
Late functional deterioration following paralytic poliomyelitis

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Summary

Many patients with previous poliomyelitis develop 'post-polio syndrome' (PPS) in which late functional deterioration follows a period of relative stability. The frequency with which PPS can be attributed to clearly defined causes remains uncertain. We reviewed 283 newly-referred patients with previous poliomyelitis seen consecutively over a 4-year period; 239 patients developed symptoms of functional deterioration at a mean of 35 (5–65) years

after the paralytic illness. Functional deterioration was associated with orthopaedic disorders in 170 cases, neurological disorders in 35, respiratory disorders in 19 and other disorders in 15. Progressive post-polio muscular atrophy was not observed. Functional deterioration following paralytic poliomyelitis is common, and associated with orthopaedic, neurological, respiratory and general medical factors which are potentially treatable.

Introduction

The incidence of acute paralytic poliomyelitis has been reduced dramatically over the past 35 years by means of mass vaccination campaigns, careful surveillance, and targeting areas in which the 'wild' virus persists. In 1988, the World Health Organisation undertook to eradicate the disease by the year 2000.¹ The strategies employed appear to be taking effect,² although outbreaks continue to occur.³ Episodes of vaccine-associated poliomyelitis now account for 75% of reported cases,^{4–6} of which two-thirds arise in unimmunized adult contacts of vaccine recipients and the remainder in the vaccine recipients themselves. In England and Wales, there were 21 cases of paralytic poliomyelitis between 1985 and 1991.⁷ Five of these were imported and the source of infection unknown, and 13 cases were vaccine-associated, of whom nine occurred in the recipient. The remaining three cases occurred in previously healthy unimmunized adolescent or adult contacts of infants who had received their first immunization. Polio-like illnesses due to other enteroviruses^{8–11}

account for the remaining cases which occur worldwide.

1996 has been designated 'Polio awareness year' (PAY). It has long been known that patients who have had acute paralytic poliomyelitis may, after many years of stable neurological impairment, undergo a progressive functional deterioration. There has been a great deal of interest over the past 10 years in the pathophysiology of this disorder, which has been termed the post-polio syndrome (PPS).^{12,13} PPS has been defined as the development of new neuromuscular symptoms at least 15 years after reaching maximum recovery from acute paralytic poliomyelitis.¹⁴ It specifically excludes symptoms related to other neurological, orthopaedic, psychiatric or systemic illness. It has been suggested that progressive deterioration in the function of surviving motor neurones occurs 20 years after the acute infection, leading to the development of new weakness and atrophy which has been termed 'post-poliomyelitis progressive muscular atrophy' (PPMA).¹⁵

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Many hypotheses concerning the aetiology of this syndrome have been advanced,^{13–16} including immunological mechanisms, attrition of axons overburdened by reinnervation, and ‘normal ageing’ of neurones. These have recently been reviewed.¹⁷

A previous report from this Unit, however, found that there was a high frequency of additional disorders, such as respiratory, orthopaedic and neurological problems, in patients presenting with late change in function.¹⁸ The frequency with which PPS can be attributed to clearly-defined causes remains uncertain, but it is clear that the development of such symptoms is common.¹⁹ It is important to gain a greater understanding of its pathophysiology, since those patients who developed acute paralytic poliomyelitis during the epidemics of the 1940s and 1950s, prior to vaccination, are now presenting in large numbers with functional deterioration 40 years on.

Methods

The Lane-Fox Unit at St Thomas’ Hospital is a 16-bed unit attended by multidisciplinary respiratory, orthopaedic surgery, neurology and anaesthetic teams, all with a specific interest in the management of poliomyelitis. Owing to close links with the British Polio Fellowship, patients with previous paralytic poliomyelitis have been referred from all parts of the UK for assessment of new or worsening symptoms and changes in function. We have reviewed all newly referred patients with previous poliomyelitis seen consecutively over a 4-year period to the Lane-Fox Unit.

The case-notes of all patients referred for assessment during 1990–1994 were examined by two of us (DK and RSH) using a standardized proforma in order to identify the nature of the functional deterioration, and to identify clinical and laboratory evidence for its cause. The assessment sought clear evidence for the diagnosis of paralytic polio to be made, the nature of stable function, the latency to onset of the functional deterioration and its clinical manifestations. All had been referred specifically to investigate the causation of late functional deterioration. Patients were assessed clinically, and laboratory, electrophysiological and radiological investigations were done when pertinent to the individual case. Patients were therefore not investigated in a standardized way.

Results

During the study period, 283 patients were referred with symptoms of functional deterioration. Three patients (1.1%) were excluded following examina-

tion, having been found likely not to have suffered acute paralytic poliomyelitis—one had infantile hemiplegia, one probable hereditary motor and sensory neuropathy (HMSN) type I, and one was found to have glutaric aciduria.²⁰

The initial illness

Of the total patient population ($n=280$), 41 did not recall sufficient details of the acute infection. In the remaining patients, severe weakness (3 or 4 limbs involved, or severe paraparesis with immobility) occurred in 117 (48.9%) and moderate weakness (1 or 2 limbs only, with mobility retained) in 122 (51.0%). Forty-eight (20.1%) had been ventilated during the acute illness.

Following recovery to maximal function, 139 (49.6%) were able to walk unaided, 109 (38.9%) walking with the aid of a stick or crutches and/or an orthosis, and 32 (11.4%) were wheelchair-bound.

Late change in function

Evidence of a deterioration in function was found in 239 patients (85.4%). The mean age of this patient group was 51.8 ± 10.9 years. The acute illness had arisen at a mean of 7.9 ± 8.4 years. The first symptoms of functional deterioration had occurred at a median of 35 (range 5–65) years after the acute illness. The mean age at the onset of functional deterioration was 42.9 ± 9.9 years.

New locomotor symptoms manifested as diminished mobility in 220 (92.0%) patients, of whom 71 (32.3%) presented with new or increased limb muscle weakness alone, 81 (36.8%) with pain alone and 53 (24.1%) with both weakness and pain. Thus 65% of all patients presenting with late functional deterioration displayed pain as a prominent symptom. Figure 1 shows the distribution of pain in the patients studied. The remaining 15 patients (6.8%) presented with more vague symptoms, such as fatigue and tiredness in association with diminished mobility, but without pain or weakness.

Nineteen (7.9%) patients presented with respiratory symptoms such as daytime hypersomnolence and early-morning headache, of whom four were in type II respiratory failure.

Causes of functional deterioration

See Figure 1.

Orthopaedic disorders

Degenerative joint disease was common (150 cases, 63%), and was confirmed radiologically in all cases. It was particularly frequent in weight-bearing joints and was more common in weakened limbs than stronger ones ($\chi^2 = 11.9$, $p < 0.0001$). In patients

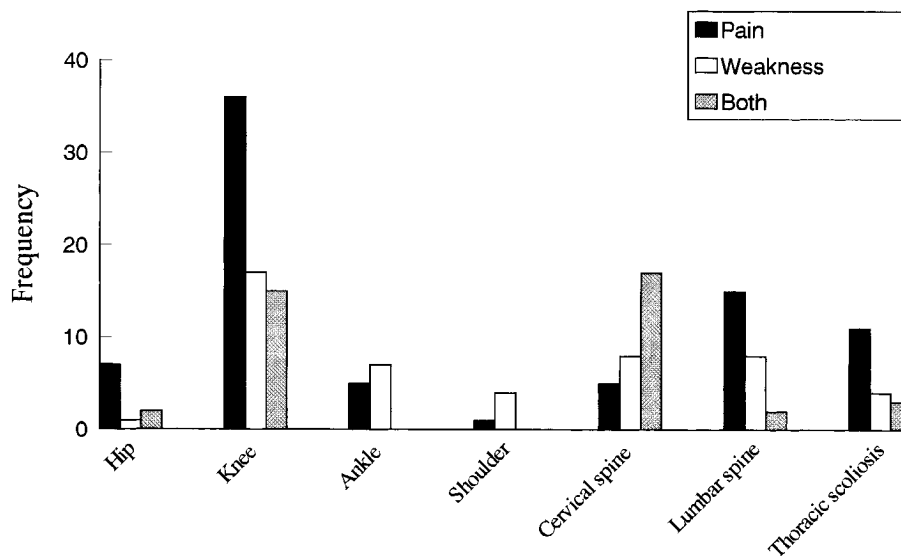


Figure 1. Frequency (number of patients) of moderate or severe osteoarthritis related to the development of late functional deterioration.

with weakness on one side only, it arose exclusively on the paretic side. Sixty-eight patients had severe degenerative disease of the knees, of whom six had bilateral disease (8.8%). Fourteen patients had a joint disorder peculiar to patients with paralytic poliomyelitis, *genu recurvatum* (Figure 2a). Only nine patients had degenerative disease of the hips. Twelve had degenerative disease of the ankle or foot. Degenerative spinal disease was also common—30 had cervical spondylosis, 25 lumbar spondylosis, and 14 had a worsening of a pre-existing thoracolumbar scoliosis. Five cases of degenerative diseases of upper-limb joints were found, all of whom had ipsilateral flail upper limbs, in which severe osteoarthritis had arisen. In two patients the joint had become dislocated.

The occurrence of severe degenerative joint disease was more common in patients in whom the acute illness had arisen in early childhood, but it was also seen in those whose illness had developed in adulthood. Patients left with severe neurological impairment following recovery were more likely to develop severe arthritis.

Degenerative disease was sufficiently severe to warrant surgery in 34 cases; 14 had patellar bone block procedures (Figure 2b), seven total knee replacements, one knee arthrodesis, two total hip replacements and three subtalar fusions. Seven patients had spinal surgery; in three this was for scoliosis and in three others for cervical radiculomyelopathy; the remaining procedure was a laminectomy for lumbar canal stenosis. A decision to perform surgery was made on an individual patient basis by FWH; the criteria were most commonly if pain was severe, or if the joint was so severely affected as to

compromise significantly the independent living of the patient.

One patient was found to have a psoriatic arthropathy. One had a spontaneous haemarthrosis of the knee, one had a ruptured quadriceps tendon and one had tennis elbow. Three patients had rotator cuff syndrome causing pain and upper-limb muscle weakness.

Neurological disorders

Complications of orthopaedic disorders were found in 30 patients: 17 patients had cervical radiculopathy, eight lumbar radiculopathy and five had cervical myelopathy (Figure 3), three of whom were treated surgically.

Entrapment neuropathies were found in seven patients: six had carpal tunnel syndrome (in two cases it was bilateral) resulting in reduced upper limb function in five cases. Surgery improved function in all these cases. One patient had an ulnar neuropathy due to compression at the elbow.

Superimposed coincidental neurological disorders (Table 1) were found in 12 patients: three patients were found to have multiple sclerosis, two motor neurone disease (amyotrophic lateral sclerosis) and three inflammatory neuropathies (two had multifocal motor neuropathy with conduction block and one had chronic inflammatory demyelinating neuropathy) in addition to polio. Cerebrovascular disease accounted for a progressive functional deterioration in three patients. One patient developed propriospinal myoclonus, possibly arising as a result of compression of the dorsal cord due to increasing scoliosis. The symptoms resolved with the use of clonazepam.



a



b



Figure 3. Sagittal T₂-weighted (TR 3000 ms, TE 90 ms) MRI scan of the cervical spine, showing marked cervical spondylosis with spinal cord compression at C3/4 causing cervical myelopathy.

Table 1 Characterization of neurological complications

Complication	<i>n</i>
<i>Entrapment neuropathies</i>	
Carpal tunnel syndrome	6
Ulnar neuropathy	1
<i>Orthopaedic complications</i>	
Cervical radiculopathy	17
Cervical myelopathy	3
Lumbar radiculopathy	8
<i>Coincidental neurological disorders</i>	
Multiple sclerosis	3
Amyotrophic lateral sclerosis	2
Inflammatory neuropathy	3
Cerebrovascular disease	3
Propriospinal myoclonus	1

Respiratory disorders

Twelve patients presented with respiratory symptoms suggestive of sleep-disordered breathing. In all cases this was confirmed using polysomnography or sleep

Figure 2. X-ray showing *genu recurvatum* (defined as an angle in recurvatum of $>10^\circ$) **a** before and **b** after treatment with patellar bone block procedure.

oximetry studies. Treatment with nasal continuous positive airways pressure (CPAP, four patients) and nocturnal nasal intermittent positive-pressure ventilation (NIPPV, six patients) corrected the disorder in 10 patients; in two it was adjudged not sufficiently severe to warrant treatment aside from weight loss and monitoring.

Four patients presented in chronic or acute-on-chronic type II respiratory failure requiring ventilation, of whom one was weaned following treatment of a lower-respiratory-tract infection, and the others remain well on NIPPV.

One patient presented with asthma, another with chronic obstructive airways disease due to smoking, and a third with severe emphysema due to α_1 antitrypsin deficiency.

Other disorders (Figure 4)

Fifteen patients presented with diminished mobility but non-specific symptoms, predominately tiredness and fatigue. One patient was found to be hypothyroid and improved following replacement therapy. Ten presented with fatigue alone and had symptoms of depression. The remaining four patients were overweight and the change was attributed to increasing obesity.

Discussion

Functional deterioration arising many years after paralytic poliomyelitis has been recognized since 1875²¹ and in the first half of this century, several cases were described.²²⁻²⁴ In 1962, Zilkha reported a further 11 cases in which new weakness developed in muscle groups previously not involved during the

acute illness after a latent period of 17-43 years. He suggested that previous poliomyelitis may predispose to the development of motor neurone disease.²⁵ It has subsequently become clear that there is no increase in the incidence of motor neurone disease following acute poliomyelitis.²⁶⁻³⁰

Estimates of the frequency with which PPS occurs have been variable.^{13,15,16} Bradley distinguished between PPMA and other causes of PPS, but this distinction has been largely overlooked by subsequent studies. Electrophysiological studies have shown evidence of continuous and widespread denervation and reinnervation (spontaneous activity with increased jitter and block on single-fibre EMG studies, and fibrillation potentials)³¹⁻³³ and muscle biopsy studies have confirmed the presence of denervation, with small angulated fibres, group atrophy and fibre type grouping.^{32,34,35} However, these features have been seen with equal frequency in patients with new muscle weakness and those with stable neurological function.

Howard *et al.*¹⁸ previously reported a series of 209 patients of whom 163 (78%) developed late functional deterioration due to respiratory factors in 99 cases, neurological signs in 20 cases, orthopaedic problems in 17 cases and general medical factors in eight cases; 31 patients deteriorated due to a combination of factors. Respiratory insufficiency was associated with respiratory muscle weakness, progressive nocturnal hypoventilation due to chest-wall deformity and progressive scoliosis or other precipitating factors stressing critically compromised ventilation. Orthopaedic deterioration was due to progressive skeletal deformities associated with severe underlying disability; scoliosis developed in 94 patients (45%) and was invariable if paralytic

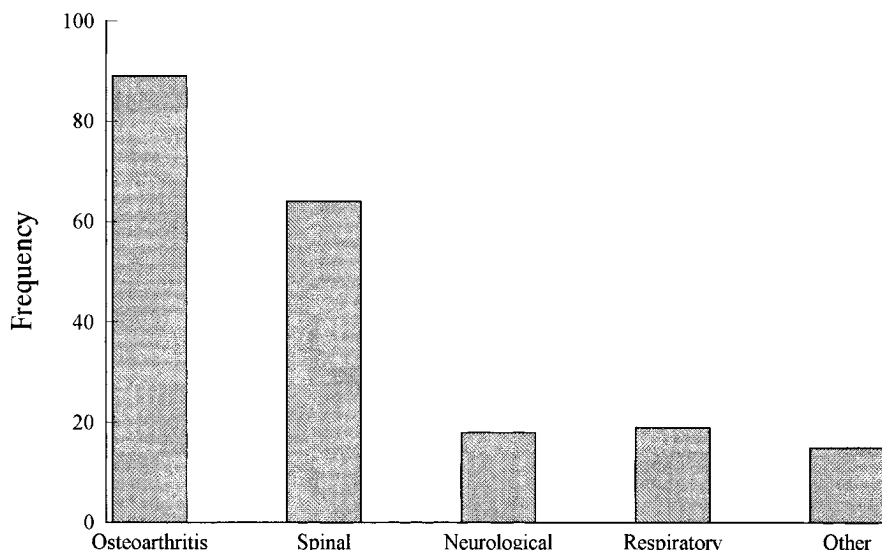


Figure 4. Frequency (number of patients) of orthopaedic, neurological, respiratory and other disorders considered to have contributed to late functional deterioration in the present series.

poliomyelitis occurred before the growth spurt, and functional deterioration was associated with progressive scoliosis in at least 18 patients. Thirty-four patients had worsening limb function due to cervical spondylosis, osteoarthritis, osteoporosis and contractures.

In a careful prospective study carried out in the Mayo Clinic,³⁶ a group of 50 patients who had been treated during the acute illness were followed up 30–50 years later; whilst 64% of patients had reported new or worsening symptoms, it was found after comparing examination findings using their structured reporting system (the Neurologic Disability Score, NDS³⁶) that only 18% had deteriorated functionally. Furthermore, in patients reporting new or worsening weakness, only four patients had truly changed on neurological examination, in all of whom reasonable evidence for the development of a superimposed neurological disorder causing the change had been found (such as diabetic neuropathy). This series has been followed up prospectively;³⁷ the frequency of symptoms of late deterioration did not change over the 5-year period, and neurological examination findings and test of manual dexterity were unaltered. The EMG studies were also unchanged.

The present study provides further evidence to suggest that the aetiology and pathophysiology of functional deterioration after paralytic poliomyelitis is multifactorial. The study did not set out to investigate the prevalence of late complications in all patients with previous poliomyelitis; patients assessed had been referred specifically for investigation of new or worsening symptoms. Owing to the referral pattern from all parts of the UK, however, it is likely that this patient group is reasonably representative of all UK patients suffering late functional deterioration. Although 84% were considered to have undergone a true functional deterioration, the vast majority were found to have orthopaedic problems and/or neurological complications related to these. Whether or not these patients have underlying PPMA cannot be determined, since there are no clear diagnostic electrophysiological abnormalities known. In four patients, no clear cause for the change was ascertained, so it is possible that they do have a progressive muscular atrophy.

Of our patients, 74% had moderate or severe degenerative joint disease; the frequency with which this occurred is much greater than in people of similar age in the normal population³⁸ and this finding differs from a previous report of the low incidence of osteoarthritis following poliomyelitis.³⁹ Degenerative changes involved the knees in the majority of patients, and less frequently, the cervical and lumbar spines, the hips and ankle joints. The high incidence of degenerative joint disease in such

young patients (mean age 51.8 ± 10.9 years) is likely to be due to the abnormal stresses placed upon them by disordered neuromuscular function. Joints disordered, for example, by avascular necrosis of bone, bone dysplasia and sepsis, have a greater incidence of osteoarthritis at a younger age than those with normal joints. Furthermore, degenerative changes progress at a greater rate if misalignment supervenes and if the patient becomes obese. Hence, if weakness around a joint is severe, stability is lost, misalignment may arise and, during weight-bearing, excessive mechanical stresses may be placed on it, leading to early and increasingly severe osteoarthritis.

Why did patients present with increasing weakness in the absence of clear evidence of ongoing denervation and muscular atrophy? Pain associated with degenerative joint disease will lead to restricted movement which may be perceived as muscle weakness, however, not all our subjects had pain (indeed, only 25–35% of patients with osteoarthritis experience pain³⁸). Another mechanism of muscle weakness in these patients may be arthrogenous inhibition,⁴⁰ in which there is a reflex inhibition of anterior horn-cell firing due to joint inflammation or trauma. This leads to reduced muscle activity and, subsequently, muscular atrophy. Evidence for this comes from both clinical and animal model experiments in which the quadriceps H reflex is suppressed when the joint capsule is stretched with a fluid infusion. Maximal voluntary quadriceps power was reduced by 30–40% following knee surgery.⁴¹ Clearly this weakness may not be appreciated in patients with normal muscle bulk and power, but may have profound effects on the function of patients with denervated muscle.

Concerning respiratory change, previous reports have shown that late respiratory insufficiency was associated with progressive nocturnal hypoventilation due to respiratory muscle weakness, progressive scoliosis and skeletal deformity,^{18,42,43} particularly in those who had received mechanical ventilatory support during the acute illness. The present series shows a much lower proportion of deterioration in respiratory function, but a considerably higher incidence of orthopaedic deterioration than in our previous series. This is likely to represent either an earlier presentation of respiratory complications with the later development of skeletal problems, or to a change in referral pattern.

In summary, of patients with previous paralytic poliomyelitis presenting with late functional deterioration at a median of 35 years after the acute illness, the majority of those who presented with new or increasing locomotor symptoms had degenerative joint disease, and this is likely to be a major factor in their functional deterioration. Neurological complications tended also to be related to degenerat-

ive bone and joint disease. Obesity played a role in the severity of the symptoms. No patient presented with clear signs of progressive muscular atrophy with fasciculation, but in 4/280 patients studied, no clear cause of the functional deterioration could be found.

The high incidence of severe joint deformity and loss of function has important implications for the management of these patients. Careful monitoring is needed, and measures should be taken to prevent and retard the progression of degenerative joint disease, including early use and more frequent reassessment of orthoses and callipers, early realignment surgery with osteotomies, and encouragement to avoid the development of obesity.

The present series has confirmed the high frequency of identifiable factors in late functional deterioration in patients with previous poliomyelitis, many of which are treatable, in contrast to PPS. We would urge caution before attributing functional deterioration to the post-polio syndrome or to progressive post-polio muscular atrophy.

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