Neuroacanthocytosis Syndromes – A Current Overview

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Abstract Neuroacanthocytosis syndromes are characterized by the presence of "thorny" red blood cells and neurodegeneration of the basal ganglia, along with peripheral neuromuscular findings, seizures, and a variety of neuropsychiatric features. In recent years significant progress has been made in understanding the molecular pathophysiology of these disorders; cases are now identified as autosomal recessive chorea-acanthocytosis, X-linked McLeod syndrome, or more rarely, pantothenase kinase-associated neurodegeneration or Huntington's disease-like 2. Molecular analysis of classic reports of neuroacanthocytosis will clarify nomenclature and improve understanding of genotype-phenotype correlations. In addition, there are issues of atypical inheritance patterns which remain to be elucidated. A relatively high incidence of chorea-acanthocytosis in Japan may indicate a genetic founder effect, and has led to significant developments from Japanese researchers.

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1 Advances in Neuroacanthocytosis

This volume follows up on "Neuroacanthocytosis syndromes" [2], which summarized the proceedings of a symposium which took place in Seeon, Bavaria, in May 2002. That meeting brought together a diverse group of researchers from around the world, including movement disorder neurologists, molecular biologists, hematologists, and neurogeneticists, and many others involved in studying this group of rare diseases. The group explored "New perspectives for the study of basal ganglia degeneration", following the discovery by scientists in England and Japan of the genetic basis of the core neuroacanthocytosis (NA) syndromes, McLeod syndrome (MLS) and chorea-acanthocytosis (ChAc) [43, 100, 142].

The collaborations initiated at this meeting led to the second Neuroacanthocytosis Symposium (Montreal Neurological Institute, Montreal, Canada, April 2005) and the third symposium, a satellite meeting of the 10th International Congress of Parkinson's disease and Movement Disorders, organised by the Movement Disorder Society, in Kyoto, Japan, October 2006 (Figs. 1 and 2 of the Foreword). An interim meeting was convened at the Third International Congress on Vascular Dementia in Prague, Czech Republic, October 2003 [27].

The present volume expands on the abstracts of the Kyoto [111] and Montreal [7] symposia. Major scientific developments since the first meeting in 2002 have included the publication of the reference method for acanthocyte detection [127], the description of *XK* mutations without full-blown MLS [54, 150], and the discovery of additional members, *XPLAC* and *XTES*, of the *XK* family [18]. The genes related to *CHAC* were found to belong to a conserved gene family involved in vacuolar protein sorting, thus leading to the renaming of *CHAC* as *VPS13A* [143]. The use of chorein antibodies for diagnosis of ChAc using Western blot assay [30] was a major clinical advance, obviating the need for molecular analysis of the large *VPS13A* gene for diagnosis in most cases.

Major developments from Japan included the observation of cellular inclusions in ChAc muscle [133] and the first animal model for ChAc [137], mice with the *VPS13A* deletion-mutation found in the Ehime province [71, 87].

The nosology of NA syndromes has evolved since the Seeon meeting. A family reported there with autosomal dominant NA [148] was identified as having Huntington's disease-like 2 [144, 146, 147, 149] (see chapter by Margolis).

The fourth "core" NA syndrome, pantothenate-kinase associated neurodegeneration (PKAN), has been better delineated with the availability of genetic testing for *PANK2* mutations. The so-called HARP syndrome (hypoprebetalipoproteinemia, acanthocytosis, retinitis pigmentosa, pallidal degeneration), of which only two cases have been reported, was proven to be allelic with PKAN [26, 46, 95]. The occurrence of acanthocytes as a feature of PKAN – in at least 8% of patients – has lately become more appreciated [39, 97].

Here we discuss the history of NA in Japan and in the English medical literature, including the appropriateness of the use of the "Levine–Critchley" eponym and the confusion in diagnosis of NA syndromes prior to the molecular era. We discuss recent developments in ChAc and issues related to the genetics of this disorder

(advances in MLS are discussed in the chapter by Jung). Therapy for NA syndromes is at present in its infancy and is limited to symptom management, however patients with these debilitating disorders may nevertheless derive significant benefit from medical and non-medical interventions, which are summarised below.

2 Neuroacanthocytosis in Japan

A historical perspective of NA (probable ChAc, but never confirmed using current methods) reveals the large number case reports in Japanese, starting with Shimizu's report of 1974 [122] and continuing into the 1990s, most of which were initially presented at local meetings of the Japanese Society of Neurology [9, 13, 35, 45, 48, 50–53, 55, 57–59, 63, 65, 66, 68, 81, 91, 92, 106, 114, 119, 120, 123, 128–130, 132, 136, 151]. According to a personal communication by Prof. Hirose (and see his chapter in this volume), the topic of NA syndromes was selected for a symposium at the 1980 Annual Meeting by the then president (Prof. Kameyama, Kyoto) of the Japanese Society of Neurology [1]. Much of what was presented there [10, 41, 64, 67, 88, 107, 112, 116, 118, 153] had already been reported locally and, since funds had been devoted to the study of NA by the Ministry of Health and Welfare of Japan to Prof. Toyokura of Tokyo University, these cases were also collected as brief reports for a government record of these activities [138]. All relevant studies were reported in more detail in journals with English abstracts such as "Rinsho Shinkeigaku" (Clinical Neurology), "Shinkeinaika" (Neurological Medicine), "No To Shinkei" (Brain and Nerve), or in international journals [12, 42, 60, 62, 72, 89, 93, 94, 96, 113, 115, 117, 121, 124, 126, 131, 134, 135, 140, 141, 152].

An exact count of case numbers in Japan is difficult because of inaccessibility of material to English speakers and duplicate publications, but the number of 71 patients mentioned by Prof. Hirose in his chapter appears to be a conservative estimate. Thus Japan, in contrast to the few reports from other parts of Asia [5, 15, 17, 28, 37, 61, 69, 83, 84, 104, 139] and the approximately 150–200 cases from the rest of the world [25], appears to have the highest diagnosis rate in the world.

3 Levine–Critchley Syndrome

To date, confirmation of the identity of the patients with the original NA "Levine–Critchley syndrome" has not been possible. Attempts to trace the New England family described since 1960 by Irving M. Levine (Fig. 1) and others [33, 34, 70, 74–76, 103] have not yet been rewarding. The description of the proband is consistent with ChAc or MLS, particularly the descriptions that "his gait was lurching in character with long strides and somewhat ataxic because of quick involuntary knee buckling movements. … Speech was moderately inarticulate because it was interrupted by involuntary tongue and facial movements." [75] However, the clinical features of other family members and the pedigree diverge to some extent from the

Fig. 1 Irving M. Levine (*right*) with Mitchell F. Brin, circa 1985. Photograph courtesy of Dr Mitchell F. Brin

features of patients with molecularly identified ChAc. There was consanguinity five generations previous to the affected family members. Examination of the pedigree shows that chorea was present in one of the proband's siblings, a maternal aunt, and a cousin who had *chorea gravidarum* [75]. All of these subjects had acanthocytosis. The neurological findings in many of the other reported family members from four generations are challenging to interpret, and consist predominantly of various combinations of hyporeflexia, mild weakness and muscle atrophy. Acanthocytosis was found mostly in family members with these findings, but did not necessarily cosegregate with the neurological abnormalities. There is apparent male–male transmission excluding the diagnosis of MLS and the inheritance pattern in general appears to be autosomal dominant. However, the variability of the neurological findings, and the presence of acanthocytes in a girl with epilepsy on the father's side of the family, which was otherwise not felt to be affected, make it difficult to draw a conclusion as to the nature of the disorder being described.

The patients reported by Edmund Critchley from two families, one from East Kentucky, USA [22, 23], the other from Lancashire, UK [16, 21], however, display the typical clinical features of genetically confirmed cases [25]. Edmund Critchley (Fig. 2) nicely has summarized his findings [20], most recently in an enjoyable "Neurologist's Tale" [19].

Fig. 2 Edmund Critchley. Photograph courtesy of Dr E.M.R. Critchley

While working at the Department of Neurology of David Barrett Clark in Lexington, Kentucky, it was his task to provide neurologic care in the small towns of the hinterland: "I went about weekly to a regional clinic. We would hire a State limousine, seating at least six people and holding an EEG set, and travel down a state highway at about 90 mph (looking out for helicopters) to a National Park, where we stay the night before an early start treating epilepsy, genetic diseases and other neurological disorders referred to us." [19] In these isolated regions he discovered his "prize patient", for whom he uses the alias Terry. "The poor were white, the Scots-Irish, the inbred white people living along the 'creeks' or narrow river valleys, the Appalachian poor. … Forced to work on the plantations of Virginia to pay their passage to America, many chose to escape and live rough as frontiersmen. They found a creek with a bit of land, safe from other feuding wild men … married and produced offspring. The progeny moved further along the creek to poorer and poorer land, intermarrying with their own kith and kin" [19].

"Terry had presented to Abe Wikler, Professor of Psychiatry, Neurology and Pharmacy, who had attempted to try to control his movement disorder to no avail. Dave Clark was determined that he should be thoroughly investigated and I was the man to do so …. Terry was a 29-year-old white male. When first seen at the age of 26, he exhibited involuntary movements and had a grossly swollen, raw, bitten tongue. He had had 15–20 similar episodes of tongue, lip and cheek biting, which often occurred at night. The episodes started 6 years earlier on a background of increased generalized weakness, nervousness, 'fits and jerks', and had increased in frequency and severity. The involuntary movements included finger-snapping, grimacing, dystonic and choreiform movements, hyperextension of the trunk, twisting movements of his shoulders, sucking noises, plosive sounds and drooling. … There had been times when he could not speak plainly: 'the inside of his mouth would draw', he would 'snap at his lips, and his stomach would stick'. When he ate, his tongue would involuntarily push food out on to his plate. For 4 years he had preferred to retire to a separate room to eat.

"He showed no psychotic or hallucinatory behaviour, but on his later admissions, appeared somewhat disinhibited sexually. Over 2 years, he had two episodes of 'passing out' preceded by abnormal noises and shaking or tremor of the abdomen and outstretched extremities, 'drawing up of the legs'. These episodes, which lasted for 30 min, were followed by confusion and a 'wild look' which persisted for approximately 1 h. On admission in 1967, his involuntary movements were so intense that he could not walk without assistance. He was alert, well-orientated, had no gross memory defects, and was disturbed by his own repulsive appearance. He slurred and stuttered when talking, was often indistinct and had occasional inappropriate laughter. Despite the involuntary movements, there was no ataxia and co-ordination tests were intact. He had generalized hypotonia, flexor plantar responses, and loss of deep tendon reflexes. There was a suspicion of thinning with coarse twitching of his calves. His IQ was 72 (WAIS), verbal 81, and performance 61. … He was the 10th child.

"The eldest died of seizures, bit her tongue and had involuntary limb movements. She became forgetful, emaciated and bedfast with violent shaking of her limbs. Two others also died about the age of 26. The fourth child had an illness of 2 years duration, with passing out spells and rejection of food from the mouth. The fifth gave birth to an unaffected child and soon afterwards became bedfast and emaciated. The ninth remained healthy till aged 31, before developing choreic movements and grand mal fits. She has always refused admission to hospital but did permit an examination on herself and her normal 17-month child. I witnessed what appeared to be an attack of hystero-epilepsy with partial loss of consciousness, opisthotonus (bending the back in hyperextension) and drawing and grasping movements of all four limbs. Speech and swallowing were normal but she showed facial grimacing sans distal choreic movements. The deep tendon reflexes were absent and the diagnosis of acanthocytosis confirmed" [19].

Critchley provides us with the vivid picture of a severe and progressive neurological condition starting in the third decade in possibly seven male and female siblings (out of ten) from a genetically isolated background favoring inter-

marriage and manifestation of autosomal recessive traits. He clearly describes severe orofacial dyskinesia with a tongue that would involuntarily push food out on to the plate, generalized chorea severely interfering with gait, sudden trunk flexion and hyperextension, some neuropsychiatric and cognitive impairment and possible epileptic seizures. Critchley also noted the resemblance to the tics of the Gilles de la Tourette syndrome [20].

It is commonly said that "chance favors the prepared mind" and this was certainly true for Edmund Critchley when he happened to see a single patient with an almost identical movement disorder, her parents unrelated, coming from different counties [20]. "Within a year of my return to England, a 30-year old patient was referred to me … her husband had noticed … that her walk was ungainly and had avoided drinking with her in company because of her tendency to slobber … increasingly irritated by grunting noises, of which at first she was unaware. … She started to lose weight … complaining of intermittent difficulty in swallowing and a tightness in the throat. … Most disturbing were the wide variety of oro-facial tics … continually present during waking hours, though fluctuating in severity from day to day … Her speech was dysarthric, partly broken by involuntary movements. She would also grunt, suck, make repetitive sounds, bite her tongue and lower lip, or struggle to control the pooling of saliva. The involuntary limb movements were sometimes dystonic and choreiform with hyperextension and flexion of her trunk and throwing out of an arm or leg … she took her own life … A coroner's post-mortem was cursorily performed …" [19].

All of Critchley's cases appear to have had a phenotype identical to that seen in patients with a molecular diagnosis of ChAc [25]. However, in the absence of genetic testing, we may never know whether Levine–Critchley syndrome truly was ChAc or some other related neurodegenerative disease, making use of the eponym rather imprecise.

4 Subsequent Neuroacanthocytosis Reports

The question of diagnosis is illustrated by the paper of Hardie and collaborators from Queen Square [38]. This often-cited NA case series has become problematic since its group of 19 patients has since been shown to be genetically heterogeneous (see chapter by Gandhi et al.). Cases 1–4 (family H) were found to be compound heterozygotes for mutations in the *VPS13A* gene (family CHAC 01 [105]). Cases 5–10 (family L) carry a McLeod mutation [44]. This family, which was originally reported as having a benign condition [79], is unique because of the severe disease expression in a female mutation carrier. Her neuropathological findings are described in chapters by Danek et al. and Geser et al. Cases 11–12 (family B) were only found to have one *VPS13A* mutation (family CHAC 09 [100]). A few of Hardie's cases have not yet been diagnosed using molecular methods.

Another report in which the diagnosis remains to be clarified is that of two Russian-Jewish brothers who presented in their 50's with proximal muscle

weakness and sensory neuropathy in addition to chorea and orofacial dyskinesia [4]. Based on an observation from Israel, where homozygous deletions of *VPS13A* (6059delC) had been found in two unrelated patients, it was postulated that these cases provide support for a founder effect of ChAc in Ashkenazi Jews [78]. However, gender, age at onset and clinical manifestations are more consistent with a diagnosis of MLS than of ChAc, as is the pedigree structure of the two brothers [4]. Motor restlessness, seizures and neuropathy in the mother would not be expected in the autosomal recessive condition of ChAc and could be better explained if she were a manifesting MLS mutation carrier.

5 Chorea-Acanthocytosis – Recent Developments

5.1 Molecular Studies

Autosomal recessive chorea-acanthocytosis (ChAc) is due to mutations of the large gene *VPS13A* [100, 25, 29, 142] which encodes for the protein chorein that appears to be fairly widely expressed in brain [11, 14, 71] (see chapter by Bader et al.). The function of its protein product, chorein, is not known, apart from that it is likely to be a sorting protein, and may be involved in intracellular protein trafficking (see chapter by Velayos-Baeza et al.). A large number of different mutations, including frameshifts (small deletions or insertions), nonsense, splice-site, deletions, and missense mutations, and deletions of whole exons have been found throughout the entire gene, making screening a challenge [29, 100, 142].

5.2 Clinical Features

The typical onset of ChAc is in young adulthood, but may occur at younger ages. Initial presentation with a variety of neuropsychological syndromes is being increasingly recognized, including depression, psychosis, obsessive-compulsive symptoms, trichotillomania [78], tourettism [90, 108], anxiety and agitation (see chapter by Sano). Self-mutilation due to lip- and tongue-biting may be due to apparent obsessive behaviors or to involuntary movements [145]. Behavioral changes suggesting a frontal lobe-type syndrome, including disinhibition and self-neglect, may present prior to development of the movement disorder. Dementia is frequently seen, with deficits primarily in memory and executive skills. The use of psychiatric medications may obscure the diagnosis for several years, as the involuntary movements are attributed to tardive dyskinesia.

The involuntary movements of ChAc are usually chorea and dystonia, but occasionally Parkinsonism. Orofacial and lingual dyskinesias are typically prominent and troublesome, and may result in marked difficulty with eating [99].

Seizures are seen in approximately 40% of patients [99], but were more common in a cluster of French-Canadian families (70–80%; discussed in more detail below). Most attacks are described as generalized, probably of temporal origin, although mesial temporal sclerosis is not documented [3]. The presence of cortical abnormalities, either structural or functional [11, 32, 98], is under discussion (see chapter by Leenders and Jung).

Neuromuscular signs comprise peripheral neuropathy and myopathy [99]. Serum creatine kinase (CK) elevation may be detected before the appearance of neurologic signs or symptoms [78]. Muscle atrophy and weakness, as well as CK elevation, may be regarded as secondary to chronic denervation. However, a primary myopathic process is suggested by nemaline rods [133] or accumulations of tissue transglutaminase [85] on muscle biopsy, and a predisposition to rhabdomyolysis [102]. In symptomatic carriers of apparently a single mutation of chorein, accumulations of chorein may be seen along the muscle cell membrane [110] (see chapter by Saiki and Tamura).

Involvement of the autonomic nervous system is occasionally noted in ChAc (see chapter by Kihara et al.).

Non-neurologic findings such as hepatosplenomegaly are sometimes, but not invariably, observed [99]. Hepatosplenomegaly does not seem to be a significant cause of morbidity, as long as its etiology is recognized, and it does not prompt invasive investigations.

Neuroimaging in ChAc is typically reported as strongly resembling that in HD [73], although quantitative studies [40] indicate that the head of the caudate nucleus is particularly vulnerable (see chapter by Henkel et al.).

Polysomnographic studies in several ChAc patients reveal sleep fragmentation, poor sleep efficiency, short total sleep time and a high rate of wakefulness after sleep onset [125] (see chapter by Ghorayeb et al.). These findings likely explain the daytime somnolence in these patients. The observations resemble those in HD and thus may be due to a common pathophysiological mechanism.

6 Inheritance Patterns

Although the inheritance of ChAc is generally accepted as being autosomal recessive, and that of MLS as being X-linked, there are reports of apparent NA families in which the inheritance pattern does not conform to either of these. As discussed above, inheritance has been suggested as being autosomal dominant in Levine's cases [75] and the same has been speculated about in Critchley's Kentucky family [23]. The daughter of the eldest sibling (who was similarly affected to her brother "Terry") also had severe neurological abnormalities, however, her syndrome was quite dissimilar (with a Friedreich's ataxia-like phenotype and developmental delay) and Critchley himself doubted a relation of the two conditions [19].

A French-Canadian case cluster, centered around Saguenay-Lac St. Jean, Quebec, a farming region with a small founding population, was initially thought

to show dominant inheritance [6]. Most cases originally presented with epilepsy as mentioned above [3]. Molecular analysis permitted clarification of the rather complex pattern of inheritance in four French Canadian pedigrees with eleven affected patients [31]. Three out of the four pedigrees were homozygous for a deletion of the four terminal exons of *VPS13A*. Two females in the fourth family were homozygous for a splicing mutation (4242 + 1 G > T). The affected males in this highly consanguineous pedigree were compound heterozygotes for the two mutations just mentioned. Identification of a common haplotype associated with the terminal deletion in four apparently unrelated families implied a founder effect for ChAc in French Canadians. Thus, the recessive transmission of *VPS13A* mutations was obscured by the high degree of consanguinity in the Saguenay-Lac St. Jean population, with the misleading impression of dominant inheritance [6].

Autosomal dominant inheritance of NA was suggested for an Italian family, although consanguinity of the parents suggests the possibility of pseudo-dominance [80]. Acanthocytes were also observed in members otherwise unaffected by NA symptoms from a further family [86]. Molecular analysis of these cases has not been reported.

Some of the descriptions of Japanese families with autosomal dominant transmission of NA syndromes could be due to isolation of the population and intermarriage. A founder effect has been shown for ChAc in Japan, in the form of the deletion mutation of *VPS13A* from the Ehime province [142]. One family has been reported with possibly autosomal dominant inheritance of ChAc, prior to the advent of genetic testing, although MLS or HDL2 (the latter unlikely in this population) was not excluded [62].

In two Japanese families apparent autosomal dominant effects of *VPS13A* mutations have been described. In one family of an affected woman with a homozygous point mutation (3889C > T causing R1297X), several relatives who carried a single copy of the diseased gene were said to display symptoms and signs characteristic for ChAc [47]. However, it is not completely clear that the neurological findings in the family could not have resulted from alternative causes.

In another family a single mutation was found of one allele of the gene, a heterozygous G > A transversion at the last nucleotide of *VPS13A* exon 57 in a brother and sister [49, 108, 109]. Their unaffected mother, not consanguineous with the father, showed a homozygous wild type sequence at that site. The father and grandfather were not available for examination, but it was presumed that the mutation had been introduced from the paternal side. Although genetic analysis was not performed, ChAc was also felt to be present in three subjects with acanthocytosis and chorea from successive generations in side branches of the pedigree, fitting a pattern of autosomal dominant inheritance. It is possible that, comparable to initial findings in the French-Canadians, additional mutations were present in this pedigree. A second mutation of the index siblings may have been missed due to technical reasons, as was not felt to be unusual in our analyses of ChAc, where the second mutation had remained undetected in altogether 12 patients from 66 pedigrees [25]. Assay of chorein levels and further genetic analysis will help clarify this issue.

7 Treatment of Neuroacanthocytosis Syndromes

7.1 Pharmacological Therapy

To date treatment for the NA syndromes is purely symptomatic. As in other choreiform disorders, reduction of involuntary movements may be achieved in principle by reducing dopaminergic neurotransmission, using atypical antipsychotic agents or tetrabenazine. However, as in HD, this may not necessarily result in functional improvement. Anticonvulsants such as levetiracetam [24, 101] and topiramate [36] can be beneficial in secondary choreas, and may be considered in NA. Levetiracetam has been reported as providing specific benefit to truncal tics in ChAc [77], yet anecdotal experience in a single case has not confirmed this effect. Carbamazepine and lamotrigine may worsen involuntary movements [8].

Neuropsychiatric issues are often a major cause of morbidity and mortality, as suicide is not infrequent (see chapter by Sano). Depression should be aggressively treated. Selective serotonin-reuptake inhibitors and tricyclic antidepressants may be useful for depression, in addition to mood-stabilizing medications such as anticonvulsants. The second-generation neuroleptics, especially clozapine and quetiapine, may improve both mood disorders and chorea. Classical neuroleptics should be avoided in order to avoid potential induction of tardive movement disorders.

7.2 Neurosurgery

With the development of experience in functional neurosurgery for other movement disorders, both hypo-and hyperkinetic, a small number of patients with NA syndromes have undergone either deep brain stimulation or ablative procedures (see chapter by Yokochi and Burbaud). The results are somewhat promising, but need to be interpreted within the context of a multi-symptomatic, progressive neurodegenerative disorder.

7.3 Other Therapeutic Issues

A multidisciplinary team approach to issues of mobility, communication, nutrition, swallowing, and psychosocial aspects is vital to address the many issues which may arise with these complex disorders. Adjunctive non-medical therapies are invaluable and must be individualised to each patient's needs and goals [82] (see chapter by McIntosh).

In MLS, clinicians should be aware of potential blood transfusion reactions. Hemolysis may result from the production of anti-Kx and anti-Kell antibodies, and autologous blood should be banked (see chapter by Tani).

Cardiac myopathies and dysrhythmias may occur in MLS, and very occasionally in ChAc [56], thus, patients should be monitored regularly and treated as indicated. Autonomic dysfunction (see chapter by Kihara et al.) may also play a role in sudden death. Sleep disorders have as yet received little therapeutic attention (see chapter by Ghorayeb et al.).

8 Conclusions

Developments in molecular biology have facilitated the diagnosis of NA syndromes and, most importantly, the provision of accurate genetic counseling. Molecular diagnosis has permitted confirmation of disease identity for patients who may present with atypical syndromes, and has revealed the diversity of phenotypic variations. As with current thinking for other, more common, movement disorders such as Parkinson's and Huntington's disease, we are increasingly recognizing non-motor aspects of NA syndromes, enabling us to address these additional clinical features in our patients.

Recent studies of neuroimaging and neuropathology are providing us with insights in basal ganglia circuitry, and may shed light upon the unique psychiatric features of NA syndromes.

Animal models and cell culture studies of protein function are vital to understand the effects of protein mutation at the level of the cell and the system. We hope that the small steps presented in this volume will ultimately lead to therapies for our patients with these neglected syndromes.

References

1. Neurological disease with acanthocytosis (1980). Clin Neurol (Tokyo) 20:1056–1084
2. Al-Asmi A, Jansen A, Badhwar A et al. (2005) Familial temporal lobe epilepsy as a presenting feature of choreoacanthocytosis. Epilepsia 46:1256–1263
3. Aminoff MJ (1972) Acanthocytosis and neurological disease. Brain 95:749–760
4. Anand IS, Khwaja GA, Gupta M (1994) Choreoacanthocytosis. J Assoc Physicians India 42:495–496
5. Andermann E, Badhwar A, Al Asmi A et al. (2002) Chorea-acanthocytosis in a large French-Canadian kindred with dominant or pseudo-dominant inheritance and variable expressivity. Am J Hum Genet 71:530
6. Andermann E, Danek A, Irvine G et al. (2005) Second international neuroacanthocytosis symposium: expanding the spectrum of choreatic syndromes: Montreal neurological hospital and institute, April 17–19 2005. Mov Disord 20:1673–1684
7. Andermann F, Jansen A, Al-Asmi A et al. (2006) Epilepsy in neuroacanthocytosis. Mov Disord 20:1680
8. Araki J, Tatsumi Y, Sannomiya Y et al. (1983) Chorea-acanthocytosis and deformability of erythrocytes [Japanese]. Jpn J Clin Hematol 24:1055–1059
9. Arima S, Mori R, Kato N (1980) A case of the familial chorea with acanthocytosis [Japanese]. Clin Neurol (Tokyo) 20:1069–1070

10. Arzberger T, Heinsen H, Buresch N et al. (2006) The neuropathology of chorea-acanthocytosis: from stereology to an immunohistochemical detection of chorein. Mov Disord 20:1679
11. Asano K, Osawa Y, Yanagisawa N et al. (1985) Erythrocyte membrane abnormalities in patients with amyotrophic chorea with acanthocytosis. Part 2. Abnormal degradation of membrane proteins. J Neurol Sci 68:161–173
12. Asano K, Oshima M (1990) Protein extractabilities from the erythrocyte membranes in patients with chorea-acanthocytosis. Jpn J Exp Med 60:355–358
13. Bader B, Arzberger T, Dobson-Stone C et al. (2007) Chorein expression in post-mortem brain tissue of chorea-acanthocytosis patients and non-affected controls. J Neural Transm 114:XXVIII
14. Behari M, Saha P, Prasad K et al. (1991) Choreoacanthocytosis with marked dysphagia and laryngeal dystonia. J Assoc Physicians India 39:967–968
15. Betts JJ, Nicholson JT, Critchley EM (1970) Acanthocytosis with normolipoproteinaemia: biophysical aspects. Postgrad Med J 46:702–707
16. Bharucha EP, Bharucha NE (1989) Choreo-acanthocytosis. J Neurol Sci 89:135–139
17. Calenda G, Peng J, Redman CM et al. (2006) Identification of two new members, XPLAC and XTES, of the XK family. Gene 370:6–16
18. Critchley E (2001) A neurologist's tale. The Memoir Club, Spennymoor
19. Critchley EMR (1971) Acanthocytosis associated with tics and involuntary movements. Z Neurol 200:336–340
20. Critchley EMR, Betts JJ, Nicholson JT et al. (1970) Acanthocytosis, normolipoproteinemia and multiple tics. Postgrad Med J 46:698–701
21. Critchley EMR, Clark DB, Wikler A (1967) An adult form of acanthocytosis. Trans Am Neurol Assoc 92:132–137
22. Critchley EMR, Clark DB, Wikler A (1968) Acanthocytosis and neurological disorder without betalipoproteinemia. Arch Neurol 18:134–140
23. D'Amelio M, Callari G, Gammino M et al. (2005) Levetiracetam in the treatment of vascular chorea: a case report. Eur J Clin Pharmacol 60:835–836
24. Danek A (ed) (2004) Neuroacanthocytosis syndromes. Springer, Dordrecht, The Netherlands
25. Danek A, Dobson-Stone C, Velayos-Baeza A et al. (2006) The phenotype of chorea-acanthocytosis: a review of 106 patients with *VPS13A* mutations. Mov Disord 20:1678
26. Danek A, Hegele A (2004) Compound heterozygous *PANK2* mutations confirm HARP and Hallervorden–Spatz syndromes are allelic (correspondence). Neurology On-line material: http://www.neurology.org/cgi/eletters/61/10/1423
27. Danek A, Jung HH, Melone MAB et al. (2005) Neuroacanthocytosis: new developments in a neglected group of dementing disorders. J Neurol Sci 229–230:171–186
28. Dixit SN, Sharma S, Behari M et al. (1993) Neuroacanthocytosis with pure chorea. J Assoc Physicians India 41:613
29. Dobson-Stone C, Danek A, Rampoldi L et al. (2002) Mutational spectrum of the *CHAC* gene in patients with chorea-acanthocytosis. Eur J Hum Genet 10:773–781
30. Dobson-Stone C, Velayos-Baeza A, Filippone LA et al. (2004) Chorein detection for the diagnosis of chorea-acanthocytosis. Ann Neurol 56:299–302
31. Dobson-Stone C, Velayos-Baeza A, Jansen A et al. (2005) Identification of a *VPS13A* founder mutation in French Canadian families with chorea-acanthocytosis. Neurogenetics 6:151–158
32. Dydak U, Mueller S, Sandor PS et al. (2006) Cerebral metabolic alterations in McLeod syndrome. Eur Neurol 56:17–23
33. Engel WK, Levy RI, Watkins SP et al. (1967) Discussion: an adult form of acanthocytosis. Trans Am Neurol Assoc 92:135–137
34. Estes JW, Morley TJ, Levine IM et al. (1967) A new hereditary acanthocytosis syndrome. Am J Med 42:868–881
35. Fujimoto Y, Isozaki E, Yokochi F et al. (1997) A case of chorea-acanthocytosis successfully treated with posteroventral pallidotomy [Japanese]. Clin Neurol (Tokyo) 37:891–894

36. Gatto EM, Uribe RC, Raina G et al. (2004) Vascular hemichorea/hemiballism and topiramate. Mov Disord 19:836–838
37. Gunatilake SB, Janaka De Silva H, Seneviratne S et al. (1997) Neuroacanthocytosis. Ceylon Med J 42:183–184
38. Hardie RJ, Pullon HWH, Harding AE et al. (1991) Neuroacanthocytosis: a clinical, haematological and pathological study of 19 cases. Brain 114:13–49
39. Hayflick SJ, Westaway SK, Levinson B et al. (2003) Genetic, clinical, and radiographic delineation of Hallervorden–Spatz Syndrome. N Engl J Med 348:33–40
40. Henkel K, Danek A, Grafman J et al. (2006) Head of the caudate nucleus is most vulnerable in chorea-acanthocytosis: a voxel-based morphometry study. Mov Disord 21:1728–1731
41. Hirayama K, Yamada T (1980) Familial neuro-acanthocytosis in adult. Special consideration on symptomatology of involuntary movements [Japanese]. Clin Neurol (Tokyo) 20:1064–1066
42. Hirayama M, Hamano T, Shiratori M et al. (1997) Chorea-acanthocytosis with polyclonal antibodies to ganglioside GM1. J Neurol Sci 151:23–24
43. Ho M, Chelly J, Carter N et al. (1994) Isolation of the gene for McLeod syndrome that encodes a novel membrane transport protein. Cell 77:869–880
44. Ho MF, Chalmers RM, Davis MB et al. (1996) A novel point mutation in the McLeod syndrome gene in neuroacanthocytosis. Ann Neurol 39:672–675
45. Hosokawa T, Omoto K, Kanaseki T et al. (1992) Studies on the erythrocyte membrane skeleton in a patient with chorea-acanthocytosis. Theoretical speculation on the mechanism of neurological involvement. Brain and Nerve (Tokyo) 44:739–744
46. Houlden H, Lincoln S, Farrer M et al. (2003) Compound heterozygous *PANK2* mutations confirm HARP and Hallervorden–Spatz syndromes are allelic. Neurology 61:1423–1426
47. Ichiba M, Muroya S, Tomemori Y et al. (2005) Inheritance pattern of ChAc in a pedigree in Kagoshima, Japan. Mov Disord 20:1678–1679
48. Imoto K (1983) A case report. Clin Neurol (Tokyo) 23:86
49. Ishida C, Makifuchi T, Saiki S et al. (2007) An autopsied case of chorea-acanthocytosis with a single detected mutation of *VPS13A*. Mov Disord 22:VI
50. Itoga E, Kito S, Fujita H (1978) A case of amyotrophic chorea with acanthocytosis. J Hiroshima Med Assoc 31:772–775
51. Itoga E, Kito S, Fujita H et al. (1979) A pedigree of amyotrophic chorea with acanthocytosis. Saishin Igaku (Osaka) 308–313
52. Itoga E, Kito S, Funakawa W et al. (1981) Amyotrophic chorea with acanthocytosis. Neurol Med (Tokyo) 15:8–15
53. Iwata M, Fuse S, Sakuta M et al. (1984) Neuropathological study of chorea-acanthocytosis. Jpn J Med 23:118–122
54. Jung HH, Hergersberg M, Vogt M et al. (2003) McLeod phenotype associated with a *XK* missense mutation without hematologic, neuromuscular, or cerebral involvement. Transfusion 43:928–938
55. Kageyama Y, Kodama Y, Tadano M et al. (2000) A case of chorea-acanthocytosis with dilated cardiomyopathy and myopathy [Japanese]. Clin Neurol (Tokyo) 40:816–820
56. Kageyama Y, Matsumoto K, Ichikawa K et al. (2007) A new phenotype of chorea-acanthocytosis with dilated cardiomyopathy and myopathy. Mov Disord 22:1669–1670
57. Kamakura K, Shimizu T, Shimada I et al. (1979) Involuntary movements associated with acanthocytosis. Report of two cases. Saishin Igaku (Osaka) 34:304–307
58. Kamakura K, Shimizu T, Toyokura Y et al. (1981) Chorea-acanthocytosis (Levine–Critchley syndrome). Report of a family with biochemical study. Neurol Med (Tokyo) 15:1–7
59. Kamiya K, Sugino F, et al. (1983) A case report of chorea-acanthocytosis. Clin Neurol (Tokyo) 23:632
60. Kawakami T, Takiyama Y, Sakoe K et al. (1999) A case of McLeod syndrome with unusually severe myopathy. J Neurol Sci 166:36–39
61. Khwaja GA (1999) Neuroacanthocytosis. J Assoc Physicians India 47:656

62. Kito S, Itoga E, Hiroshige Y et al. (1980) A pedigree of amyotrophic chorea with acanthocytosis. Arch Neurol 37:514–517
63. Kobayashi J (1983) A case of myoclonus epilepsy, mitochondrial myopathy and acanthocytosis. Clin Neurol (Tokyo) 23:86
64. Kohriyama T, Yoshida Y, Nakamura N et al. (1980) Pathogenesis of chorea with acanthocytosis. Clin Neurol (Tokyo) 20:1076–1078
65. Kohriyama T, Yoshida Y, Nakamura N et al. (1981) Chorea-acanthocytosis. Report of two cases with study on membrane-abnormality. Neurol Med (Tokyo) 15:30–35
66. Kohriyama T, Yoshida Y, Nakamura N et al. (1980) Progressive chorea with acanthocytosis. A report of two cases and biochemical studies. Nihon Naikagakkai-shi 69:26–32
67. Kondo K, Ueno E, Makishita H et al. (1980) Clinical studies of 4 cases of chorea with acanthocytosis. Clin Neurol (Tokyo) 20:1073–1075
68. Kondo K, Yanagisawa N (1981) Familial chorea with neuropathy and acanthocytosis: report of six cases with special reference to its clinical variety. Neurol Med (Tokyo) 15:118–127
69. Kumari KTS, Ravikumar A, Nair RA et al. (1997) Changes in the glycosaminoglycans, glycoproteins and lipid components of erythrocyte membrane in neuroacanthocytosis. Neurology (India) 45:23–27
70. Kuo PT, Bassett DR (1962) Blood and tissue lipids in a family with hypo-beta-lipoproteinemia. Circulation 26:660
71. Kurano Y, Nakamura M, Ichiba M et al. (2007) In vivo distribution and localization of chorein. Biochem Biophys Res Commun 353:431–435
72. Kuroiwa Y, Ohnishi A, Sato Y et al. (1984) Chorea acanthocytosis: clinical pathological and biochemical aspects. Int J Neurol 18:64–74
73. Kutcher JS, Kahn MJ, Andersson HC et al. (1999) Neuroacanthocytosis masquerading as Huntington's disease: CT/MRI findings. J Neuroimaging 9:187–189
74. Levine IM (1964) An hereditary neurological disease with acanthocytosis. Neurology 14:272
75. Levine IM, Estes JW, Looney JB (1968) Hereditary neurological disease with acanthocytosis, a new syndrome. Arch Neurol 19:403–409
76. Levine IM, Yettra M, Stefanini M (1960) A hereditary neurological disorder with acanthocytosis. Neurology 10:425
77. Lin FC, Wei LJ, Shih PY (2006) Effect of levetiracetam on truncal tic in neuroacanthocytosis. Acta Neurol Taiwan 15:38–42
78. Lossos A, Dobson-Stone C, Monaco AP et al. (2005) Early clinical heterogeneity in choreoacanthocytosis. Arch Neurol 62:611–614
79. Lowe D, Ibbotson RM, Loizou A (1977) Benign normolipoproteinaemic acanthocytosis. Br Med J 2:99–100
80. Marson AM, Bucciantini E, Gentile E et al. (2003) Neuroacanthocytosis: clinical, radiological, and neurophysiological findings in an Italian family. Neurol Sci 24:188–189
81. Matsumoto H (1986) Meal-time assistance of a patient with chorea-acanthocytosis [Japanese]. Kurinikaru Sutadi 7:888–893
82. McIntosh J (2006) Speech/Occupational therapy for neuroacanthocytosis. Mov Disord 20:1682
83. Meenakshi-Sundaram S, Arun Kumar MJ, Sridhar R et al. (2004) Neuroacanthocytosis misdiagnosed as Huntington's disease: a case report. J Neurol Sci 219:163–166
84. Mehndiratta MM, Malik S, Kumar S et al. (2000) McLeod syndrome (a variant of neuroacanthocytosis). J Assoc Physicians India 48:356–357
85. Melone MA, Di Fede G, Peluso G et al. (2002) Abnormal accumulation of tTGase products in muscle and erythrocytes of chorea-acanthocytosis patients. J Neuropathol Exp Neurol 61:841–848
86. Metzer WS (1990) Neuroacanthocytosis with autosomal dominant inheritance, normal serum CK and preserved myotatic reflexes. Mov Disord 5(Suppl 1):92
87. Mizuno E, Nakamura M, Agemura A et al. (2007) Brain-specific transcript variants of 5′ and 3′ ends of mouse *VPS13A* and *VPS13C*. Biochem Biophys Res Commun 353:902–907

88. Mori K, Ide Y, Haku R (1980) A case with choreic involuntary movement and acanthocytosis, who responded to steroid treatment. Clin Neurol (Tokyo) 20:1071–1072
89. Mukoyama M, Kazui H, Sunohara N et al. (1986) Mitochondrial myopathy, encephalopathy, lactic acidosis, and stroke-like episodes with acanthocytosis: a clinicopathological study of a unique case. J Neurol 233:228–232
90. Müller-Vahl KR, Berding G, Emrich HM et al. (2007) Chorea-acanthocytosis in monozygotic twins: clinical findings and neuropathological changes as detected by diffusion tensor imaging, FDG-PET and (123)I-beta-CIT-SPECT. J Neurol 254:1081–1088
91. Nagashima T, Iwashita H, Kuroiwa Y et al. (1979) Chorea-acanthocytosis. A report of a family [Japanese]. Clin Neurol (Tokyo) 19:609–615
92. Nakanishi K, et al. (1983) A case of chorea-athetosis and poikilocytosis. Proceedings of 24th Japanese Neurology Meeting 62
93. Ohnishi A, Sato Y, Nagara H et al. (1981) Neurogenic muscular atrophy and low density of large myelinated fibres of sural nerve in chorea-acanthocytosis. J Neurol Neurosurg Psychiatry 44:645–648
94. Okamoto K, Ito J, Furusawa T et al. (1997) CT and MR findings of neuroacanthocytosis. J Comput Assist Tomogr 21:221–222
95. Orrell RW, Amrolia PJ, Heald A et al. (1995) Acanthocytosis, retinitis pigmentosa, and pallidal degeneration: a report of three patients, including the second reported case with hypoprebetalipoproteinemia (HARP syndrome). Neurology 45:187–192
96. Oshima M, Osawa Y, Asano K et al. (1985) Erythrocyte membrane abnormalities in patients with amyotrophic chorea with acanthocytosis. Part 1. Spin labeling studies and lipid analyses. J Neurol Sci 68:147–160
97. Pellecchia MT, Valente EM, Cif L et al. (2005) The diverse phenotype and genotype of pantothenate kinase-associated neurodegeneration. Neurology 64:1810–1812
98. Rafalowska J, Drac H, Jamrozik S (1996) Neuroacanthocytosis. Review of literature and case report. Folia Neuropathol 34:178–183
99. Rampoldi L, Danek A, Monaco AP (2002) Clinical features and molecular bases of neuroacanthocytosis. J Mol Med 80:475–491
100. Rampoldi L, Dobson-Stone C, Rubio JP et al. (2001) A conserved sorting-associated protein is mutant in chorea-acanthocytosis. Nat Genet 28:119–120
101. Recio MV, Hauser RA, Louis ED et al. (2005) Chorea in a patient with cerebral palsy: treatment with levetiracetam. Mov Disord 20:762–764
102. Robinson D, Smith M, Reddy R (2004) Neuroacanthocytosis. Am J Psychiatry 161:1716
103. Rovito DA, Pirone FJ (1963) Acanthrocytosis associated with schizophrenia. Am J Psychiatry 120:182–185
104. Roy MK, Saha SP, Gangopadhya PK et al. (1999) A case of chorea with neuroacanthocytosis. J Assoc Physicians India 47:242–243
105. Rubio JP, Danek A, Stone C et al. (1997) Chorea-acanthocytosis: genetic linkage to chromosome 9q21. Am J Hum Genet 61:899–908
106. Ryu S, Awasaki H, Yamaguchi A (1982) A case report on chorea acanthocytosis. Clin Neurol (Tokyo) 22:734–734
107. Sahashi I, Takahashi A, Mitsuma A et al. (1980) Familial onset of abnormal erythrocytes, Shy–Drager syndrome, and involuntary movements. Clinical and hereditary studies. Clin Neurol (Tokyo) 20:1082–1084
108. Saiki S, Hirose G, Sakai K et al. (2004) Chorea-acanthocytosis associated with Tourettism. Mov Disord 19:833–836
109. Saiki S, Sakai K, Kitagawa Y et al. (2003) Mutation in the *CHAC* gene in a family of autosomal dominant chorea-acanthocytosis. Neurology 61:1614–1616
110. Saiki S, Sakai K, Murata KY et al. (2007) Primary skeletal muscle involvement in chorea-acanthocytosis. Mov Disord 22:848–852
111. Saiki S, Sano A, Danek A et al. (2007) Third international neuroacanthocytosis symposium: the Asian perspective; Kyoto Prefectural University of Medicine, October 28 2006. Mov Disord 22:I–VI

112. Saito T, Hasegawa I, Kowa H (1980) Symposium: neurological disorder with acanthocytosis. Clin Neurol (Tokyo) 20:1079–1081
113. Sakai T, Antoku Y, Iwashita H et al. (1991) Chorea-acanthocytosis: abnormal composition of covalently bound fatty acids of erythrocyte membrane proteins. Ann Neurol 29:664–669
114. Sakai T, Goto I, Kuroiwa Y et al. (1981) Chorea-acanthocytosis and Huntington's chorea [Japanese]. Neurol Med (Tokyo) 15:24–29
115. Sakai T, Iwashita H, Kakugawa M (1985) Neuroacanthocytosis syndrome and choreo-acanthocytosis (Levine–Critchley syndrome). Neurology 35:1679
116. Sakai T, Iwashita H, Sato Y et al. (1980) Chorea-acanthocytosis: familial and sporadic case [Japanese]. Clin Neurol (Tokyo) 20:1062–1063
117. Sakai T, Mawatari S, Iwashita H et al. (1981) Choreoacanthocytosis. Clues to clinical diagnosis. Arch Neurol 38:335–338
118. Sakuta M, Takemura T, Kamakura K et al. (1980) An autopsy case of chorea-acanthocytosis [Japanese]. Clin Neurol (Tokyo) 20:1059–1061
119. Sato Y, Ohnishi A, Tateishi J et al. (1984) An autopsy case of chorea-acanthocytosis. Special reference to the histopathological and biochemical findings of basal ganglia. Brain and Nerve (Tokyo) 36:105–111
120. Senda Y, Koike Y, Sugimura K et al. (1987) Chorea-acanthocytosis with catecholamine abnormality and orthostatic hypotension: a case report [Japanese]. Clin Neurol (Tokyo) 27:898–903
121. Shibasaki H, Sakai T, Nishimura H et al. (1982) Involuntary movements in chorea-acanthocytosis: a comparison with Huntington's chorea. Ann Neurol 12:311–314
122. Shimizu T, Inoue S, Sugita H et al. (1974) Self-mutilation, choreoathetosis, muscular hypotonia, absence of deep tendon reflexes and normouricemia, report of adult case [Japanese]. Neurol Med (Tokyo) 1:135–136
123. Shiokawa T, Suga S, Beppu H et al. (1982) Familial cases in chorea-acanthocytosis [Japanese]. Clin Neurol (Tokyo) 22:735
124. Shizuka M, Watanabe M, Aoki M et al. (1997) Analysis of the McLeod syndrome gene in three patients with neuroacanthocytosis. J Neurol Sci 150:133–135
125. Silvestri R, Raffaele M, De Domenico P et al. (1995) Sleep features in Tourette's syndrome, neuroacanthocytosis and Huntington's chorea. Neurophysiol Clin 25:66–77
126. Sobue G, Mukai E, Fujii K et al. (1986) Peripheral nerve involvement in familial chorea-acanthocytosis. J Neurol Sci 76:347–356
127. Storch A, Kornhass M, Schwarz J (2005) Testing for acanthocytosis: a prospective reader-blinded study in movement disorder patients. J Neurol 252:84–90
128. Sugimura K, Katsui Y, Nakazhima K et al. (1987) Peripheral nerve involvement in chorea-acanthocytosis [Japanese]. Clin Neurol (Tokyo) 27:211–217
129. Tabira T (2000) Chorea-acanthocytosis [Japanese]. Ryoikibetsu Shokogun Shirizu 188–189
130. Takahashi Y, Kojima T, Atsumi Y et al. (1983) A case of chorea-acanthocytosis with various psychotic symptoms. Seishin Shinkeigaku Zasshi 85:457–472
131. Takashima H, Sakai T, Iwashita H et al. (1994) A family of McLeod syndrome, masquerading as chorea-acanthocytosis. J Neurol Sci 124:56–60
132. Takiyama Y, Saito T, Kaneko J et al. (1986) An unusual case associated with atrophy of the caudate nucleus, acanthocytosis and severe muscular wasting–neuroacanthocytosis syndrome [Japanese]. Clin Neurol (Tokyo) 26:1130.1137
133. Tamura Y, Matsui K, Yaguchi H et al. (2005) Nemaline rods in chorea-acanthocytosis. Muscle Nerve 31:516–519
134. Tanaka M, Hirai S, Kondo S et al. (1998) Cerebral hypoperfusion and hypometabolism with altered striatal signal intensity in chorea-acanthocytosis: a combined PET and MRI study. Mov Disord 13:100–107
135. Terada N, Fujii Y, Ueda H et al. (1999) Ultrastructural changes of erythrocyte membrane skeletons in chorea-acanthocytosis and McLeod syndrome revealed by the quick-freezing and deep-etching method. Acta Haematol 101:25–31

136. Terao S, Sobue G, Takahashi M et al. (1995) Disturbances of hypothalamic-pituitary hormone secretion in familial chorea-acanthocytosis [Japanese]. Brain and Nerve (Tokyo) 47:57–61
137. Tomemori Y, Ichiba M, Kusumoto A et al. (2005) A gene-targeted mouse model for chorea-acanthocytosis. J Neurochem 92:759–766
138. Toyokura Y, Kamakura K, Shimada Y (1982) Familial chorea-acanthocytosis (the Levine–Critchley syndrome): a review of the reported cases in Japan. In: The ministry of health and welfare of Japan (ed.) Annual report of the research committee of CNS degenerative diseases (Tokyo) pp 335–351
139. Tsai C-H, Chen R-S, Chang H-C et al. (1997) Acanthocytosis and spinocerebellar degeneration: a new association?. Mov Disord 12:456–459
140. Uchida K, Nakajima K, Shima H et al. (1992) The first example of the McLeod phenotype in a Japanese baby with chronic granulomatous disease. Transfusion 32:691
141. Ueno E, Oguchi K, Yanagisawa N (1982) Morphological abnormalities of erythrocyte membrane in the hereditary neurological disease with chorea, areflexia and acanthocytosis. A study with freeze fracture electron microscopy. J Neurol Sci 56:89–97
142. Ueno S-I, Maruki Y, Nakamura M et al. (2001) The gene encoding a newly discovered protein, chorein, is mutated in chorea-acanthocytosis. Nat Genet 28:121–122
143. Velayos-Baeza A, Vettori A, Copley RR et al. (2004) Analysis of the human *VPS13* gene family. Genomics 84:536–549
144. Walker RH, Jankovic J, O'Hearn E et al. (2003) Phenotypic features of Huntington's disease-like 2. Mov Disord 18:1527–1530
145. Walker RH, Liu Q, Ichiba M et al. (2006) Self-mutilation in chorea-acanthocytosis: manifestation of movement disorder or psychopathology? Mov Disord 21:2268–2269
146. Walker RH, Melnick A, Walsh M et al. (1997) Dominantly inherited chorea-parkinsonism-dementia-acanthocytosis with red cell protein membrane abnormalities. Ann Neurol 42:407–408
147. Walker RH, Morgello S, Davidoff-Feldman B et al. (2002) Autosomal dominant chorea-acanthocytosis with polyglutamine-containing neuronal inclusions. Neurology 58:1031–1037
148. Walker RH, Morgello S, Davidoff-Feldman B et al. (2004) Autosomal-dominant chorea-acanthocytosis: report of a family and neuropathology. In: Danek A (ed) Neuroacanthocytosis syndromes. Springer, Dordrecht, pp 55–65
149. Walker RH, Rasmussen A, Rudnicki D et al. (2003) Huntington's disease-like 2 can present as chorea-acanthocytosis. Neurology 61:1002–1004
150. Walker RH, Danek A, Uttner I et al. (2007) McLeod phenotype without the McLeod syndrome. Transfusion 47:299–305
151. Yamada T, Hirayama K, Akai J (1986) One autopsy case of Levine–Critchley syndrome: clinico-pathological study [Japanese]. Clin Neurol (Tokyo) 26:156–161
152. Yamamoto T, Hirose G, Shimazaki K et al. (1982) Movement disorders of familial neuroacanthocytosis syndrome. Arch Neurol 39:298–301
153. Yamamoto T, Hirose G, Takado M et al. (1980) A familial neurological disorder with acanthocytosis. Special reference to movement disorders [Japanese]. Clin Neurol (Tokyo) 20:1067–1068

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