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Polyneuropathy in late Lyme borreliosis – a clinical, neurophysiological and morphological description

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In a prospective study, detailed clinical and neurophysiological examinations were performed in 17 patients with polyneuropathy associated with the late borrelial manifestation acrodermatitis chronica atrophicans (ACA). Similar clinical and neurophysiological signs were found in most of the patients. The findings were those of a sensory polyneuropathy, mainly affecting large nerve fibres. Marked abnormality of vibration threshold was a common finding and in 4 patients this raised a suspicion of spinal cord engagement, in addition to a polyneuropathy. Sural nerve biopsy, performed in 3 of the patients, showed a mainly axonal neuropathy. Biopsy findings did not confirm earlier reports of vasculitis of epineural vessels in ACA-associated polyneuropathy.

E. Kindstrand[1], B. Y. Nilsson[2], A. Hovmark[3], I. Nennesmo[4], R. Pirskanen[5], G. Solders[1], E. Åsbrink[3]

Divisions of [1]Neurology, [2]Clinical Neurophysiology and [4]Pathology, Karolinska Institute, Huddinge University Hospital; [5]Division of Neurology, Karolinska Hospital; [3]Department of Dermatology, Söder Hospital, Stockholm, Sweden

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Eva Kindstrand, Division of Neurology, Huddinge University Hospital, S-141 86 Huddinge, Sweden

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Acrodermatitis chronica atrophicans (ACA) is a late manifestation of Lyme borreliosis with bluish-red inflammatory skin lesions mainly localized to the acral part of the extremities. ACA mainly affects elderly persons and there is a female predominance. The spirochetal etiology was established in 1984, with the cultivation of *Borrelia burgdorferi* from an ACA lesion (1). Earlier studies have shown signs of peripheral neuropathy in 40–53% of patients with ACA (2–5). Our recent study of 63 consecutive untreated patients with ACA showed a neuropathy frequency of 64% in ACA patients which was significantly higher than that of 27% in age- and sex-matched controls (6). In all studies the most common type was a sensory polyneuropathy. The ACA-associated polyneuropathy has, however, so far never been described in detail.

The purpose of this prospective study was to describe the clinical and neurophysiological characteristics in consecutive untreated patients with ACA-associated polyneuropathy. In addition, histopathological nerve biopsy findings from 3 of the patients were compared with the results in earlier studies (4, 7).

Patients and methods

Patients

All patients were primarily seen at the Department of Dermatology, Söder Hospital, Stockholm. The inclusion criteria were: 1) clinical dermatological diagnosis of ACA, confirmed by elevated serum IgG antibodies to *B. burgdorferi* and histopathological picture consistent with ACA, 2) neurological and neurophysiological signs of polyneuropathy and 3) no other disease, predisposing for polyneuropathy. A mild type II diabetes for 3 years in 1 patient was not considered as predisposing for polyneuropathy. The patients had not received antibiotic treatment for ACA, prior to the study.

The inclusion criteria were fulfilled by 21 patients, 15 of whom belonged to the study of 63 ACA patients mentioned earlier (6). Four patients were

excluded since the neurophysiological investigation had not been complete, according to our study design. The remaining 17 patients were included in the study.

Neurological examination

The patients were asked about weakness, pain or sensory disturbances in the extremities. They were also asked about exaggerated pain reaction in ACA-affected extremities which, in earlier Swedish studies, has been a characteristic symptom in many ACA patients (6, 8). A neurological examination was performed with emphasis on the peripheral nervous system. The details of the clinical examination have been presented elsewhere (6). In short, touch sensation was tested with cotton wool, superficial pain with pin prick, cold with a metal object of room temperature and vibration sense with a tuning fork (128 Hz). Appreciation of passive movement of the distal phalanges of toes and fingers as well as the heel–knee and finger–nose tests were used for estimation of position sense.

Neurophysiological examination

Neurophysiological investigation was performed, as previously described (6). In short, bipolar needle electromyography (EMG) was recorded in the biceps brachii, abductor digiti minimi, abductor pollicis brevis, quadriceps femoris and anterior tibial muscles on one side. Electroneurography (ENeG) was performed bilaterally and included measurements of motor conduction velocity, F-response and distal latency in the median, ulnar, peroneal and tibial nerves, sensory nerve action potential amplitude and sensory conduction velocity in the median, ulnar and sural nerves. Vibration thresholds were registered bilaterally on the dorsal hand, the second digit, the tibia and the foot (9). Temperature thresholds were measured on the dorsal hand and foot bilaterally (10). A total of 8 neurophysiological parameters were investigated, as shown in Table 4.

The neurological examinations were done without any knowledge of the neurophysiological results and vice versa. All examinations were performed by the same investigators (neurological examinations EK, neurophysiological examinations BYN).

Classification of abnormal neurological and neurophysiological signs

Each parameter was classified as normal or with moderate or major abnormality. According to the number of abnormal signs and to the severity of the changes, the polyneuropathy was classified as moderate or major. The neurophysiological assessment of polyneuropathy severity was based on abnormalities in nerve conduction studies and EMG changes. For the final evaluation, abnormalities in sensory thresholds were also taken into consideration. The neurophysiological criteria for demyelinating versus axonal polyneuropathy (Table 1) were based on nerve conduction velocities, nerve action potential amplitudes and EMG findings (11, 12).

The classifications are shown in Tables 2a and b.

Laboratory investigations

Serum antibody values to *B. burgdorferi* were determined, using an indirect ELISA method with a sonicate antigen (13). Values above the 98th percentile of the absorbance value of controls, i.e. >450 for IgG and >550 for IgM were considered as elevated (14). In addition, ESR and blood cell analysis, protein electrophoresis, the Wassermann reaction (WR), fasting glucose, vitamin B_{12}, folate and tests for liver and renal function were performed. The urine was tested for glucose and albumin.

The first 11 of the 17 patients had a lumbal puncture performed with analysis of cerebrospinal fluid (CSF) cells and protein content, Borrelia antibody values and protein electrophoresis. The presence of oligoclonal bands was evaluated with immunofixation after agarose electrophoresis. When appropriate, the specific Borrelia antibody titre index was calculated, using the formula: CSF/serum antibody: CSF/serum albumin. An IgG index >2.0 and IgM index >1.0 were considered as reflecting intrathecal antibody production (15).

Nerve and muscle biopsy studies

A biopsy from the sural nerve was examined in patients 8, 9 and 14 (Tables 3 and 4). In local anesthesia a part from the nerve was sampled behind the lateral malleolus and the tissue was divided in different pieces. One part each was frozen in cold isopenthane for immunohistochemistry or

Table 1. Neurophysiological criteria for demyelination vs axonal damage

Demyelination	Axonal damage
MCV, SCV*	
<39 m/s in the arm	At least 39 m/s in the arm
<35 m/s in the leg	At least 35 m/s in the leg
SNAP**	
At least 5 microV in the hand	<5 microV in the hand
At least 3 microV in the sural nerve	<3 microV in the sural nerve
Denervation in EMG	
No	Yes

* Motor and sensory nerve conduction velocity.
** Sensory nerve action potential amplitude.

Table 2. Classification of neurological and neurophysiological abnormalities and polyneuropathy grade

Moderate	Major
(a) Neurological abnormalities	
Change in touch, pain and cold sensation	
Impairment restricted to legs	Impairment in legs and hands
Change in vibration sense	
Impairment restricted to legs	Loss in legs and impairment below ribs or in hands
Reflex changes	
Loss restricted to legs	Loss in legs and arms
Polyneuropathy grade	
At least moderate impairment of one sensory modality	Major impairment of all sensory modalities and reflex loss at least in legs
(b) Neurophysiological abnormalities	
ENeG changes	
2–3 SD	>3 SD
ENeG evaluation	
>1/3 of the values abnormal with >50% moderate changes	At least 2/3 of the values abnormal with >50% major changes
EMG changes	
Reduced interference pattern and/or MUPs with increased amplitude and duration	Discharges of a few MUPs and MUPs with increased amplitude and duration
EMG evaluation	
>1/3 of the muscles with EMG abnormalities, >50% moderate changes	At least 2/3 of the muscles with EMG abnormalities, >50% major changes
Sensory threshold changes	
<3 times the reference value	At least 3 times the reference value
Sensory threshold evaluation	
Increased thresholds in >1/3 of the sites with >50% moderate changes	Increased thresholds in at least 2/3 of the sites with >50% major changes
Polyneuropathy grade	
<3 evaluations with major abnormality	At least 3 evaluations with major abnormality

SD = standard deviations from the laboratory reference values; MUP = motor unit potential; ENeG = electroneurography; EMG = electromyography.

Table 3. Clinical data, neurological signs and polyneuropathy grade in patients with ACA associated polyneuropathy

Patient no.	Age (years)	Sex	Sensation				Reflex loss	Pnp grade
			Touch	Pain	Cold	Vibration		
1	63	M	n	+	n	+	++	+
2	73	M	n	+	n	+	n	+
3	67	F	n	n	n	+	n	+
4	75	F	n	n	+	++	n	+
5	80	F	+	+	n	++	+	+
6	71	F	+	+	+	++	n	+
7	72	M	n	n	++	++	n	+
8	76	F	+	+	+	++	+	+
9	80	M	n	+	n	++	++	+
10	55	M	n	+	n	+	n	+
11	77	M	+	+	n	++	+	+
12	80	M	+	n	++	++	++	+
13	79	M	n	+	+	+	+	+
14	73	M	+	+	+	+	+	+
15	76	F	n	+	n	+	n	+
16	82	M	n	n	+	++	n	+
17	84	F	n	n	n	++	+	+
Total (%) abnormalities			35	65	47	100	53	100
Major (%) abnormalities			0	0	12	53	18	0

n = normal; + = moderate; ++ = major; pnp = polyneuropathy.

Table 4. Neurophysiological signs and polyneuropathy grade in patients with ACA associated polyneuropathy

Patient no.	MCV	F	DL	SCV	SNAP	VT	TT	EMG	Pnp grade
1	+	n	n	n	++	++	n	n	+
2	++	++	+	+	++	+	+	+	++
3	+	n	+	+	+	+	+	n	+
4	n	n	n	n	+	++	+	n	+
5	n	+	n	+	+	++	n	+	+
6	n	n	n	n	n	++	n	+	+
7	n	+	n	n	++	+	n	+	+
8	+	++	n	+	++	n	n	+	+
9	++	++	n	+	++	+	n	+	++
10	n	n	n	+	+	+	+	n	+
11	+	+	+	+	++	+	+	n	+
12	+	+	n	+	+	+	n	+	+
13	++	++	+	++	+	++	+	+	++
14	n	+	n	+	+	+	n	+	+
15	+	+	+	n	+	n	+	n	+
16	+	n	+	+	++	+	+	+	+
17	+	n	n	n	+	++	n	+	+
Total (%) abnormalities	65	59	35	65	94	88	47	59	100
Major (%) abnormalities	18	24	0	6	41	35	0	0	18

MCV = motor nerve conduction velocity; F = F-response; DL = distal latency; SCV = sensory nerve conduction velocity; SNAP = sensory nerve action potential amplitude; VT = vibration threshold; TT = temperature threshold; EMG = electro myography; Pnp = polyneuropathy.
n = normal, + = moderate, ++ = major.

fixed in 4% formaldehyde for paraffin embedding and routine stainings with Htx-eosin and Luxol fast blue. One part was placed in BSK II medium for spirochete cultivation (16) and another part was fixed in 2.5% glutaraldehyde for plastic embedding and 1 micrometer thick sections stained with toluidine blue. Teased fibre preparations were also done in patients 9 and 14. Immunostainings with antibodies against $CD3^+$, $CD4^+$, and $CD8^+$, T-lymphocytes as well as $CD19^+$ B-lymphocytes (Becton-Dickinson) were performed on frozen sections. In each of the 3 patients a biopsy was also taken from the anterior tibial muscle and the tissue was frozen. Routine stainings with Htx-eosin, oilred, PAS, Gomori trichrome, as well as enzyme (ATP-ase, NADH)- and immunostainings with the same antibodies as above were done on cryostat sections.

Ethical approval

The nerve and muscle biopsy studies had been approved by the local ethics committee.

Results

Of the 17 patients, 10 (59%) were men. The mean age of the patients was 75 years (median 76, range 55–84). For the men the mean age was 75, for the women 76 years. The duration of ACA skin lesions, before diagnosis ranged from 0.5–20 years (mean 4.3, median 1.3 years). In 8 patients 1 extremity, in 3 patients 2 and in 6 patients 3 extremities had visible ACA lesions. In 12 of the 17 patients (71%), one or both of the lower extremities were affected.

Laboratory investigations

The serum IgG antibody values to *B. burgdorferi* ranged from 940–7500 (mean 3715, median 3300). IgM values were below cut off in all but 1 patient who had a slightly elevated value. The laboratory investigations in blood and urine were normal with the exception of a moderate ESR elevation in 5 patients. CSF analysis showed normal results.

Neurological symptoms and signs

Eleven of the 17 patients (65%) had symptoms, consistent with peripheral neuropathy. Five patients complained of numbness below the knee and 2 of them also had spontaneous pain in the legs. Three patients had spontaneous pain in the legs as the only symptom and another 3 had paresthesia in the feet or hands. Nine patients had an exaggerated pain reaction, allodynia, when accidentally knocking a bony prominence underlying an ACA lesion slightly against a hard object.

The neurological signs are shown in Table 3.

The signs were those of a moderate, symmetric sensory polyneuropathy. None of the patients fulfilled the criteria for a major polyneuropathy. The most consistent finding was impairment of vibration perception, present in all 17 ACA patients and with major impairment in 10 patients. The vibration disturbance was not associated with impaired position sense when examined with passive joint movements and in only 2 cases with a pathological heel–knee test. In 3 patients (patients 4, 16, 17) there was a discrepancy between marked abnormality of vibration perception versus only slight changes in touch, pain and cold sensation and tendon reflexes.

Neurophysiological signs

The neurophysiological signs in each patient are summarized in Table 4.

No patient fulfilled the criteria for primary demyelination. Three patients fulfilled the criteria for primary axonal polyneuropathy and 4 had signs of both demyelination and axonal damage. Eight patients were considered to have a predominantly axonal polyneuropathy and in the remaining 2 cases (patients 6, 10), the polyneuropathy could not be classified. Three of the 17 patients fulfilled the neurophysiological criteria for a major polyneuro-

pathy. Abnormalities in vibration thresholds were found more often than changes in temperature sensibility.

Biopsy findings

In the nerve biopsies a mild (patients 8, 14) or moderate (patient 9) loss of myelinated fibres was found. Both small and large myelinated fibres were involved. In 1 patient (patient 9) a few groups of regenerating fibres were detected. On sections stained with antibodies against different subsets of T lymphocytes some scattered cells of all 3 types ($CD3^+$, $CD4^+$, $CD8^+$) were present in the nerve and in the epineurium. In patient 14 some of the cells had a perivascular distribution in the epineurium but there were no signs of vasculitis. B cells were not found. In teased preparations a few fibres with segmental demyelination and Wallerian degeneration were present in patient 14. No spirochetes could be cultivated from any of the 3 nerve biopsy samples. Muscle biopsy revealed small groups of atrophic fibres indicating neurogenic atrophy in 2 of the patients (patients 8, 9). The muscle biopsy from the third patient was normal. There were no signs of inflammation in any of the muscle biopsies.

Discussion

The patients in this study had some distinguishing characteristics when compared with ACA patients in general. The mean age of 75 years was higher than that usually reported for patients with ACA which is 55–64 years (2, 5, 6, 8). The majority of the polyneuropathy patients were men while a female predominance of 68–82% has been found in earlier ACA studies (2, 5, 6, 8) and this may be compared to the findings in syphilis, another spirochetosis. Untreated tertiary syphilis with neurological manifestations has been shown more frequently in men and "benign" tertiary syphilis, with manifestations from the skin, bones and joints, more frequently in women (17).

The polyneuropathy symptoms in our patients had no characteristics, differentiating ACA patients from other patients with polyneuropathy. The allodynia in ACA areas, present in 9 patients, was not considered as a true neuropathy symptom. It may be secondary to tissue inflammation with engagement of nociceptors and/or distal nerve endings. This exaggerated pain reaction to ordinarily non-noxious stimuli seems to be a common symptom in ACA and has been commented on in other studies (6, 18). The most conspicuous clinical sign was a marked impairment of vibration sense. In 3 patients (patients 4, 16, 17), abnormality of vibration perception was much more pronounced than reflex loss or changes in touch, pain and cold sensation. Although a certain degree of deterioration of vibration sense occurs in old age (19, 20), the vibration impairment in our patients was more pronounced than would be expected as age related changes.

The neurophysiological findings indicated a mainly axonal rather than a demyelinating polyneuropathy, similar to the findings of Kristoferitsch (4, 5). Also in studies of neuropathy associated with Lyme borreliosis other than ACA, neurophysiological results have suggested mainly axonal damage (21–23) although there are a few case reports of demyelinating neuropathy accompanying Lyme disease (24, 25). The marked abnormality in vibration thresholds found in most of our patients has not been described previously in patients with neuropathy associated with ACA (2–5) or with Lyme borreliosis other than ACA (23, 26).

When clinical and neurophysiological findings were considered together, the changes in most patients were consistent with large fibre axonal polyneuropathy. This could, at least partly, account for the observed discrepancy between vibration abnormality and changes in superficial sensation. Loss of the fast-conducting large nerve fibres is a known cause of slowed nerve conduction in axonal polyneuropathy (11, 27) and could explain the moderate abnormalities in nerve conduction velocity seen in many of the patients. A loss of large myelinated nerve fibres also could account for the diminished amplitude of the sensory nerve action potential since the amplitude of sensory potentials has been shown to be proportional to the number of large nerve fibres activated (28). In 1 patient (patient 6), the clinical abnormalities of both deep and superficial sensation were accompanied by only minor neurophysiological changes. We consider it possible that the clinical findings in this patient as well as in patients 4, 16 and 17, in part may be caused by medullary engagement. Although CNS manifestations including myelopathy are well known in late neuroborreliosis (29–31), CNS engagement seems to be very rare in ACA.

Nerve biopsy findings in 3 of the patients verified the neurophysiological signs of a mainly axonal neuropathy. The histopathological appearance was unspecific and did not suggest any particular underlying pathogenesis. Nerve biopsy has previously been performed in 5 patients with ACA associated neuropathy (4, 7). In those studies and in nerve biopsy studies of neuropathy associated with Bannwarth's syndrome (7, 22), perivascular inflammation in the epineurium was found and this finding was considered suggestive of vasculitic neuropathy. In the present study 1 patient had

inflammatory cells with perivascular distribution in the epineurium. However, since there was neither a destructive inflammation of the vessels nor inflammatory infiltration of the vessel wall, essential for a vasculitis diagnosis, we do not consider our findings indicative of vasculitis (32).

In conclusion, the results of this study showed that most of our patients with ACA associated polyneuropathy had similar clinical and neurophysiological signs. Nerve biopsy findings did not permit an interpretation as to the underlying pathogenetic mechanism for the peripheral nerve damage in this late borrelial manifestation. A possible contribution of medullary engagement to the clinical findings in some patients is intriguing and calls for further studies.

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References

1. Åsbrink E, Hovmark A, Hederstedt B. The spirochetal etiology of acrodermatitis chronica atrophicans Herxheimer. Acta Derm Venereol (Stockh) 1984;**64**:506–12.
2. Hopf HC. Acrodermatitis chronica atrophicans (Herxheimer) und Nervensystem. Monogr Neurol Psychiatr. Heft 114. Berlin: Springer-Verlag, 1966.
3. Hopf HC. Peripheral neuropathy in acrodermatitis chronica atrophicans (Herxheimer). J Neurol Neurosurg Psychiatry 1975;**38**:452–8.
4. Kristoferitsch W, Sluga E, Graf M et al. Neuropathy associated with acrodermatitis atrophicans. Ann NY Acad Sci 1987;**539**:35–45.
5. Kristoferitsch W. Neuropathien bei Lyme-Borreliose. Wien: Springer-Verlag, 1989.
6. Kindstrand E, Nilsson BY, Hovmark A, Pirskanen R, Åsbrink E. Peripheral neuropathy in acrodermatitis chronica atrophicans – a late Borrelia manifestation. Acta Neurol Scand 1997;**95**:338–45.
7. Meier C, Grahmann F, Engelhardt A, Dumas M. Peripheral nerve disorders in Lyme-Borreliosis. Acta Neuropathol 1989;**79**:271–8.
8. Åsbrink E, Hovmark A, Olsson I. Clinical manifestations of acrodermatitis chronica atrophicans in 50 Swedish patients. Zentralbl Bakteriol Mikrobiol Hyg[A] 1986;**263**:253–61.
9. Goldberg JM, Lindblom U. Standardized method of determining vibratory perception thresholds for diagnosis and screening in neurological investigation. J Neurol Neurosurg Psychiatry 1979;**42**:793–803.
10. Fruhstorfer H, Lindblom U, Schmidt WG. Method for quantitative estimation of thermal thresholds in patients. J Neurol Neurosurg Psychiatry 1976;**39**:1071–5.
11. Kimura J. Nerve conduction studies and electromyography. In: Dyck PJ et al., eds. Peripheral neuropathy. Philadelphia: WB Saunders, 1993;598–644.
12. Fowler CJ. Electromyography and nerve conduction. In: Osselton JW, ed-in-chief. Clinical neurophysiology. Oxford: Butterworth Heinemann, 1995;43–321.
13. Olsson I, von Stedink L-V, Hansson H-S, von Stedink M, Åsbrink E, Hovmark A. Comparison of four different serological methods for detection of antibodies to *Borrelia burgdorferi* in erythema migrans. Acta Derm Venereol (Stockh) 1991;**71**:127–33.
14. Kindstrand E. Antibodies to *Borrelia burgdorferi* in patients with carpal tunnel syndrome. Acta Neurol Scand 1992;**86**:73–5.
15. Stiernstedt G, Granström M, Hederstedt B, Skjöldenberg B. Diagnosis of spirochetal meningitis by enzyme-linked immunosorbent assay in serum and cerebrospinal fluid. J Clin Microbiol 1985;**21**:819–25.
16. Barbour AG. Isolation and cultivation of Lyme disease spirochetes. Yale J Biol Med 1984;**57**:521–5.
17. Gjestland T. The Oslo study of untreated syphilis. Acta Derm Venereol 1955;**35(Suppl. 34)**:147–368.
18. Brehmer-Andersson E, Hovmark A, Åsbrink E. Acrodermatitis chronica atrophicans: Histopathologic findings and clinical correlations in 111 cases. Acta Derm Venereol (Stockh) 1998;**78**:207–13.
19. Skre H. Neurological signs in a normal population. Acta Neurol Scand 1972;**48**:575–606.
20. Kenshalo DR. Age changes in touch, vibration, temperature, kinesthesis and pain sensitivity. In: Birren JE, Schai KW, eds. Handbook of the physiology of aging. New York: van Norwand Reinhold, 1977;562–79.
21. Wulff CH, Hansen K, Strange P, Trojaborg W. Multiple mononeuritis and radiculitis with erythema, pain, elevated CSF protein and pleocytosis (Bannwarth's syndrome). J Neurol Neurosurg Psychiatr 1983;**46**:485–90.
22. Vallat JM, Hugon J, Lubeau M, Leboutet MJ, Dumas M, Desproges-Gotteron R. Tick-bite meningoradiculoneuritis: Clinical, electrophysiologic and histologic findings in 10 cases. Neurology 1987;**37**:749–53.
23. Halperin J, Luft BJ, Volkman DJ, Dattwyler RJ. Lyme neuroborreliosis. Peripheral nervous system manifestations. Brain 1990;**113**:1207–21.
24. Sterman AB, Nelson S, Barclay P. Demyelinating neuropathy accompanying Lyme disease. Neurology 1982;**32**:1302–5.
25. Clavelou P, Vernay D, Cuoq N et al. Les atteintes demyelinisantes au cours des neuropathies borreliennes. Rev Neurol (Paris) 1993;**149,5**:320–5.
26. Logigian EL, Steere AC. Clinical and electrophysiologic findings in chronic neuropathy of Lyme disease. Neurology 1992;**42**:303–11.
27. Logigian EL, Kelly JJ, Adelman LS. Nerve conduction and biopsy correlation in over 100 consecutive patients with suspected polyneuropathy. Muscle Nerve 1994;**17**:1010–20.
28. Behse F, Buchtal F. Sensory action potentials and biopsy of the sural nerve in neuropathy. Brain 1978;**101**:473–93.
29. Ackermann R, Rehse-Kupper B, Gollmer E. Progressive Borrelia encephalomyelitis. Zentralbl Bakteriol Mikrobiol Hyg[A] 1986;**263**:297–300.
30. Pachner AR, Duray P, Steere AC. Central nervous system manifestations of Lyme disease. Arch Neurol 1989;**46**:790–5.
31. Hansen K, Lebech A-M. The clinical and epidemiological profile of Lyme borreliosis in Denmark 1985–1990. Brain 1992;**115**:399–423.
32. Churg A, Churg J, eds. Systemic vasculitides. New York, Tokyo: IGKU-SHOIN, 1991.

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