Late residua of acute idiopathic polyneuritis

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SUMMARY An account is given of four patients with acute idiopathic polyneuritis, leading within a few days to almost total paralysis. Two of these (cases 3 and 4) began to recover voluntary movement in the limbs in a month or less, and showed complete clinical recovery in three and 10 months respectively. The other two (cases 1 and 2) began to recover proximal limb movements after three months, reached a plateau of recovery in about two years, and never recovered movements in the distal parts of the limbs, which underwent muscular atrophy. Patient 2 died 14 years after the acute illness and was examined post mortem. The difference in recovery is explained by supposing that in patients 3 and 4 the lesions consisted predominantly of segmental demyelination, whereas in patients 1 and 2 there was extensive axon destruction at a proximal level. Recovery in the latter depended upon nerve regeneration, which restored the power of the proximal muscles, but was too slow for effective reinnervation of distal muscles. This explanation is supported by post mortem findings in patient 2. A further observation in patient 2 was of degeneration of the posterior white columns of the spinal cord, which was not due to loss of posterior root fibres. It is believed that in such cases prognosis as to ultimate recovery of muscle power can be made about a month after the acute phase according to whether movement has begun to return in the distal parts of the limbs. If recovery does not occur within two years it will not occur at all.

The prognosis in non-fatal cases of acute idiopathic polyneuritis (Guillain-Barré syndrome) is generally excellent. According to Sigwald and Nouailhat (1970), permanent sequelae are rare.

'At the most they consist of permanent residual areflexia, mild motor loss (in, for example, the dorsiflexors of the feet), slight residual facial anomaly, occasional intermittent paraesthesiae, and minor deficit in deep sensibility in the distal parts of the extremities.'

Asbury *et al.* (1969) describe the disease as 'potentially completely reversible'. A rather less cheerful picture is given by Pleasure *et al.* (1968), who found residual deficits in 29 out of 49 cases followed up for two years or more. Of these, eight cases suffered from disabling residua in the form of severe weakness of distal limb muscles, in some cases accompanied by sensory impairment of glove-and-stockings distribution. Hewer *et al.* (1968), in their follow-up studies of 29 long-term survivors from acute polyneuritis severe enough to require artificial

respiration, found five with substantial residual weakness of distal muscles, especially in the legs. Three of their patients, including the two most disabled, are described in this paper. One with severe residua died 14 years after the acute illness, and the pathological findings are described.

CASE 1

V.P. (R.I. 88574) was admitted at the age of 53 years. Seven days earlier she had developed malaise and sore throat. Three days before admission her legs felt weak, and the day before admission she had been unable to stand, her hands had been weak, her feet had tingled and she had difficulty in breathing. On admission there was no voluntary movement in the upper limbs and very little in the lower. She was unable to lift her head off the bed and was having difficulty in breathing. A tracheotomy was performed and artificial respiration by intermittent positive pressure was begun. She was fed by nasogastric tube. Cerebrospinal fluid was normal. Electrophysiological studies by Dr. G. Rushworth

TABLE

COURSE OF DISEASE IN FOUR PATIENTS WHO HAD COMPLETE OR ALMOST COMPLETE PARALYSIS IN ACUTE STAGE

	Case 1 V.P.	Case 2 A.P.L.	Case 3 J.D.	Case 4 A.S.
Age at onset (yr)	53	58	16	23
Time from first neurological symptom to maximum paralysis (d)	11	7	3	10
Extent of maximum paralysis	Complete except for minimal eye movements	Complete	Complete except for elevation of eyes	Complete
Maximum paralysis to start of recovery				
head and trunk	1 mth	1 wk	3 d	1 wk
limbs, proximal	3 mth	3 mth	about 2 wk	1 mth
limbs, distal	—	—	about 2 wk	1 mth
Time to maximum recovery (mth)	24	24	7	10
Final state				
head and trunk	Normal except for vocal cords	Normal	Normal	Normal
shoulders and hip muscles	Very strong	Normal	Normal	Normal
elbow and knee muscles	Fair power but weaker than more proximal muscles	Moderately weak	Normal	Normal
hand and foot muscles	Paralysed	Paralysed	Normal	Normal
sensation	Marked superficial and deep loss distally	Marked deep loss distally	Normal	Normal

two weeks after the onset showed evidence of widespread denervation but no fibrillation. Eleven days after the onset she was incapable of any voluntary movement except for slight movements of the eyes. One month later the cranial nerves began to improve, and three months after reaching maximum paralysis the proximal limb muscles began to contract. Recovery continued for nearly two years; muscles proximal to the elbows and knees were then moderately strong, but more distal muscles were wasted and very weak. Ten months after the onset she was able to breathe unassisted. She had a persistent laryngeal palsy, so that both vocal cords were adducted and the airway was inadequate. The right vocal cord was therefore surgically fixed in partial abduction (Mr. Livingstone), and it was then possible to close the tracheostomy. Seventeen years after her illness there had been no recurrence. The cranial nerves were normal, except that it was impossible to assess the vocal cords owing to the surgical intervention. Muscles acting on the shoulder were very strong, those acting on the elbow were within normal limits. The forearm muscles were very weak. The small muscles of the hand were paralysed and wasted. Hip and trunk muscles were strong, knee muscles had useful power though they were not normal, and there was no movement in the muscles below the knees. Superficial sensation was severely impaired over the fingers and the feet. Joint position sense was poor at the fingers and wrists and at all joints in the lower limbs. The strength in the lower limbs was

enough for her to walk, but she did not do so because of sensory loss. Electrophysiological examination about that time (Dr. Rushworth) showed relatively slow conduction velocity of motor nerves, indicating that the nodal spacing of the regenerated fibres was not normal. There was little evidence of peripheral sprouting of motor nerve fibres.

CASE 2

A.P.L. (R.I. 203814) was admitted at the age of 58 years. About four days previously she had had an acute feverish illness with coryza. On admission she was complaining of widespread weakness and of sensory disturbance distally in the limbs. In addition to a severe kyphoscoliosis there was severe paralysis of all limbs, slight movement remaining only at the shoulders and ankles. She had facial weakness, could not swallow, was having difficulty in breathing and could not take a deep enough breath to cough. Vital capacity was recorded as 40 ml. There was sensory impairment distally. Cerebrospinal fluid had to be obtained by cisternal puncture, owing to the kyphoscoliosis. It contained protein 80 mg/100 ml., but was otherwise normal. A tracheotomy was performed and artificial respiration by intermittent positive pressure was begun. She was fed through a nasogastric tube. About a week after the first symptom she was incapable of any voluntary movement. After a further week she began to get movements of the head and trunk. Recovery was slow, and it was

FIG. 1. Case 2. Posterior belly of the digastric muscle. (a), (b), and (c): abnormal patterns of innervation, with multiple endings on single muscle fibres. Schofield, $\times 360$.

six months before it was considered safe to close the tracheostomy, but ultimately the cranial nerves became normal. Proximal limb muscles began to recover in about three months and ultimately became usefully strong, improvement continuing for nearly two years. Distal muscles remained paralysed or almost paralysed. Ten years after the illness her cranial nerves were normal, shoulder and hip movements were strong, and elbow and knee movements almost normal. There was severe muscle wasting below the knees and elbows, but she was able to walk for a short distance with support. Position and vibration sense was impaired in the limbs, but superficial sensation was normal. Fourteen years after the illness there had been no recurrence. She fell and fractured the shaft of the right femur and died a week later.

The clinical course of cases 1 and 2 is very

similar. Cases 3 and 4 are reported as examples of the more usual course of the illness. Both patients were totally paralysed in the acute stage, but began to recover more quickly than cases 1 and 2, and within a year made complete clinical recoveries. The contrast is shown in the Table.

CASE 3

J.D. (R.I. 179909) was admitted at the age of 16 years. Ten days earlier she had developed a heavy cold and cough which began with a rigor, and largely passed off within 12 hours, leaving her lethargic. The day before admission she developed a stiff neck and malaise, but continued normal activities including vigorous games of tennis. On the day of admission she stayed in bed and during the day her legs became so weak that she could not stand. On

FIG. 2. Case 2. Flexor muscle from the forearm. (a) Transverse section, showing advanced atrophy, with fatty and fibrous replacement. A nerve bundle and a muscle spindle appear normal. (b) Transverse section, showing a mixture of atrophic and preserved fascicles. (c) The same in longitudinal section. (d) Higher magnification, showing infiltration by chronic inflammatory cells. H and E: (a), (b), and (c) $\times 100$, (d) $\times 250$.

FIG. 3. Case 2. Lateral popliteal nerve, showing lymphocytic infiltration of epineurial vessel. *H and E*, $\times 170$.

admission that evening she had considerable weakness of all limbs, especially in proximal joints. In the next 24 hours her limbs became weaker and she developed dysphagia and weakness of respiratory muscles. She was artificially ventilated, for one day in a tank respirator, and thereafter by intermittent positive pressure through a tracheostomy. She was fed by nasogastric tube. On the third day after the onset of weakness she had paralysis of all voluntary movements except some external ocular movements. Cerebrospinal fluid 11 days after admission contained protein 150 mg/100 ml. and no cells. Three days after she reached the maximum paralysis, she began to recover head rotation, and about two weeks after maximum paralysis recovery began in the limbs. It proceeded rapidly so that within seven months recovery was complete, though the tendon reflexes were diminished. There has been no recurrence in the subsequent 19 years.

CASE 4

A.S. (R.I. 521458B) was admitted at the age of 23 years. Ten days previously she had had a cold, and

three days later a sore throat with malaise and backache. Five days before admission she developed pins and needles and tingling in the tongue, hands, and feet which subsequently spread all over her body. Two days before admission she became unable to lift her arms and legs, and the day before admission had difficulty in swallowing. On admission there was detectable movement at all joints but she was unable to raise her limbs from the bed. The cerebrospinal fluid contained 80 mg protein per 100 ml., and no cells. Her vital capacity was 1.9 l. and subsequently fell lower. A tracheotomy was performed and artificial ventilation by intermittent positive pressure was begun. She was fed through a nasogastric tube. Two-and-a-half weeks after the onset she reached her worst, and was incapable of any voluntary movement. A week later the cranial nerves began to recover, and a month after reaching maximum paralysis movement in the proximal and distal parts of the limbs began to recover. Electrophysiological examination (Dr. Rushworth) showed

FIG. 4. Case 2. Lumbar posterior root, showing 'onion-bulb' scarring. Nerve fibres are present in the centres of the formations. *H and E*, $\times 560$.

(a)

(b)

(c)

FIG. 5. Case 2. Transverse sections of spinal cord; (a) cervical, (b) thoracic, (c) lumbar, showing degeneration of posterior columns. Posterior roots appear intact. Myelin stain.

evidence of severe segmental demyelination. Eight weeks after the onset she was able to breathe spontaneously. After 10 months she had made a complete recovery, except that ankle jerks were absent.

The striking difference between the course of clinical recovery in the first two cases and that in the third and fourth cases requires explanation. The necropsy findings in case 2 provide, we think, valuable clues to the nature of this difference.

NECROPSY FINDINGS (case 2) The body of an old woman with a recent fracture of the shaft of the right

femur had gross scoliosis, with a sharp convexity of the lumbar spine to the right. Muscles below the elbows and knees were severely wasted, pale and flaccid. There were no joint contractures. Viscera were unremarkable apart from emphysema, a moderate degree of aortic and coronary atheroma, and cholelithiasis. Dissection of the spine showed increased density of bone in the lumbar region, and osteoporosis elsewhere. There were cervical and lumbar disc protrusions, but no significant compression deformity of the spinal cord or roots. The brain (1540 g) and spinal cord were macroscopically normal, apart from shrinkage and grey discoloura-

tion of the posterior columns at all levels of the cord.

Histologically, muscles innervated from the brainstem (tongue, digastric, sternomastoid) showed a slightly abnormal variation in muscle fibre calibre, without signs of neurogenic atrophy; but silver impregnations of the digastric (posterior belly, innervated by the facial nerve) showed an abnormal pattern of innervation, with excessive branching of terminal axons and multiple end-plates on single muscle fibres (Fig. 1). Pectoralis major, psoas, and diaphragm showed variation in fibre size, but no atrophy. Quadriceps, and more distal limb muscles (brachioradialis, a flexor muscle from the forearm, gastrocnemius) showed moderate to severe longstanding atrophy with fatty and fibrous replacement and occasional lymphocytic infiltrations (Fig. 2). The atrophy in these muscles was of neurogenic type, with isolated fascicles of normal or hypertrophic muscle fibres and other fascicles in which

sarcoplasm was almost or entirely lost, muscle fibres being represented by chains or clusters of small darkly-staining nuclei. Among the atrophic fibres were scattered small muscle fibres with preserved cross-striations and myofibrillar structure. These were presumably innervated, but had undergone disuse atrophy as a result of their position inside non-contracting fascicles. The picture was not that seen in progressive denervation—for example, in motor neurone disease—where all stages of neurogenic atrophy are seen simultaneously. Silver impregnations of a forearm flexor muscle showed bundles of nerve fibres, not obviously depleted, running among totally atrophic fascicles. Impregnations of the skin of the hand showed normal innervation, with free and compact nerve endings.

Nerves of mixed type (median, lateral popliteal) showed some loss of fibres, evidenced in transverse sections by the fact that the fascicles were angular rather than circular in outline. There was moderate increase in the interstitial connective tissue, which in places contained small aggregations of lymphocytes associated with small vessels (Fig. 3). These were not seen within the nerve fascicles. In cervical and lumbar sensory ganglia, loss of cells was either slight or inapparent; but a lumbar ganglion showed some

FIG. 6. Case 2. Sixth cervical segment of cord; longitudinal section, showing entry of a posterior rootlet. Fibres are seen entering and branching in the normal manner. Holmes silver stain $\times 50$.

FIG. 7. Case 2. Sixth cervical segment; longitudinal section of posterior columns, showing neuromatous tangles of nerve fibres of peripheral type. Holmes silver stain $\times 60$.

scarring of 'onion-bulb' type (Fig. 4), and a cervical ganglion, in silver impregnations, contained areas showing a disorderly pattern of nerve fibres, including figures resembling Perronco spirals (Cajal, 1928), which presumably represent an abortive regeneration of nerve fibres. Similar abortive endings were occasionally seen in silver impregnations of muscles. Sections of sympathetic nerves and ganglia, and of vagus and phrenic nerves, appeared normal.

In the spinal cord there was shrinkage, loss of myelin, and rather less complete loss of fibres, in the posterior columns at all levels (Fig. 5). This was clearly not due to loss of incoming sensory roots, which appeared normal in both transverse and longitudinal sections. Some roots showed abnormal entry zones, in that the transition between the peripheral segment, containing collagen and Schwann cells, and the central segment, containing oligodendroglia, instead of being well outside the cord, occurred at the surface or just inside. Nerve fibres were seen entering the cord and bifurcating in the normal manner (Fig. 6); and there was relative preservation of the most peripherally-placed myelinated fibres in the posterior columns at all levels. At the sixth cervical segmental level, there was actual invasion of the posterior columns by myelinated nerve fibres of peripheral type, with Schwann cells and collagen forming fibres of well-defined neuromatous tangles (Fig. 7). These were not seen elsewhere, and were not present on the surface of the cord. In other respects—lateral and anterior white columns, posterior, lateral and anterior horns and thoracic nuclei—the cord looked normal. In particular there was no sign of previous cord ischaemia.

In the brain-stem, there was heavy gliosis in the gracile and cuneate nuclei (due to loss of incoming fibres) and some gliosis, without obvious cell loss, in the vestibular nuclei, inferior olives, and substantia nigra. There was no sign of degeneration in the descending trigeminal tracts, and the rest of the brain appeared entirely normal.

In summary, there was neurogenic muscle atrophy, severe in the distal parts of the limbs, mild in the proximal parts, and sparing the muscles of the trunk and neck, though there were abnormalities in their pattern of innervation. Peripheral nerves and sensory ganglia showed minor changes proximally, and loss of fibres distally. The posterior columns of the spinal cord were grossly degenerated, although posterior roots were well preserved: and there was local invasion of the cord by nerve fibres of peripheral type, apparently arising from posterior roots.

DISCUSSION

According to Asbury *et al.* (1969), the earliest

changes in acute polyneuritis consist in the extravasation from small endoneurial and epineurial vessels of inflammatory cells, mostly lymphocytes. This is quickly followed by segmental disruption of myelin sheaths. Segmental demyelination, followed by gradual remyelination, is the rule; but fragmentation of axons, entailing Wallerian degeneration, is frequently seen, especially in relation to points where inflammatory exudations are severe. In the central nervous system, perivenous exudations are rare, and of slight extent. Chromatolytic changes (presumably due to axonal damage) are sometimes found in motor cells in the anterior horns: and occasionally there is Wallerian degeneration in the posterior columns, attributable to destruction of posterior nerve roots. Asbury *et al.* (1969) regard the condition as a cell-mediated immunological disorder, in which peripheral nervous tissue, in particular myelin, is attacked by specifically sensitized lymphocytes; and they stress the clinical and pathological analogies with experimental allergic neuritis (Waksman and Adams, 1955, 1956). Work from elsewhere (Caspary *et al.*, 1971; McQuillen, 1971) has tended to confirm the presence of sensitized lymphocytes in this condition. Asbury *et al.* (1969) differ from the earlier account of Haymaker and Kernohan (1949) in their insistence that lymphocytic exudation occurs at the earliest stage and persists, at scattered foci, for at least several years thereafter, and in their finding that lesions occur at all levels between the spinal roots and the distal nerve terminals, and are not specially concentrated in the region of the spinal ganglia.

In this account—with which we have no reason to disagree—it is to be noted that the lesions of the acute phase, though mainly demyelinating, may include some disintegration of axons. It follows from this that in cases with a relatively large amount of axon destruction the prognosis will be worse, since recovery will depend on the slow and uncertain course of regeneration; and this, we think, provides the explanation for the differences in the later clinical courses of our four cases.

In the acute phase of their disease all four were similarly afflicted, and the only reasonable diagnosis was that of acute idiopathic polyneuritis. The antecedent illness, the symptoms

and signs, and the rate of onset were typical. The normal protein content of the cerebrospinal fluid in case 1 does not exclude the diagnosis, normal protein levels being not uncommon in this disease, especially if only a single specimen is examined (Haymaker and Kernohan, 1949). In all four cases, there was universal paralysis within 10 days of onset, necessitating tracheostomy and artificial respiration. It was only in the later stages that a clinical difference became apparent between the two cases with relatively rapid, and ultimately complete, recovery and the two cases with slow and incomplete recovery. It would be illogical, on this basis alone, to suppose that the two pairs of cases were suffering from different diseases. The most reasonable explanation of the clinical difference between the two pairs is in terms of a difference in the amount of proximal axonal destruction relative to the amount of segmental demyelination.

Theoretically, there are several possible ways in which functional recovery can take place after an acute polyneuritis. The nature of the physiological disturbance due to segmental demyelination is not well understood; but it appears from experimental work (Cragg and Thomas, 1964; Hall, 1967; Morgan-Hughes, 1968) and from clinical observations (Bannister and Sears, 1962) that after the acute phase, which may cause a short-lasting conduction block, the main effect is a slowing of conduction velocity. In cases of polyneuritis, nerve conduction velocity remains slow, with little tendency to accelerate, for many months after clinical recovery is complete (Rushworth, 1972). To what extent recovery depends on re-formation of myelin sheaths is not known; but, whatever the mechanism, one would expect recovery of function to occur more or less simultaneously in all parts—proximal and distal—of the nerve. If, however, there has been disintegration of axons, functional recovery will depend partly on compensatory sprouting of the terminals of surviving axons (Wohlfart, 1957, 1958) and partly on axonal regeneration from the point where they have been interrupted. The rate of functional recovery will then depend on the rate of regeneration, and on the distance to be covered.

The rate of axonal regeneration depends on a number of variables, including the animal species, the nature of the nerve injury, and the

age and state of health of the subject. Estimates based on a variety of natural and experimental conditions range between 1 and 10 mm a day (Sunderland, 1968). From their observations on muscle biopsies from patients with reversible nerve lesions of various duration, Bowden and Gutmann (1944) concluded that the usual rate of regeneration in healthy human subjects was not less than 3 mm a day. On this estimate, motor fibres which have been interrupted close to the spinal ganglia would take about six months to reach the motor points of the muscles in the forearm, and nearly twice as long to reach the muscles in the calf. To these must be added the period needed to establish functioning neuromuscular connections.

The time course and spatial pattern of recovery in our first two cases make it highly probable that in both of them there had been a widespread destruction of motor axons at a proximal level, followed by regeneration. Electrophysiological studies in case 1 and the histological findings in case 2 support this view. At proximal levels, the only detectable histological changes are a slight drop-out of sensory ganglion cells, an area of 'onion-bulb' scarring in a ganglion, and a few disorderly tangles of nerve fibres, suggesting misdirected efforts at regeneration. In a nearby muscle, showing no sign of denervation atrophy, there is an abnormal pattern of innervation, such as might be expected if the original innervation had been destroyed, and replaced by regenerated fibres (Gutmann and Young, 1944). More distal nerve bundles, unlike the proximal ones, show considerable depletion, suggesting that many fibres had failed to reach their destination, and ended abortively on the way. Finally, there are fairly well-stocked nerve bundles among the totally atrophic muscles of the extremities. Although a proportion of the fibres are, no doubt, of sensory type, the presence of these nerve bundles indicates that regenerating motor fibres had arrived in these areas too late for effective reinnervation of the denervated muscles.

Gutmann and Young (1944) and Gutmann (1948) studied the process of reinnervation of muscle in rabbits with various periods of delay after an experimental nerve lesion. They concluded that motor reinnervation with functional recovery becomes progressively more difficult

with longer periods of denervation, and after a certain lapse of time (probably under two years in the rabbit) ceases altogether. As possible causes of this progressive difficulty they suggested various changes, including fibrosis at the denervated end-plate; disappearance of end-plates, necessitating the formation of new ones; and finally irreversible changes in the muscle itself. After 10 months of denervation, they observed 'areas in which the muscle fibres had failed to recover, in spite of the presence of nerve fibres among them'. In man, Bowden and Gutmann (1944) consider that there is a similar progressive difficulty in reinnervation, with about three years as the time limit for successful recovery. Cases 1 and 2 suggest that for them the time limit was one and a half to two years.

The degeneration of the posterior columns in case 2 is difficult to account for. Cases have been described—for example, Asbury *et al.* (1969) cases 12, 13, and 17—in which there was Wallerian degeneration in the posterior columns, clearly due to loss of incoming sensory fibres. In our case 2, there was no appreciable loss, at any level, of posterior root fibres. It could be argued that these fibres had disintegrated at the time of the acute illness, and subsequently regenerated. Against this is the fact that the posterior root fibres were seen to cross the boundary between the peripheral, Schwann-celled part of the root and the central, glia-containing part in the normal manner, and continue for some distance, as myelinated fibres, in the lateral zone of the posterior column. On present-day views of regeneration in the central nervous system, it is very improbable that these central axons could have regenerated from the periphery. If regeneration of interrupted sensory root fibres had occurred, the expected final picture would be of multiple neuromatous nodules of peripheral nerve type, invading the leptomeninges of the cord. These were not seen. Cases of fatal polyneuritis have also been described (Russell and Moore, 1943; Asbury *et al.*, 1969, case 11) showing ischaemic lesions in the posterior part of the cord. In our case 2, there are no signs of previous ischaemic damage, except in one cervical segment; and we cannot envisage any kind of circulatory disturbance which would affect the whole of the posterior columns, leaving the grey matter and the other white columns intact. A

further possibility, with fewer theoretical objections but no positive supporting evidence, is that at the time of the acute illness there was a 'dying-back' of the upper—that is, more distal—parts of the posterior column fibres, which were not restored by regeneration. Such an explanation would account for the preservation, at all levels, of myelinated fibres in the most lateral parts of the posterior columns, this being the position of the fibres which have entered the cord only a short distance below, and have not travelled far.

On the clinical aspect, our four case histories have a distinct bearing on prognosis in cases of severe acute polyneuritis. Until quite recently, a disease of such severity would inevitably have been fatal. Even now, an illness of this kind causes great anxiety in the patients and their relatives, and the doctors concerned are bound to be pressed for a prognosis. If respiratory paralysis is adequately dealt with in the acute phase, the prognosis for survival is very good. Prognosis for ultimate recovery cannot be made at the time of maximum paralysis, or for a few weeks thereafter, even with the aid of electromyography and nerve conduction studies. If at the end of a month movement is already returning to the distal parts of the limbs, it is reasonable to assume that wholesale proximal axon destruction has not occurred, and the outlook for complete clinical recovery is good. If on the other hand recovery is gradual, slowly spreading from proximal to distal musculature, and has not reached the distal parts at the end of a year the prospect of recovering useful hand and foot movements is poor.

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REFERENCES

- Asbury, A. K., Arnason, B. G., and Adams, R. D. (1969). The inflammatory lesion in idiopathic polyneuritis. *Medicine (Baltimore)*, **48**, 173–215.
- Bannister, R. G., and Sears, T. A. (1962). The changes in nerve conduction in acute idiopathic polyneuritis. *Journal of Neurology, Neurosurgery, and Psychiatry*, **25**, 321–328.
- Bowden, R. E. M., and Gutmann, E. (1944). Denervation and re-innervation of human voluntary muscle. *Brain*, **67**, 273–313.

- Cajal, S. Ramón y (1928). *Degeneration and Regeneration of the Nervous System*, 2 vols. Translated and edited by R. M. May. Hafner: New York.
- Caspary, E. A., Currie, S., Walton, J. N., and Field, E. J. (1971). Lymphocyte sensitization to nervous tissues and muscle in patients with the Guillain-Barré syndrome. *Journal of Neurology, Neurosurgery, and Psychiatry*, **34**, 179–181.
- Cragg, B. G., and Thomas, P. K. (1964). Changes in nerve conduction in experimental allergic neuritis. *Journal of Neurology, Neurosurgery, and Psychiatry*, **27**, 106–115.
- Gutmann, E. (1948). Effect of delay of innervation on recovery of muscle after nerve lesions. *Journal of Neurophysiology*, **11**, 279–294.
- Gutmann, E., and Young, J. Z. (1944). Re-innervation of muscle after various periods of atrophy. *Journal of Anatomy*, **78**, 15–43.
- Hall, J. I. (1967). Studies on demyelinated peripheral nerves in guinea-pigs with experimental allergic neuritis. Part 2. Electrophysiological observations. *Brain*, **90**, 313–332.
- Haymaker, W., and Kernohan, J. W. (1949). The Landry-Guillain-Barré syndrome. *Medicine (Baltimore)*, **28**, 59–141.
- Hewer, R. L., Hilton, P. J., Smith, A. C., and Spalding, J. M. K. (1968). Acute polyneuritis requiring artificial respiration. *Quarterly Journal of Medicine*, **37**, 479–491.
- McQuillen, M. P. (1971). Idiopathic polyneuritis: serial studies of nerve and immune functions. *Journal of Neurology, Neurosurgery, and Psychiatry*, **34**, 607–615.
- Morgan-Hughes, J. A. (1968). Experimental diphtheritic neuropathy: a pathological and electrophysiological study. *Journal of Neurological Science*, **7**, 157–175.
- Pleasure, D. E., Lovelace, R. E., and Duvoisin, R. C. (1968). The prognosis of acute polyradiculoneuritis. *Neurology (Minneapolis)*, **18**, 1143–1148.
- Rushworth, G. (1972). Personal communication.
- Russell, W. O., and Moore, W. L. (1943). Permanent damage to the nervous system following an attack of polyradiculoneuritis (Guillain-Barré syndrome). *Archives of Neurology and Psychiatry*, **49**, 895–903.
- Sigwald, J., and Nouailhat, F. (1970). The Guillain-Barré syndrome. In *Handbook of Clinical Neurology*, Vol. 7, pp. 495–509. Edited by P. J. Vinken and G. W. Bruyn. North-Holland: Amsterdam.
- Sunderland, S. (1968). *Nerves and Nerve Injuries*. Livingstone: Edinburgh.
- Waksman, B. H., and Adams, R. D. (1955). Allergic neuritis: an experimental disease of rabbits induced by the injection of peripheral nervous tissue and adjuvants. *Journal of Experimental Medicine*, **102**, 213–236.
- Waksman, B. H., and Adams, R. D. (1956). A comparative study of experimental allergic neuritis in the rabbit, guinea pig, and mouse. *Journal of Neuropathology and Experimental Neurology*, **15**, 293–334.
- Wohlfart, G. (1957). Collateral regeneration from residual motor nerve fibers in amyotrophic lateral sclerosis. *Neurology (Minneapolis)*, **7**, 124–134.
- Wohlfart, G. (1958). Collateral regeneration in partially denervated muscles. *Neurology (Minneapolis)*, **8**, 175–180.