles, most frequent in the leg. In the cord lesion it appears to have a purely accidental distribution most marked in the lumbar enlargement. It is possible, however, that there are other factors than the cord lesion which determine the ultimate condition of affected muscles.

**ANALYSIS OF SEVERITY DISTRIBUTION IN ARM AND LEG**

Another interesting finding observed by Lovett (1915) was that the muscles of the upper extremity are more severely affected nearest the trunk and less severely lower down. But this relation is reversed in the leg and the largest proportion of severe paralysis is in the lower leg and foot. This is estimated on the proportion of total to partial paralysis in the individual muscles.

This puzzling phenomenon is more nearly correlated to the weight coming on each muscle in the activities of the upright position than to any other factor. The great majority of these patients were walking in some form or other so that the weight bearing position may fairly be taken into account.

At the shoulder, the deltoid, triceps and biceps all help to hold the arm up against the shoulder joint. The weight to be met is not only in this suspensory function, but also in attempted movements. It is greatest
at the shoulder and less as one goes down the arm, because the weight of the whole arm is obviously more than the weight of the lower one or two segments. Upper arm muscles consequently, have more weight to handle than forearm and hand muscles.

In the leg, on the other hand, the weight to be met in muscular function increases as we go from the hip to the feet. There is greater superincumbent weight at the lower leg than at the hips, so that the lower leg muscles raise more weight than hip muscles in walking. There is of course, no proof that this variation in severity of paralysis is caused by this greater or less weight to be met in muscular function. However, the explanation accords with the facts better than any other seems to do.

Severity distribution can not be correlated with size of muscles or function of a peculiar sort. It can not be explained by local circulatory sluggishness affecting dependent parts. It is not associated with anterior or posterior muscles nor is easy to correlate it with spinal localization.

It seems purely a segmental limb distribution and whether it is or is not correct explanation, severity of paralysis is proportionate to the weight to be met by the muscles of different levels. This factor does not influence the original affection of the cells in any way but it may retard the recovery of those muscles working against the greatest weight.
SEGMENTAL INNERVATION IN RELATION TO AFFECTION OR PARALYSES OF MUSCLES

Sharrard tells if the paralysis in a muscle is not related to any feature of the muscle itself, there remains the possibility that it may be related to its innervation, or, more precisely, to the site and extent of changes in the motor cells of the anterior horn of the spinal cord.

Evidence of such a relationship is given by an enquiry into the segmental incidence of muscle affection. For each spinal segment, the total number of affected muscles that receive a supply from the segment were noted, thus, in the third lumbar segment, the muscles were the hip flexors, the hip adductors and quadriceps. The mean number of affected muscles - in this segment was calculated and used to plot a curve, which represented the segmental incidence of muscle affection. The highest incidence was found in the second and third lumbar segments; below this level, there is a uniform decrease in the numbers of affected muscles that successive spinal segment supply.

The segmental incidence of paralysis, derived in the same way, is altogether different. It is included for comparison with an almost identical curve obtained in the same way by Seddon et al (1945) in an analysis of a large number of cases of poliomyelitis in the Malta
epidemic of 1942-43. A high incidence was found in all spinal segments between the 4th lumbar and the second sacral segments. The curve was irregular and indicated no direct relationship between segmental innervation and frequency of paralysis.

Attempts by earlier authors (Lovett, 1915, Skinhoj, 1943) to explain similar findings in terms of spinal cord lesion were hampered by the paucity of information concerning the localization of function in the motor cells in man and by the incomplete accounts of the sites by destruction of these cells in poliomyelitis.

THE SITES OF MOTOR CELL DESTRUCTION IN POLIOMYELITIS

A method of reconstruction by projection microscopy of the nerve cell content of the lumbosacral spinal cord was devised by Sharrard (1953).

The general distribution of motor cell destruction in the anterior horns of poliomyelitic spinal cords showed several constant features.

The second and third lumbar spinal segments were the most frequently and extensively attacked in all the cords. Segments caudal to this were less affected, the third and fourth sacral segments, being specially likely to be spared. A similar segmental incidence of motor cell destruction has been noted by others (Horanyi-Hechst, 1935, Peers 1943, Elliot 1945, 1947).
Destruction was found not to be diffuse but localized in discrete foci of varying length and width with interposed lengths of grey matter of more normal cell content. In the transverse plane the centre of the anterior horn appeared to be the most vulnerable area at most segmental levels.

Motor cell destruction was always much more severe than would have been expected. One case in which there had never been any demonstrable weakness in any muscle in the lower limbs had suffered losses of upto 40 percent of the normal number of cells in some cell columns. Far from these being any evidence that residual motor cells were functionally inactive, it was surprising to discover how small a proportion of cells had been required to produce a useful contraction in the muscle they supplied. The residual power of a muscle was found to be closely related to the proportion of remaining motor cells that supplied it.

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<th>Muscle power (MRC Scale)</th>
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The relationship between muscle power and residual motor cells in the spinal cord.
THE RELATIONSHIP BETWEEN THE DISTRIBUTION OF THE ANALYSIS AND THE DESTRUCTION OF MOTOR NERVE CELLS

The segmental incidence of muscle affection derived from the analysis of the clinical material (Sharrard 1953) agrees exactly with the general distribution of motor cell destruction. Since the upper lumbar spinal segments supply muscles in the region of the hip and thigh, while the lower lumbar and sacral segments generally supply the muscles of the leg and foot, it is easy to see why there is, apparently a greater incidence of affection in proximal than in distal muscles in the limb. It is interesting to note that the hip muscle that derives its main supply from the sacral segments i.e. the gluteus maximus - is less frequently affected than other hip muscles. This is also true of the small external rotator muscles of the hip.

The findings of Sharrard (1953) in the spinal cord also account for the large number of paralyses found in muscles such as tibialis anterior, tibialis posterior and the long flexor and extensor muscles of the toes. Muscles supplied by short columns of cells are the most frequently paralysed. Those supplied by long columns are more likely to be paretic. The high incidence of paralyses in muscles supplied by the lower lumbar and upper sacral segments is due to the fact that most of them - tibialis anterior, tibialis posterior, peroneal and the long muscles of the toes are supplied by short columns.
There is yet no adequate explanation for the greater incidence of motor cell destruction in the upper lumbar segments and the progressively smaller incidence more caudally. In the transverse plane, the central sites of cell loss also found by Elliot (1945, 1947) in the anterior horn, resemble those found by Krogh (1945) in experimental hypoxaemia of the spinal cord, and it is possible that vascular factors are partly responsible for them.

**ASSOCIATED PARALYSIS**

That certain muscles appear to be paralysed or weakened together has been noted by several authors (Courtney 1896, Wickman 1913, Lovett 1915). Their observations were unfortunately incomplete and relied on clinical impressions rather than on numerical analysis.

Lovett (1915) observed the muscles in the leg most closely associated functionally are the gluteals, the quadriceps and the gastrocnemius, for they are the muscles which maintain the upright position. The gastrocnemius holds the tibia upright on the foot, the quadriceps hold the knee straight and the gluteals hold the trunk erect on the legs. The associations were as follows:

If the quadriceps is paralysed, either the gluteals or the gastrocnemius or both are almost always associated with it. In 109 cases there were only two exceptions. In three cases the quadriceps had no association in the leg. In the 109 cases of quadriceps paralysis, to contrast with
the 106 associations of gluteals or gastrocnemius, there were only 58 associations of paralyses of one or both hamstrings. The quadriceps, therefore, is affected nearly twice as often with its associated muscles as with its antagonist.

When the gastrocnemius is involved, the quadriceps or gluteals were involved in 108 out of 109 cases; but the antagonist of the gastrocnemius, the extensor digitorum longus and the tibialis anterior, either one or both, were paralysed in combination with it in only 66 cases.

Jahss (1917) studied 400 cases of anterior poliomyelitis of 1916 epidemic and commented about association of paralysis: "the most frequent combination of muscles attacked in the leg has been those supplied by the anterior tibial nerve. In the thigh, the quadriceps, adductors and hamstrings have shown a distinct tendency to be involved together (a mixture of both the lumbar and sacral plexuses)."

When the external rotators of the hip were involved the internal rotators always, accompanied them. In no case were they affected alone. In the arm, the deltoid, pectoralis major and latissimus dorsi have been associated in paralysis. The latissimus dorsi was affected in 51 cases and in 50 of these the foregoing took place. The upper arm type or the forearm type of paralysis did not occur in any instance.
Sharrard (1955) reviewed the muscle charts of the 203 lower limbs to find out whether those impressions were correct and to reveal associations of paralysis that might otherwise be overlooked. Coincident sparing or absence of paralyses in muscles, which is equally important and likely to escape clinical observation, was also noted.

Some associated paralyses for instance between the long toe extensors and the peronei or between the hip abductors (Gl. medius and minimus) and the gluteus maximus - might be explained by the closely allied functions of the muscles, as had been suggested by Lovett (1915). Other associations such as those between the calf muscles (Triceps surae) and the biceps femoris (first described by Bennett in 1952) or between quadriceps, the hip adductors and the hip flexors can not be explained so easily.

The absence of a strong association between the inner hamstring muscles and the biceps femoris or between the long toe flexors and the intrinsic foot muscles provides further evidence against the theory that associated function leads to associated paralysis of muscles.

Funatar and Patel (1977) could draw the same results during their study and found that certain muscles have a tendency to be spared or paralysed together. These associations most probably depend on the position
of the spinal nuclei of the muscles. In their study a surprising association was found between the paralysis of flexors of hip and internal rotators. If one of these was paralysed then in 7 out of 10 cases the other was likely to be paralysed. On the other hand, some muscles with a common nerve supply like hip abductors and extensors did not have associated paralysis.

**EXPLANATIONS OF PREDOMINANCE OF ASSOCIATION PARALYSIS**

According to Lovett (1915) this predominance of paralysis is susceptible of several possible explanations, of which the following may be mentioned:

1. The muscles which maintain erect posture are all very large and must have large centres composed of many motor cells. On account of this, they are more likely to be affected than smaller muscles by a generally distributed destructive process in the cord. But this is not altogether acceptable because the tibialis anterior and peronei, which are small, are of high incidence. Reciprocal to this the pectoralis major a large muscle is of low incidence.

2. The second explanation given by Lovett is that associated muscles may be so intimately grouped in the arrangement of their motor centres in the cord that they are more likely to be involved in the same lesion than opposed muscles would be.

3. The third explanation for the predominance of residual paralysis in associated rather than antagonistic
groups may be in the functional relation of the muscles themselves. Three muscles, the glutei, the quadriceps and the gastrocnemius work together to maintain the upright position, if a whole leg is lightly affected, it may be that the association of these muscles in function may retard their recovery by their intimate and necessary functional dependence on each other. Especially if one of these muscle were seriously affected, it might retard the recovery of muscles associated with it by throwing more work on them than they were able to perform in their affected condition.

Sharrard (1955) explained about association of paralysis when the whole of the motor column that supplied a muscle had been destroyed, it was likely that one or more adjacent motor columns that occupied the same length of spinal cord was completely destroyed or severely affected. This is reflected in clinical distribution of muscle paralysis. For example, the columns that supply extensor hallucis longus, extensor digitorum longus and peronei lie next to each other and occupy approximately the same length of spinal cord. Therefore, paralysis of one of these muscles is frequently associated with paralyses of the other two. Conversely, absence of paralysis in one muscle is likely to be associated with absence of paralyses in the others.
## ASSOCIATED PARALYSES IN THE LOWER LIMB
*(Table given by Shagard)*

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Associated muscles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip flexors (psoas)</td>
<td>Quadriceps, abductors</td>
</tr>
<tr>
<td>Abductors</td>
<td>Quadriceps, inner hamstring muscles, hip flexors</td>
</tr>
<tr>
<td>Quadriceps</td>
<td>Hip flexors, adductors, inner hamstring muscles</td>
</tr>
<tr>
<td>Inner hamstring muscles</td>
<td>Adductors, quadriceps, hip abductors</td>
</tr>
<tr>
<td>Hip abductors (gluteus medius and minimus)</td>
<td>Gluteus maximus, biceps femoris, tensor fasciae latae</td>
</tr>
<tr>
<td>Tensor fasciae latae</td>
<td>Hip abductors, gluteus maximus</td>
</tr>
<tr>
<td>Gluteus maximus</td>
<td>Hip abductors, biceps femoris, tensor fasciae latae</td>
</tr>
<tr>
<td>Biceps femoris</td>
<td>Gluteus maximus, hip abductors, calf muscles</td>
</tr>
<tr>
<td>Calf muscles (triceps surae)</td>
<td>Biceps, femoris, flexor digitorum longus</td>
</tr>
<tr>
<td>Flexor hallucis longus</td>
<td>Flexor digitorum longus, extensor hallucis longus</td>
</tr>
<tr>
<td>Flexor digitorum longus</td>
<td>Flexor hallucis longus, extensor hallucis longus</td>
</tr>
<tr>
<td>Extensor hallucis longus</td>
<td>Extensor digitorum longus, peronei, flexor hallucis longus</td>
</tr>
<tr>
<td>Extensor digitorum longus</td>
<td>Extensor hallucis longus, peronei</td>
</tr>
<tr>
<td>Peronei</td>
<td>Extensor digitorum longus, extensor hallucis longus</td>
</tr>
<tr>
<td>Tibialis posterior</td>
<td>Tibialis anterior, extensor hallucis longus</td>
</tr>
<tr>
<td>Tibialis anterior</td>
<td>Tibialis posterior</td>
</tr>
<tr>
<td>Intrinsic foot muscles</td>
<td>Calf muscles, peronei</td>
</tr>
</tbody>
</table>
Unusual associations, like that between the calf muscles (Triceps surae) and the biceps femoris, can be accounted for in the same way, since their motor cell columns are so closely associated. The factor common to all strongly associated pairs of muscles is that their motor cell columns lie adjacent to one another and their segmental levels of supply correspond or overlap.

ASSOCIATED PARALYSIS AND THE PROGNOSIS FOR PARALYSED MUSCLES

In another paper Sharrard (1955) has shown the prognosis for a paralysed muscle to be related to the degree of paralysis in the muscles supplied by the same spinal segment. Associated paralysis between muscles may also be applied to determine prognosis for recovery.

Ten muscles were chosen in which it may be important to know the prognosis for recovery. The probability of recovery to a functional power (MRC grade 2 or greater) was worked out for each muscle -

1. When both of its most strongly associated muscles were paralysed.

2. When one associated muscle was paretic or normal and the other paralysed, and

3. When both associated muscles were paretic or normal.

When both associated muscles were paralysed, the prognosis was very bad, particularly for the quadriceps,
the hip abductors, tibialis anterior, tibialis posterior and the long toe extensors. When both associated muscles were parietic or normal there was an excellent prognosis for all muscles - except tibialis anterior.