

GENETIC TESTING: EPILEPSY, NEURODEGENERATIVE, AND NEUROMUSCULAR DISORDERS

OVERVIEW

Genetic testing for hereditary epilepsy, neurodegenerative, and neuromuscular disorders may be used to confirm a diagnosis in a patient who has signs and/or symptoms of the disease, but conventional diagnostic methods have been unsuccessful. Confirming the diagnosis may alter some aspects of management and may eliminate the need for further diagnostic workup. This document addresses genetic testing for neurodegenerative and neuromuscular genetic diseases.

POLICY REFERENCE TABLE

Below are a list of higher volume tests and the associated laboratories for each coverage criteria section. This list is not all inclusive.

Coverage Criteria Sections	Example Tests; Labs	Common CPT Codes	Common ICD Codes	Ref
Known Familial Variant Analysis for Epilepsy, Neurodegenerative, and Neuromuscular Disorders				
Known Familial Variant Analysis for Epilepsy, Neurodegenerative, and Neuromuscular Disorders	Targeted Mutation Analysis for a Known Familial Variant	81403, 81174, 81186, 81190, 81289, 81326, 81337		35
Comprehensive Neuromuscular Disorders Panel				
Comprehensive Neuromuscular Disorders Panel	Comprehensive Neuromuscular Panel (PreventionGenetics)	81161, 81404, 81405, 81406, 81479	G12, G13, G23-G26, G31, G32,	31, 36, 39

			G36, G37	
	Neuromuscular NGS Panel (Sequencing & Deletion/Duplication) (Fulgent Genetics)			
	Neuromuscular Disorders Panel (GeneDx)			
Comprehensive Ataxia Panel				
Comprehensive Ataxia Panel	Genomic Unity Ataxia Repeat Expansion Analysis (Variantyx, Inc.)	0216U	G11.1, G11.19, G11.8, G11.9, Z82.0	12
	Genomic Unity Comprehensive Ataxia Analysis (Variantyx, Inc.)	0217U		
	Ataxia Xpanded Panel (GeneDx)	81185, 81189, 81286, 81403, 81404, 81479		
	Ataxia Panel (Blueprint Genetics)			
Spinal Muscular Atrophy				
SMN1 Sequencing and/or Deletion/Duplication Analysis	SMN1 Deletion/Duplication Analysis	81329, 81401	G12, Z84.81	7
	SMN1 Sequencing Analysis	81336, 81405		
	Genomic Unity SMN1/2 Analysis (Variantyx Inc.)	0236U		
SMN2 Deletion/Duplication Analysis	SMN2 Deletion/Duplication Analysis	81401		
Epilepsy				
Epilepsy Multigene Panel	Childhood-Onset Epilepsy Panel, Sequencing and Deletion/Duplication (ARUP Laboratories)	81185, 81189, 81302, 81406, 81419, 81479	G40.001- G40.919	37
	Infantile Epilepsy Panel, Sequencing Analysis and Exon-Level Deletion/Duplication (ARUP Laboratories)			
	Infantile Epilepsy Panel (GeneDx)			

	Childhood-Onset Epilepsy Panel (GeneDx)			
	Invitae Epilepsy Panel (Invitae)			
Alzheimer Disease				
PSEN1, PSEN2, and APP Sequencing and/or Deletion/Duplication Analysis or Multigene Panel	PSEN1 Full Gene Sequencing and Deletion/Duplication (Invitae)	81405, 81479	F03, G30, G31.1, R41.0, R41.81, Z13.858, Z82.0, Z84.81	2, 4, 5, 6
	Alzheimer's Disease, Familial via the PSEN2 Gene (PreventionGenetics)	81406, 81479		
	APP Full Gene Sequencing and Deletion/Duplication (Invitae)	81406, 81479		
	Alzheimer Disease, Familial, Panel (PreventionGenetics)	81405, 81406, 81479		
	Hereditary Alzheimer's Disease Panel (Invitae)			
APOE, TREM2, and Other Variant Analysis	APOE Single Gene Test (Blueprint Genetics)	81401, 81479, S3852		
	TREM2 Full Gene Sequencing and Deletion/Duplication (Invitae)	81479		
Amyotrophic Lateral Sclerosis (ALS)				
Familial Amyotrophic Lateral Sclerosis (FALS) Multigene Panel	Amyotrophic Lateral Sclerosis (ALS) Panel (PreventionGenetics)	81179, 81403, 81404, 81405, 81406, 81407, 81479, S3800	G12.21	8, 10
	Amyotrophic Lateral Sclerosis Panel - Primary Genes (Invitae)			
Duchenne and Becker Muscular Dystrophy				
DMD Sequencing and/or Deletion/Duplication Analysis	DMD Deletion/Duplication Analysis	81161	G71.01, R62.59, Z84.81	11, 30
	DMD Sequencing Analysis	81408		
	Genomic Unity DMD Gene Analysis (Variantyx)	0218U		
Facioscapulohumeral Muscular Dystrophy (FSHD)				
	FSHD1 Southern Blot Test (Quest)	81404	G71.02,	1, 29

FSHD1 Deletion/Duplication or Haplotype Analysis, and/or SMCHD1 and DNMT3B Sequencing and/or Deletion/Duplication Analysis or Multigene Panel	Diagnostics)		Z84.81	
	FSHD-(FSHD1 & FSHD2) Detection of Abnormal Alleles with Interpretation - 4qA/4qB Haplotyping (University of Iowa Hospitals and Clinics - Department of Pathology)	81404		
	Facioscapulohumeral Muscular Dystrophy 2 via the SMCHD1 Gene (PreventionGenetics)	81479		
	DNMT3B Full Gene Sequencing And Deletion/Duplication (Invitae)			
	FSHD-(FSHD1 & FSHD2) Detection of Abnormal Alleles with Interpretation(University of Iowa Hospitals and Clinics - Department of Pathology)	81404, 81479		
Friedreich's Ataxia				
FXN Repeat Analysis and/or Sequencing Analysis	FXN Repeat Analysis	81284, 81285	G11, Z84.81	9, 12
	FXN Sequencing Analysis	81286, 81404		
	Genomic Unity FXN Analysis (Variantyx Inc)	0233U		
Huntington Disease (HD)				
HTT Repeat Analysis	HTT Repeat Analysis	81271, 81274	G10, Z84.81	8, 13
Inherited Peripheral Neuropathy (Charcot-Marie-Tooth and Hereditary Neuropathy with Liability to Pressure Palsies)				
PMP22 Sequencing and/or	PMP22 Duplication/Deletion Analysis	81324	G60.0, G60.8, G60.9	3, 14
	PMP22 Sequencing Analysis	81325		

Deletion/Duplication Analysis or Multigene Panel	Charcot-Marie Tooth (CMT) - Comprehensive Panel (PreventionGenetics)	81448		
	Charcot-Marie-Tooth Panel (GeneDx)			
Limb-Girdle Muscular Dystrophies (LGMD)				
Limb Girdle Muscular Dystrophy Multigene Panel	Limb-Girdle Muscular Panel (GeneDx)	81405, 81406, 81408, 81479	G71.0, Z13.71, Z82.0, Z84.81	6
	Limb-Girdle Muscular Dystrophy Panel (Invitae)			
Myotonic Dystrophy				
DMPK and/or CNBP (ZNF9) Repeat Analysis	DMPK Repeat Analysis	81234, 81239, 81401, 81404, S3853	G71.11, Z84.81	15, 16, 17, 18, 40
	CNBP Repeat Analysis	81187, S3853		
Hereditary Dystonia				
Hereditary Dystonia Multigene Panel	Dystonia Panel (GeneDx)	81404, 81405, 81406, 81407, 81408, 81479	G24.1, G24.9	19
	Dystonia Panel (PreventionGenetics)			
	Dystonia Comprehensive Panel (Invitae)			
Parkinson Disease				
LRRK2, Sequencing and/or Deletion/Duplication Analysis and Parkinson Disease Multigene Panel	LRRK2 Sequencing and/or Deletion/Duplication Analysis	81408, 81479	G20	20, 38
	Parkinson Disease Panel (BluePrint Genetics)	81479		
	Parkinson Disease Panel (GeneDx)			
	Invitae Parkinson Disease and Parkinsonism Panel (Invitae)			
Hereditary Spastic Paraplegia				

Hereditary Spastic Paraplegia Multigene Panel	Comprehensive Hereditary Spastic Paraplegia Panel (GeneDx)	81448	G11.4, G82.2	21, 22, 23 24, 25
	Hereditary Spastic Paraplegia Comprehensive Panel - Primary Genes (Invitae)			
Congenital Myasthenic Syndrome				
Congenital Myasthenic Syndromes Multigene Panel	Congenital Myasthenic Syndrome Panel (PreventionGenetics)	81406, 81407, 81479	G70.2	26
	Congenital Myasthenic Syndrome Panel (Invitae)			
Myotonia Congenita				
CLCN1 Sequencing and/or Deletion/Duplication Analysis	Myotonia Congenita via the <i>CLCN1</i> Gene (PreventionGenetics)	81406, 81479	G71.12	27
	CLCN1 Full Gene Sequencing and Deletion/Duplication (Invitae)			
Hypokalemic Periodic Paralysis				
CACNA1S and SCN4A Sequencing and/or Deletion/Duplication Analysis	CACNA1S Sequencing and/or Deletion/Duplication Analysis	81406, 81479	E87.6, G72.3	28
	SCN4A Sequencing and/or Deletion/Duplication Analysis			
Other Covered Epilepsy, Neurodegenerative, and Neuromuscular Disorders				
Other Covered Epilepsy, Neuromuscular, and Neurodegenerative Disorders	See list below	81400-81408, 81479		32, 33, 34

OTHER RELATED POLICIES

This policy document provides coverage criteria for genetic testing for hereditary neurodegenerative and neuromuscular diseases. Please refer to:

- **Genetic Testing: Prenatal Diagnosis (via amniocentesis, CVS, or PUBS) and Pregnancy Loss** for coverage related to prenatal and pregnancy loss diagnostic

genetic testing for tests intended to diagnose genetic conditions following amniocentesis, chorionic villus sampling, PUBS, or pregnancy loss.

- **Genetic Testing: Prenatal and Preconception Carrier Screening** for coverage criteria related to prenatal carrier screening, preimplantation testing of embryos, or preconception carrier screening (including carrier screening for Duchenne/Becker muscular dystrophy and SMA).
- **Genetic Testing: Pharmacogenetics** for coverage criteria related to genetic testing prior to the initiation of drug treatment with carbamazepine.
- **Genetic Testing: Metabolic, Endocrine, and Mitochondrial Disorders** for coverage criteria related to genetic testing for mitochondrial disorders.
- **Genetic Testing: Prenatal Diagnosis (via amniocentesis, CVS, or PUBS) and Pregnancy Loss** for coverage related to prenatal and pregnancy loss diagnostic genetic testing.
- **Genetic Testing: Preimplantation Genetic Testing** for coverage criteria related to genetic testing of embryos prior to in vitro fertilization.
- **Genetic Testing: General Approach to Genetic Testing** for coverage criteria related to epilepsy, neuromuscular, and neurodegenerative disorders not specifically discussed in this or another non-general policy.

COVERAGE CRITERIA

KNOWN FAMILIAL VARIANT ANALYSIS FOR EPILEPSY, NEURODEGENERATIVE, AND NEUROMUSCULAR DISORDERS

- I. Targeted mutation analysis for a known familial variant (81403, 81174, 81186, 81190, 81289, 81326, 81337) for an epilepsy, neurodegenerative, or neuromuscular disorder is considered **medically necessary** when:
 - A. The member has a [close relative](#) with a known pathogenic or likely pathogenic variant causing the condition.

- II. Targeted mutation analysis for a known familial variant (81403, 81174, 81186, 81190, 81289, 81326, 81337) for an epilepsy, neurodegenerative, or neuromuscular disorder is considered **investigational** for all other indications.

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COMPREHENSIVE NEUROMUSCULAR DISORDERS PANEL

- I. Comprehensive neuromuscular panel analysis to establish a genetic diagnosis for a neuromuscular disorder (81161, 81404, 81405, 81406, 81479) is considered **medically necessary** when:
 - A. The member displays clinical features of a neuromuscular disorder, **AND**
 - B. One of the following:
 1. The member is not highly suspected to have a specific neuromuscular disorder for which single-gene analysis (e.g., *SMN1*, *DMD*, *PMP22*) would be more appropriate, **OR**
 2. The member previously underwent single-gene analysis for a neuromuscular disorder (e.g., *SMN1*, *DMD*, *PMP22*) and the results did not definitively lead to a diagnosis.
- II. Comprehensive neuromuscular panel analysis to establish a genetic diagnosis for a neuromuscular disorder (81161, 81404, 81405, 81406, 81479) is considered **investigational** for all other indications.

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COMPREHENSIVE ATAXIA PANEL

- I. Comprehensive ataxia panel analysis to establish a genetic diagnosis of an ataxia (81185, 81189, 81286, 81403, 81404, 81479, 0216U, 0217U) is considered **medically necessary** when:
 - A. The member displays one or more of the following clinical features of spinocerebellar ataxia:

1. Poorly coordinated gait and finger/hand movements, **OR**
 2. Weakness of the eye muscles (ophthalmoplegia), **OR**
 3. Dysarthria, **OR**
 4. Eye movement abnormalities (nystagmus, abnormal saccade movements), **AND**
- B. Non-genetic causes of ataxia have been ruled out (e.g., alcoholism, vitamin deficiencies, multiple sclerosis, vascular disease, primary or metastatic tumors, and paraneoplastic disease associated with occult carcinoma of the ovary, breast, or lung, and spinal muscular atrophy).
- II. Comprehensive ataxia panel analysis to establish a genetic diagnosis of an ataxia (81185, 81189, 81286, 81403, 81404, 81479, 0216U, 0217U) is considered **investigational** for all other indications.

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SPINAL MUSCULAR ATROPHY

SMN1 Sequencing and/or Deletion/Duplication Analysis

- I. *SMN1* sequencing and/or deletion/duplication analysis (81329, 81336, 81401, 81405, 0236U) to establish or confirm a diagnosis of Spinal Muscular Atrophy is considered **medically necessary** when:
 - A. The member has a positive newborn screen for SMA, **OR**
 - B. The member has any of the following clinical features of SMA:
 1. History of motor difficulties, especially with loss of skills, **OR**
 2. Proximal to distal muscle weakness, **OR**
 3. Hypotonia, **OR**
 4. Areflexia/hyporeflexia, **OR**
 5. Tongue fasciculations, **OR**

6. Hand tremor, **OR**
 7. Recurrent lower respiratory tract infections or severe bronchiolitis in the first few months of life, **OR**
 8. Evidence of motor unit disease on electromyogram.
- II. *SMN1* sequencing and/or deletion/duplication analysis (81329, 81336, 81401, 81405, 0236U) to establish or confirm a diagnosis of Spinal Muscular Atrophy is considered **investigational** for all other indications.

***SMN2* Deletion/Duplication Analysis**

- I. *SMN2* deletion/duplication analysis (81401) is considered **medically necessary** when:
 - A. The member has a diagnosis of spinal muscular atrophy.
- II. *SMN2* deletion/duplication analysis (81401) is considered **investigational** for all other indications.

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EPILEPSY

Epilepsy Multigene Panel

- I. The use of an epilepsy multigene panel (81185, 81189, 81302, 81406, 81419, 81479) is considered **medically necessary** when:
 - A. The member has a history of unexplained epilepsy (e.g., seizures not caused by acquired etiology such as trauma, infection, structural brain abnormality, and/or stroke).
- II. The use of an epilepsy multigene panel (81185, 81189, 81302, 81406, 81419, 81479) is considered **investigational** for all other indications.

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ALZHEIMER DISEASE

***PSEN1*, *PSEN2*, and *APP* Sequencing and/or Deletion/Duplication Analysis or Multigene Panel**

- I. *PSEN1* (81405, 81479), *PSEN2* (81406, 81479), and/or *APP* (81406, 81479) sequencing and/or deletion/duplication analysis or multigene panel (81405, 81406, 81479) to establish a diagnosis or determine future risk to develop [early-onset Alzheimer disease](#) is considered **medically necessary** when:
 - A. The member is 18 years of age or older, **AND**
 - B. The member is asymptomatic*, **AND**
 1. The member has a [close relative](#) with a known early-onset Alzheimer disease-causing mutation in *PSEN1*, *PSEN2*, or *APP*, **OR**
 2. The member has an apparently autosomal dominant family history of dementia with one or more cases of early-onset Alzheimer disease, **OR**
 - C. The member is symptomatic, **AND**
 1. Has a diagnosis of dementia 65 years of age or younger, **AND**
 - a) The member has a [close relative](#) diagnosed with dementia, **OR**
 - b) An unknown family history (e.g., adoption), **OR**
 2. Has a diagnosis of dementia at any age, **AND**
 - a) An autosomal dominant family history of dementia, **AND**
 - b) One or more [close relatives](#) with a diagnosis of dementia less than 65 years of age.
- II. *PSEN1* (81405, 81479), *PSEN2* (81406, 81479), and/or *APP* (81406, 81479) sequencing and/or deletion/duplication analysis or multigene panel (81405, 81406, 81479) to establish the diagnosis or determine future risk to develop [early-onset Alzheimer disease](#) is considered **investigational** for all other indications.

APOE, TREM2 and Other Variant Analysis

- I. Genetic testing to establish a diagnosis or determine future risk to develop Alzheimer disease via other genes, including but not limited to, *APOE* (81401 81479, S3852) or *TREM2* (81479) is considered **investigational**.

* Predictive testing should only be performed in the setting and context of thorough pre- and post-test counseling

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AMYOTROPHIC LATERAL SCLEROSIS (ALS)

Familial Amyotrophic Lateral Sclerosis (FALS) Multigene Panel

- I. Multigene panel analysis to establish a genetic etiology of familial amyotrophic lateral sclerosis (FALS) (81179, 81403, 81404, 81405, 81406, 81407, 81479, S3800) is considered **medically necessary** when:
 - A. The member is 18 years of age or older, **AND**
 - B. The member displays all of the following clinical features of ALS:
 1. Evidence of lower motor neuron (LMN) degeneration, **AND**
 2. Evidence of upper motor neuron (UMN) degeneration, **AND**
 3. Progressive spread of symptoms, **AND**
 4. No evidence of other disease processes that could explain the LMN and UMN degeneration, **AND**
 - C. The panel includes, at a minimum, the following genes: *C9orf72*, *SOD1*, *FUS*, and *TARDBP*.
- II. Multigene panel analysis to establish a genetic etiology of familial amyotrophic lateral sclerosis (FALS) (81179, 81403, 81404, 81405, 81406, 81407, 81479, S3800) is considered **investigational** for all other indications.

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DUCHENNE AND BECKER MUSCULAR DYSTROPHY

DMD Sequencing and/or Deletion/Duplication Analysis

- I. *DMD* sequencing and/or deletion/duplication analysis (81161, 81408, 0218U) to establish or confirm a diagnosis of Duchenne muscular dystrophy (DMD) or Becker muscular dystrophy (BMD) is considered **medically necessary** when:
 - A. The member is a male, **AND**
 1. The member meets one of the following:
 - a) All of the following clinical findings of DMD:
 - (1) Progressive symmetric muscular weakness - proximal greater than distal, often with calf hypertrophy (enlargement), **AND**
 - (2) Symptoms presenting before age five years, **AND**
 - (3) Wheelchair dependency before age 13 years, **AND**
 - (4) Elevated serum creatine kinase concentration, typically more than 10 times the normal levels, **OR**
 - b) For BMD, the member meets the following:
 - (1) The member has an elevated serum creatine kinase concentration, typically more than 5 times the normal levels, **AND**
 - (2) Any of the following:
 - (a) Progressive symmetric muscle weakness (proximal more so than distal) often with calf hypertrophy; weakness of quadriceps femoris in some cases the only sign, **OR**
 - (b) Activity-induced cramping, **OR**
 - (c) Flexion contractures of the elbows, **OR**

(d) Wheelchair dependency (after age 16 years),
OR

(e) Preservation of neck flexor muscle strength, **OR**

2. The member is asymptomatic, **AND**

a) Has a biological sibling with a clinical and/or molecular diagnosis of Duchenne or Becker muscular dystrophy, **OR**

b) Has a biological mother that is an obligate carrier for Duchenne or Becker muscular dystrophy, **OR**

B. The member is a female, **AND**

1. Has a [first- or second-degree relative](#) with a clinical diagnosis of Duchenne or Becker muscular dystrophy.

II. *DMD* sequencing and/or deletion/duplication analysis (81161, 81408, 0218U) to establish a diagnosis of Duchenne muscular dystrophy (DMD) or Becker muscular dystrophy (BMD) is considered **investigational** for all other indications.

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FACIOSCAPULOHUMERAL MUSCULAR DYSTROPHY (FSHD)

***FSHD1* Deletion/Duplication or Haplotype Analysis, and/or *SMCHD1* and *DNMT3B* Sequencing and/or Deletion/Duplication Analysis or Multigene Panel**

I. *FSHD1* deletion/duplication or haplotype analysis (81404), and/or *SMCHD1* (81479) and *DNMT3B* (81479) sequencing and/or deletion/duplication analysis or multigene panel analysis (81404, 81479) to establish or confirm a diagnosis of facioscapulohumeral muscular dystrophy is considered **medically necessary** when:

A. The member displays any of the following clinical features of FSHD:

1. Weakness (which is often asymmetric) that predominantly involves the facial, scapular stabilizer, or foot dorsiflexor muscles without associated ocular or bulbar muscle weakness, **OR**
 2. Progression of weakness after pregnancy, **OR**
 3. Prior diagnosis of FSHD with inflammatory myopathy that was refractory to immunosuppression, **AND**
- B. The member does not have a [first-degree relative](#) with a confirmed genetic diagnosis of FSHD.
- II. *FSHD1* deletion/duplication or haplotype analysis (81404), and/or *SMCHD1* (81479) and *DNMT3B* sequencing and/or deletion/duplication analysis (81479) or multigene panel analysis (81404, 81479) to establish or confirm a diagnosis of facioscapulohumeral muscular dystrophy is considered **investigational** for all other indications.

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FRIEDREICH'S ATAXIA

FXN Repeat Analysis and/or Sequencing Analysis

- I. *FXN* repeat analysis (81284, 81285, 0233U) and/or sequencing analysis (81286, 81404) to establish or confirm a diagnosis of Friedreich's Ataxia is considered **medically necessary** when:
 - A. The member is asymptomatic, **AND**
 1. The member has a biological sibling diagnosed with Friedreich's ataxia, **OR**
 - B. The member meets both of the following:
 1. The member has been diagnosed with cerebellar ataxia, **AND**
 2. Non-genetic causes for the ataxia have been ruled out (examples: alcoholism, vitamin deficiencies, multiple sclerosis, vascular disease, tumors).

- II. *FXN* repeat analysis (81284, 81285, 0233U) and/or sequencing analysis (81286, 81404) to establish or confirm a diagnosis of Friedreich's Ataxia is considered **investigational** for all other indications.

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HUNTINGTON DISEASE

HTT Repeat Analysis

- I. Genetic testing of *HTT* repeat analysis to establish a diagnosis or for predictive testing of Huntington disease (HD) (81271, 81274) is considered **medically necessary** when:
 - A. The member displays any of the following clinical features of Huntington disease:
 1. Progressive motor disability featuring chorea, where voluntary movement may also be affected, **OR**
 2. Cognitive decline, **OR**
 3. Changes in personality, **OR**
 4. Depression, **OR**
 5. Family history of any of the above symptoms consistent with autosomal dominant inheritance, **OR**
 - B. The member is undergoing predictive testing*, **AND**
 1. The member is presymptomatic/asymptomatic, **AND**
 - a) The member has a [close relative](#) with CAG trinucleotide repeat expansion of 27 or more in *HTT*, **OR**
 - b) The member has a [first-degree relative](#) with a clinical diagnosis of HD without prior genetic testing.

- II. Genetic testing of *HTT* repeat analysis to establish a diagnosis or for predictive testing of Huntington disease (HD) (81271, 81274) is considered **investigational** for all other indications.

* Predictive testing should only be performed in the setting and context of thorough pre- and post-test counseling.

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INHERITED PERIPHERAL NEUROPATHIES (EXAMPLES: CHARCOT-MARIE-TOOTH DISEASE AND HEREDITARY NEUROPATHY WITH LIABILITY TO PRESSURE PALSIES)

***PMP22* Sequencing and/or Deletion/Duplication Analysis or Multigene Panel**

- I. *PMP22* sequencing and/or deletion/duplication analysis (81324, 81325) or multigene panel analysis to establish a genetic diagnosis of an inherited peripheral neuropathy (81448) is considered **medically necessary** when:
 - A. The member does not have a clinical diagnosis of Charcot-Marie-Tooth (CMT) or hereditary neuropathy with liability to pressure palsies (HNPP), **AND**
 - B. The member displays one or more of the following clinical features of an inherited motor or sensory peripheral neuropathy:
 - 1. Distal muscle weakness and atrophy, sensory loss, **OR**
 - 2. Pes cavus foot deformity, **OR**
 - 3. Weak ankle dorsiflexion, **OR**
 - 4. Depressed tendon reflexes, **OR**
 - 5. Recurrent acute focal sensory and motor neuropathies mainly at entrapment sites, **OR**
 - 6. Painless nerve palsy after minor trauma or compression, **OR**

7. Evidence on physical examination of previous nerve palsy such as focal weakness, atrophy, or sensory loss, **OR**
 8. Complete spontaneous recovery from neuropathies, **AND**
- C. The panel includes at a minimum all of the following genes: *PMP22*, *GDAP1*, *GJB1*, *HINT1*, *MFN2*, *MPZ*, *SH3TC2*, *SORD*.
- II. *PMP22* sequencing and/or deletion/duplication analysis (81324, 81325) or multigene panel analysis (81448) to establish a genetic diagnosis of an inherited peripheral neuropathy is considered **investigational** for all other indications.

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LIMB-GIRDLE MUSCULAR DYSTROPHY (LGMD)

Limb-girdle Muscular Dystrophy Multigene Panel

- I. Multigene panel analysis to establish a diagnosis of limb-girdle muscular dystrophy (81405, 81406, 81408, 81479) is considered **medically necessary** when:
 - A. The member displays slowly progressive, symmetrical weakness with any of the following clinical features of limb-girdle muscular dystrophy:
 1. Limb-girdle pattern of weakness affecting proximal muscles of the arms and legs, **OR**
 2. Scapuloperoneal weakness, **OR**
 3. Distal weakness, **OR**
 4. Elevated serum creatine kinase levels, **OR**
 - B. The member is asymptomatic, **AND**
 - C. The member has a [close relative](#) diagnosed with limb-girdle muscular dystrophy whose genetic status is unavailable.
- II. Multigene panel analysis to establish a diagnosis of limb-girdle muscular dystrophy (81405, 81406, 81408, 81479) is considered **investigational** for all other indications.

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MYOTONIC DYSTROPHY

***DMPK* and/or *CNBP (ZNF9)* Repeat Analysis**

- I. *DMPK* repeat analysis (81234, 81239, 81401, 81404, S3853) and/or *CNBP* repeat analysis (81187, S3853) to establish a diagnosis of myotonic dystrophy is considered **medically necessary** when:
 - A. The member meets either of the following:
 1. The member is a [neonate](#) with two or more of the following:
 - a) Hypotonia, **OR**
 - b) Facial muscle weakness, **OR**
 - c) Generalized weakness, **OR**
 - d) Positional malformations, including clubfoot, **OR**
 - e) Respiratory insufficiency, **OR**
 2. The member is any age and displays any of the following clinical features of myotonic dystrophy:
 - a) Muscle weakness, especially of the distal leg, hand, neck, and face, **OR**
 - b) Myotonia, which often manifests as the inability to quickly release a hand grip (grip myotonia), **OR**
 - c) Posterior subcapsular cataracts, **OR**
 - d) Cardiac conduction defects or progressive cardiomyopathy, **OR**
 - e) Insulin insensitivity, **OR**
 - f) Hypogammaglobulinemia, **OR**

- B. The member is asymptomatic, **AND**
 - 1. The member is 18 years of age or older, **AND**
 - 2. The member has a [first-degree relative](#) with Myotonic dystrophy type 1 or 2.
- II. *DMPK* repeat analysis (81234, 81239, 81401, 81404, S3853) and *CNBP* repeat analysis (81187, S3853) to establish a diagnosis of myotonic dystrophy is considered **investigational** for all other indications.

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HEREDITARY DYSTONIA

Hereditary Dystonia Multigene Panel

- I. Multigene panel analysis to establish a genetic diagnosis of hereditary dystonia (81404, 81405, 81406, 81407, 81408, 81479) is considered **medically necessary** when:
 - A. The member has all of the following clinical features of a hereditary dystonia:
 - 1. Sustained or intermittent muscle contractions, **AND**
 - 2. Abnormal or repetitive movements and/or postures, **AND**
 - 3. The dystonia is initiated or worsened by voluntary action.
- II. Multigene panel analysis to establish a genetic diagnosis of hereditary dystonia (81404, 81405, 81406, 81407, 81408, 81479) is considered **investigational** for all other indications.

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PARKINSON DISEASE

***LRRK2* Sequencing and/or Deletion/Duplication Analysis or Parkinson Disease Multigene Panel**

- I. *LRRK2* (81408, 81479) sequencing and/or deletion/duplication analysis or multigene panel testing (81479) to establish a genetic diagnosis of Parkinson disease is considered **medically necessary** when:
 - A. The member has a clinical diagnosis of Parkinson disease, **AND**
 - B. A family history of Parkinson disease **AND**
 - C. The panel includes, at a minimum, the *LRRK2* gene.
- II. *LRRK2* (81408, 81479) sequencing and/or deletion/duplication analysis or multigene panel testing (81479) to establish a genetic diagnosis of Parkinson disease is considered **investigational** for all other indications.

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HEREDITARY SPASTIC PARAPLEGIA

Hereditary Spastic Paraplegia Multigene Panel

- I. Multigene panel analysis to establish a genetic diagnosis of hereditary spastic paraplegia (81448) is considered **medically necessary** when:
 - A. The member has any of the following:
 1. Lower-extremity spasticity especially in hamstrings, quadriceps, adductors, and gastrocnemius-soleus muscles, **OR**
 2. Weakness especially in the iliopsoas, hamstring, and tibialis anterior, **OR**
 3. Lower-extremity hyperreflexia and extensor plantar responses, **OR**
 4. Mildly impaired vibration sensation in the distal lower extremities, **AND**

- B. A multigene panel must include the following genes, at a minimum: *SPAST*, *ATL1*, *KIF1A*, *CYP7B1*, *SPG7*, *SPG11*.
- II. Multigene panel analysis to establish a genetic diagnosis of hereditary spastic paraplegia (81448) is considered **investigational** for all other indications.

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CONGENITAL MYASTHENIC SYNDROMES

Congenital Myasthenic Syndromes Multigene Panel

- I. Multigene panel analysis to establish a genetic diagnosis of congenital myasthenic syndromes (81406, 81407, 81479) is considered **medically necessary** when:
 - A. The member has a history of fatigable weakness involving ocular, bulbar, and limb muscles with onset at or shortly after birth or in early childhood, **AND**
 - B. A decremental EMG response of the compound muscle action potential (CMAP) on low-frequency (2-3 Hz) stimulation, **AND**
 - C. A positive response to acetylcholinesterase (AChE) inhibitors, **AND**
 - D. Absence of anti-acetylcholine receptor (anti-AChR) and anti-MuSK antibodies in the serum, **AND**
 - E. Lack of improvement of clinical symptoms with immunosuppressive therapy, **AND**
 - F. Absence of major pathology in a skeletal muscle biopsy specimen despite considerable muscle weakness.
- II. Multigene panel analysis to establish a genetic diagnosis of congenital myasthenic syndromes (81406, 81407, 81479) is considered **investigational** for all other indications.

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MYOTONIA CONGENITA

CLCN1 Sequencing and/or Deletion/Duplication Analysis

- I. *CLCN1* sequencing and/or deletion/duplication analysis (81406, 81479) to establish a genetic diagnosis of myotonia congenita is considered **medically necessary** when:
 - A. The member has episodes of muscle stiffness (myotonia*) or cramps beginning in early childhood that are alleviated by brief exercise, **AND**
 - B. Myotonic contraction is elicited by percussion of muscles, **AND**
 - C. Serum creatine kinase concentration that may be slightly elevated (3-4x the upper limits of normal), **AND**
 - D. Electromyography (EMG) performed with needle electrodes discloses characteristic showers of spontaneous electrical activity (myotonic bursts).
- II. *CLCN1* sequencing and/or deletion/duplication analysis (81406, 81479) to establish a genetic diagnosis of myotonia congenita is considered **investigational** for all other indications.

*Myotonia is defined as impaired relaxation of skeletal muscle after voluntary contraction.

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HYPOKALEMIC PERIODIC PARALYSIS

CACNA1S and SCN4A Sequencing and/or Deletion/Duplication Analysis

- I. *CACNA1S* and *SCN4A* sequencing and/or deletion/duplication analysis (81406, 81479) to establish a genetic diagnosis of periodic paralysis is considered **medically necessary** when:
 - A. The member has had two or more attacks of muscle weakness with documented serum potassium less than 3.5 mEq/L, **OR**
 - B. The member has had one attack of muscle weakness, **AND**

1. Has a [close relative](#) who has had one attack of muscle weakness in with documented serum potassium less than 3.5 mEq/L, **OR**
- C. The member has three or more of the following features:
1. Onset of symptoms in the first or second decade, **OR**
 2. Muscle weakness involving at least 1 limb lasting longer than two hours, **OR**
 3. The presence of triggers (previous carbohydrate rich meal, symptom onset during rest after exercise, stress), **OR**
 4. Improvement in symptoms with potassium intake, **OR**
 5. A family history of a clinical or genetic diagnosis of hypokalemic periodic paralysis in a [close relative](#), **OR**
 6. Positive long exercise test, **AND**
- D. Alternative causes of hypokalemia have been excluded (e.g., renal, adrenal, thyroid dysfunction; renal tubular acidosis; diuretic and laxative abuse).
- II. *CACNA1S* and *SCN4A* sequencing and/or deletion/duplication analysis (81406, 81479) to establish a genetic diagnosis of periodic paralysis is considered **investigational** for all other indications.

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OTHER COVERED EPILEPSY, NEUROMUSCULAR, AND NEURODEGENERATIVE DISORDERS

- I. Genetic testing to establish or confirm one of the following epilepsy, neuromuscular, and neurodegenerative conditions to guide management is considered **medically necessary** when the member demonstrates clinical features* consistent with the disorder (the list is not meant to be comprehensive, see II below):
 - A. [Hereditary Transthyretin Amyloidosis](#)
 - B. [X-linked Adrenoleukodystrophy](#)

- C. [L1 Syndrome](#)
 - D. [SCN9A Neuropathic Pain Syndromes](#)
 - E. [Cerebral Cavernous Malformation, Familial](#)
 - F. [STAC3 Disorder](#)
- II. Genetic testing to establish or confirm the diagnosis of all other epilepsy, neurodegenerative, and neuromuscular disorders not specifically discussed within this or another medical policy will be evaluated by the criteria outlined in *General Approach to Genetic Testing* (see policy for coverage criteria).

*Clinical features for a specific disorder may be outlined in resources such as [GeneReviews](#), [OMIM](#), [National Library of Medicine](#), [Genetics Home Reference](#), or other scholarly source.

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NOTES/DEFINITIONS

1. **Close relatives** include first, second, and third degree blood relatives on the same side of the family:
 - a. **First-degree relatives** are parents, siblings, and children
 - b. **Second-degree relatives** are grandparents, aunts, uncles, nieces, nephews, grandchildren, and half siblings
 - c. **Third-degree relatives** are great grandparents, great aunts, great uncles, great grandchildren, and first cousins
2. **Infantile- or early-childhood-onset epilepsy** are disorders in which epilepsy is the core clinical symptom. These include: Dravet syndrome, early infantile epileptic encephalopathy, generalized epilepsy with febrile seizures plus, epilepsy and intellectual disability limited to females, nocturnal frontal lobe epilepsy. Neonatal onset is before 44 weeks of gestational age, while infantile onset is before 1 year of age.
3. **Early onset Alzheimer disease** is defined as Alzheimer disease occurring in an individual under age 65
4. A **neonate** is a baby who is four weeks old or younger

5. A **minor** is any person under the age of 18.
6. **Childhood** is the period of development until the 18th birthday.

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BACKGROUND AND RATIONALE

Known Familial Variant Analysis for Epilepsy, Neurodegenerative, and Neuromuscular Disorders

Genetic Support Foundation

The Genetic Support Foundation’s Genetics 101 information on inheritance patterns says the following about testing for familial pathogenic variants:

Genetic testing for someone who may be at risk for an inherited disease is always easier if we know the specific genetic cause. Oftentimes, the best way to find the genetic cause is to start by testing someone in the family who is known or strongly suspected to have the disease. If their testing is positive, then we can say that we have found the familial pathogenic (harmful) variant. We can use this as a marker to test other members of the family to see who is also at risk.

Comprehensive Neuromuscular Disorders Panel

American Association of Neuromuscular & Electrodiagnostic Medicine (AANEM)

The American Association of Neuromuscular & Electrodiagnostic Medicine (AANEM) developed a position statement in 2016 regarding the clinical usefulness of genetic testing in the diagnosis of neuromuscular disease. “The AANEM believes that genetic testing and arriving at a specific molecular diagnosis is critical to providing high quality care to NM [neuromuscular] patients.” The same statement also remarks: “There is a role for single gene testing in cases with characteristic phenotypes, in addition to larger gene panels...”. (p. 1007)

Winder et al (2020)

Winder et al published a study in 2020 in *Neurology: Genetics* which reported results of genetic testing of 25,356 individuals who were suspected to have a neuromuscular disorder. Twenty percent of the cohort was found to have a definitive molecular diagnosis. (page 3). The authors comment: “Multigene NGS [next generation sequencing] analysis advances the interpretation of heterogeneity for any single clinical disorder and also helps refine differential diagnoses. Panels can also be useful for individuals for whom a single-gene test cannot be confidently selected because of a mild or uncharacteristic phenotype” (page 7). Regarding the utility of a larger, multi-gene panel, the authors also note that “...in 2,501 instances in which a clinician received a negative result for a single-gene or small panel test and subsequently pursued testing using a larger panel, a positive diagnostic result was obtained for 200 individuals.” (p. 7)

American Association of Neuromuscular & Electrodiagnostic Medicine (AANEM)

In 2021, the AANEM published guidelines for genetic testing of muscle and neuromuscular junction disorders. They state that the overall approach to genetic testing in inherited muscle and neuromuscular junction disorders is guided by the patient's phenotype. First and foremost, clinicians must identify those whose phenotypes suggest a myopathy that requires targeted genetic testing (ie, myotonic dystrophies, FSHD, OPMD, OPDM, DMD, and mitochondrial myopathies). In the remainder of patients, the best initial step is a gene panel encompassing a large number of genes related to myopathy and CMSs, and which also includes copy number variation analysis. (p. 264)

Comprehensive Ataxia Panel

American College of Medical Genetics and Genomics (ACMG)

ACMG (2013, p. 673) stated the following in regard to “establishing the diagnosis of hereditary ataxia:

1. Detection on neurological examination of typical clinical signs including poorly coordinated gait and finger/hand movements, dysarthria (incoordination of speech), and eye movement abnormalities such as nystagmus, abnormal saccade movements, and ophthalmoplegia.
2. Exclusion of nongenetic causes of ataxia.
3. Documentation of the hereditary nature of the disease by finding a positive family history of ataxia, identifying an ataxia-causing mutation, or recognizing a clinical phenotype characteristic of a genetic form of ataxia”

“Differential diagnosis of hereditary ataxia includes acquired, nongenetic causes of ataxia, such as alcoholism, vitamin deficiencies, multiple sclerosis, vascular disease, primary or metastatic tumors, and paraneoplastic diseases associated with occult carcinoma of the ovary, breast, or lung, and the idiopathic degenerative disease multiple system atrophy (spinal muscular atrophy). The possibility of an acquired cause of ataxia needs to be considered in each individual with ataxia because a specific treatment may be available.”

Spinal Muscular Atrophy

SMN1 Sequencing and/or Deletion/Duplication Analysis and SMN2 Deletion/Duplication Analysis

GeneReviews: Spinal Muscular Atrophy

GeneReviews is an expert-authored review of current literature on a genetic disease, and goes through a rigorous editing and peer review process before being published online. The recommendations for genetic testing for Spinal Muscular Atrophy are as follows:

Newborn Screening (NBS) for spinal muscular atrophy (SMA) is primarily based on real-time PCR that detects the common *SMN1* deletion and may also detect *SMN2* copy number on dried blood spots. Follow-up molecular genetic testing confirmation of a positive NBS result is recommended.

A symptomatic individual who has EITHER atypical findings associated with later-onset SMA OR infantile-onset SMA that has not been treated (either because NBS was not performed or because it yielded a false negative result) molecular genetic testing approaches can include single-gene testing (*SMN1*) or use of a multigene panel that includes *SMN1*, *SMN2*, and other genes of interest.

- History of motor difficulties, especially with loss of skills
- Proximal > distal muscle weakness
- Hypotonia
- Areflexia/hyporeflexia
- Tongue fasciculations
- Hand tremor

- Recurrent lower respiratory tract infections or severe bronchiolitis in the first few months of life
- Evidence of motor unit disease on electromyogram

Gene-targeted deletion/duplication analysis to determine *SMN2* copy number can be performed to provide additional information for clinical correlation if the diagnosis of SMA is confirmed on molecular genetic testing.

Epilepsy Multigene Panel

National Society of Genetic Counselors

The National Society of Genetic Counselors (NSGC) published evidence-based practice guidelines for individuals with unexplained epilepsy (Smith et al, 2022). The NSGC recommendations are as follows (page 4):

- Individuals with unexplained epilepsy should be offered genetic testing, without limitation of age.
- Multi-gene, comprehensive testing, such as exome sequencing, genome sequencing or a multigene panel as a first-tier test is strongly recommended*

Per the practice guideline, the multi-gene panel should have a minimum of 25 genes and include copy number analysis. However, specific genes to be included in such panels were not outlined in the guidelines. For this reason, the number of genes included in the multi-gene panel was not added to the clinical coverage criteria. In rare situations, an epilepsy panel of less than 25 genes may be performed, in which case alternate coverage criteria should be used (please refer to Concert Genetics medical policy “General Approach to Genetic Testing”).

Alzheimer Disease - *PSEN1*, *PSEN2*, and *APP* Sequencing and/or Deletion/Duplication Analysis or Multigene Panel

American College of Medical Genetics and Genomics (ACMG) and National Society of Genetic Counselors (NSGC)

The American College of Medical Genetics jointly with the National Society of Genetic Counselors (2011) issued joint practice guidelines, which have since been reaffirmed and reclassified as a practice resource (2019, p. 601). These guidelines state that:

- Pediatric testing for AD should not occur.
- Prenatal testing for AD is not advised if the patient intends to continue a pregnancy with a mutation.
- Testing for genes associated with early-onset autosomal dominant AD should be offered in the following situations:
 - A symptomatic individual with EOAD in the setting of a family history of dementia or the setting of an unknown family history (eg, adoption).
 - Autosomal dominant family history of dementia with one or more cases of EOAD.
 - A relative with a mutation consistent with EOAD (currently *PSEN1/2* or *APP*).

Alzheimer Disease - *APOE*, *TREM2*, and Other Variant Analysis

American Academy of Neurology

The American Academy of Neurology (2001) made the guideline recommendations that routine use of *APOE* genotyping in patients with suspected AD is not recommended (p. 1149).

American College of Medical Genetics and Genomics (ACMG)

The American College of Medical Genetics and Genomics has listed genetic testing for apolipoprotein E (*APOE*) alleles as 1 of 5 recommendations in the Choosing Wisely initiative. The recommendation is “Don’t order *APOE* genetic testing as a predictive test for Alzheimer disease.” The stated rationale is that *APOE* is a susceptibility gene for late-onset Alzheimer disease (AD), the most common cause of dementia: “The presence of an $\epsilon 4$ allele is neither necessary nor sufficient to cause AD. The relative risk conferred by the $\epsilon 4$ allele is confounded by the presence of other risk alleles, gender, environment and possibly ethnicity, and the *APOE* genotyping for AD risk prediction has limited clinical utility and poor predictive value” (p. 1).

Amyotrophic Lateral Sclerosis - Familial Amyotrophic Lateral Sclerosis (FALS) Multigene Panel

GeneReviews: Amyotrophic Lateral Sclerosis Overview

GeneReviews is an expert-authored review of current literature on a genetic disease, and goes through a rigorous editing and peer review process before being published online. The recommendations for genetic testing for Amyotrophic Lateral Sclerosis are as follows:

It is estimated that about 10%-15% of individuals with ALS have genetic ALS. Some of the genetic forms of ALS may confer particular clinical characteristics, although intra- and interfamilial variability of age at onset and disease progression is common.

The diagnosis of ALS requires characteristic clinical features and specific findings on electrodiagnostic testing, as well as exclusion of other health conditions with related manifestations. Criteria for diagnosis include:

- The presence of all of the following:
 - Evidence of lower motor neuron (LMN) degeneration by clinical, electrophysiologic, or neuropathologic examination
 - Evidence of upper motor neuron (UMN) degeneration by clinical examination
 - Progressive spread of symptoms or signs within a region or to other regions, as determined by history or examination
- Together with the absence of both of the following:
 - Electrophysiologic or pathologic evidence of other disease processes that could explain the signs of LMN and/or UMN degeneration
 - Neuroimaging evidence of other disease processes that could explain the observed clinical and electrophysiologic signs

Clinical evidence of UMN and LMN signs in the four regions of the central nervous system (i.e., brain stem, cervical, thoracic, or lumbosacral spinal cord) can be obtained through detailed or focused history and physical and neurologic examinations.

National Society of Genetic Counselors - Genetic Testing of Minors for Adult-Onset Conditions

The National Society of Genetic Counselors (NSGC) issued a statement in 2018 which encourages deferring predictive genetic testing of minors for adult-onset conditions when results will not impact childhood medical management or significantly benefit the child. Predictive testing should optimally be deferred until the individual has the capacity to weigh the associated risks, benefits, and limitations of this information, taking his/her

circumstances, preferences, and beliefs into account to preserve his/her autonomy and right to an open future.

Duchenne and Becker Muscular Dystrophy - DMD Sequencing and/or Deletion/Duplication Analysis

DMD Care Considerations Working Group

The DMD Care Considerations Working Group (2018), selected by the CDC, created guidelines for the diagnosis and management of DMD, stating the following:

“Because approximately 70% of individuals with DMD have a single-exon or multi-exon deletion or duplication in the dystrophin gene, dystrophin gene deletion and duplication testing is usually the first confirmatory test. Testing is best done by multiplex ligation dependent probe amplification (MLPA) or comparative genomic hybridisation array, since use of multiplex PCR can only identify deletions. Identification of the boundaries of a deletion or duplication mutation by MLPA or comparative genomic hybridisation array might indicate whether the mutation is predicted to preserve or disrupt the reading frame. If deletion or duplication testing is negative, genetic sequencing should be done to screen for the remaining types of mutations that are attributed to DMD (approximately 25–30%). These mutations include point mutations (nonsense or missense), small deletions, and small duplications or insertions, which can be identified using next-generation sequencing. Finally, if genetic testing does not confirm a clinical diagnosis of DMD, then a muscle biopsy sample should be tested for the presence of dystrophin protein by immunohistochemistry of tissue cryosections or by western blot of a muscle protein extract.”(p. 254)

GeneReviews: Dystrophinopathies

GeneReviews is an expert-authored review of current literature on a genetic disease, and goes through a rigorous editing and peer review process before being published online. A dystrophinopathy should be suspected in an individual with the following clinical and laboratory test findings that support the diagnosis of DMD, BMD, or DMD-associated DCM – especially when they occur in addition to a positive family history compatible with X-linked inheritance. Findings are most commonly noted in males, but females may also be affected.

Duchenne muscular dystrophy (DMD)

- Progressive symmetric muscle weakness (proximal > distal) often with calf hypertrophy
- Symptoms present before age five years
- Wheelchair dependency before age 13 years

GeneReviews notes that 100% of patients with DMD have serum creatine phosphokinase levels that are >10X normal values.

Becker muscular dystrophy (BMD):

- Progressive symmetric muscle weakness (proximal > distal) often with calf hypertrophy; weakness of quadriceps femoris in some cases the only sign
- Activity-induced cramping (present in some individuals)
- Flexion contractures of the elbows (if present, late in the course)
- Wheelchair dependency (after age 16 years); although some individuals remain ambulatory into their 30s and in rare cases into their 40s and beyond
- Preservation of neck flexor muscle strength (differentiates BMD from DMD)

GeneReviews notes that 100% of patients with BMD have serum creatine phosphokinase levels that are >5X normal values.

Facioscapulohumeral Muscular Dystrophy (FSHD) - *FSHD1* Deletion/Duplication or Haplotype Analysis and/or *SMCHD1* and *DNMT3B* Sequencing and/or Deletion Analysis or Multigene Panel

American Academy of Neurology and American Association of Neuromuscular & Electrodiagnostic Medicine

The American Academy of Neurology and American Association of Neuromuscular & Electrodiagnostic Medicine guidelines (2015) on FSHD state that genetic testing can confirm the diagnosis in many patients with FSHD type 1 and further state that if the patient tests negative for the D4Z4 contraction, testing for FSHD type 2 or other myopathies can be done. In the setting of atypical or sporadic cases, genetic confirmation is important for genetic counseling, especially with the recent discovery of 2 genetically distinct forms of FSHD. They recommend that clinicians should obtain genetic confirmation of FSHD1 in patients with atypical presentations and no first-degree relatives with genetic confirmation of the disease. (p. 360)

GeneReviews-Facioscapulohumeral Muscular Dystrophy

GeneReviews is an expert-authored review of current literature on a genetic disease, and goes through a rigorous editing and peer review process before being published online.

Facioscapulohumeral muscular dystrophy (FSHD) should be suspected in individuals with the following:

- Weakness that predominantly involves the facial, scapular stabilizer, or foot dorsiflexor muscles without associated ocular or bulbar muscle weakness. Weakness is often asymmetric.
- Progression of weakness after pregnancy
- Prior diagnosis with inflammatory myopathy that was refractory to immunosuppression Family history of FSHD

Friedreich's Ataxia - FXN Repeat Analysis and/or Sequencing Analysis

American College of Medical Genetics

The American College of Medical Genetics (ACMG, 2013) states the following regarding testing for hereditary ataxias:

“Establishing the diagnosis of hereditary ataxia requires:

- Detection on neurological examination of typical clinical signs including poorly coordinated gait and finger/hand movements, dysarthria (incoordination of speech), and eye movement abnormalities such as nystagmus, abnormal saccade movements, and ophthalmoplegia.
- Exclusion of nongenetic causes of ataxia
- Documentation of the hereditary nature of the disease by finding a positive family history of ataxia, identifying an ataxia-causing mutation, or recognizing a clinical phenotype characteristic of a genetic form of ataxia.” (p. 673)

“Differential diagnosis of hereditary ataxia includes acquired, nongenetic causes of ataxia, such as alcoholism, vitamin deficiencies, multiple sclerosis, vascular disease, primary or metastatic tumors, and paraneoplastic diseases associated with occult carcinoma of the ovary, breast, or lung, and the idiopathic degenerative disease multiple system atrophy (spinal muscular atrophy). The possibility of an acquired cause of ataxia needs to be considered in each individual with ataxia because a specific treatment may be available.” (p. 673)

GeneReviews: Friedreich Ataxia

GeneReviews is an expert-authored review of current literature on a genetic disease, and goes through a rigorous editing and peer review process before being published online. The recommendations for genetic testing According to GeneReviews (Bidichandani and Delatycki, 2017) in the Diagnosis Suggestive Findings section, Friedreich ataxia (FRDA) should be suspected in individuals with a combination of the following clinical features and family history for Friedreich's Ataxia (Bidichandani and Delatycki, 2017) are as follows:

- Neurologic findings, typically with onset before age 25 years*. These include:
 - progressive ataxia of gait and limbs , dysarthria, decrease in/loss of position sense and/or vibration sense in lower limbs, pyramidal weakness of the legs, extensor plantar responses *Note: In atypical cases, onset may be delayed
- Musculoskeletal features include muscle weakness, scoliosis, pes cavus
- Hypertrophic non-obstructive cardiomyopathy
- Endocrinologic features include glucose intolerance, diabetes mellitus 2
- Optic atrophy and/or deafness
- Family history consistent with autosomal recessive inheritance

Friedreich ataxia (FRDA) should be suspected in individuals with a combination of the following clinical features and family history:

- Neurologic findings, typically with onset before age 25 years*
 - Progressive ataxia of gait and limbs
 - Dysarthria
 - Decrease in/loss of position sense and/or vibration sense in lower limbs ○
 - Pyramidal weakness of the legs, extensor plantar responses

*Note: In atypical cases, onset may be delayed

- Musculoskeletal features
 - Muscle weakness
 - Scoliosis
 - Pes cavus
- Hypertrophic non-obstructive cardiomyopathy
- Endocrinologic features
 - Glucose intolerance
 - Diabetes mellitus
- Optic atrophy and/or deafness

- Family history consistent with autosomal recessive inheritance Note: Absence of a family history of autosomal recessive inheritance does not preclude the diagnosis.

Huntington Disease - *HTT* Repeat Analysis

GeneReviews-Huntington Disease

GeneReviews is an expert-authored review of current literature on a genetic disease, and goes through a rigorous editing and peer review process before being published online. The recommendations for genetic testing for Huntington disease are as follows:

Huntington disease (HD) should be suspected in individuals with any of the following:

- Progressive motor disability featuring chorea. Voluntary movement may also be affected.
- Mental disturbances including cognitive decline, changes in personality, and/or depression
- Family history consistent with autosomal dominant inheritance

Testing is performed by targeted analysis of CAG repeats within the *HTT* gene.

At-risk asymptomatic adult family members may seek testing in order to make personal decisions regarding reproduction, financial matters, and career planning. For asymptomatic minors at risk for adult-onset conditions for which early treatment would have no beneficial effect on disease morbidity and mortality, predictive genetic testing is considered inappropriate, primarily because it negates the autonomy of the child with no compelling benefit. In a family with an established diagnosis of HD, it is appropriate to consider testing of symptomatic individuals regardless of age.

National Society of Genetic Counselors - Genetic Testing of Minors for Adult-Onset Conditions

The National Society of Genetic Counselors (NSGC) issued a statement in 2018 which encourages deferring predictive genetic testing of minors for adult-onset conditions when results will not impact childhood medical management or significantly benefit the child. Predictive testing should optimally be deferred until the individual has the capacity to weigh the associated risks, benefits, and limitations of this information, taking his/her circumstances, preferences, and beliefs into account to preserve his/her autonomy and right to an open future.

Inherited Peripheral Neuropathy (Charcot-Marie-Tooth and Hereditary Neuropathy with Liability to Pressure Palsies) - *PMP22* Sequencing and/or Deletion/Duplication Analysis or Multigene Panel

GeneReviews is an expert-authored review of current literature on a genetic disease, and goes through a rigorous editing and peer review process before being published online.

GeneReviews: Charcot-Marie-Tooth Hereditary Neuropathy Overview

Individuals with CMT [Charcot-Marie-Tooth] manifest symmetric, slowly progressive distal motor neuropathy of the arms and legs usually beginning in the first to third decade and resulting in weakness and atrophy of the muscles in the feet and/or hands. The affected individual typically has distal muscle weakness and atrophy, weak ankle dorsiflexion, depressed tendon reflexes, and *pes cavus* foot deformity (i.e., high-arched feet).

Table 4 lists the most commonly involved genes in individuals with CMT: *GDAP1*, *GJB1*, *HINT1*, *MFN2*, *MPZ*, *PMP22*, *SH3TC2*, *SORD*.

GeneReviews: Hereditary Neuropathy with Liability to Pressure Palsies

Hereditary neuropathy with liability to pressure palsies (HNPP) should be suspected in individuals with the following clinical findings, electrophysiologic studies, imaging studies, and family history.

Typical clinical findings:

- Recurrent acute focal sensory and motor neuropathies mainly at entrapment sites
- Painless nerve palsy after minor trauma or compression
- Evidence on physical examination of previous nerve palsy such as focal weakness, atrophy, or sensory loss

Complete spontaneous recovery from neuropathies (in 50% of occurrences) within weeks

Limb-Girdle Muscular Dystrophies (LGMD)

Limb Girdle Muscular Dystrophy Multigene Panel

American Academy of Neurology and American Association of Neuromuscular and Electrodiagnostic Medicine

The American Academy of Neurology and the American Association of Neuromuscular and Electrodiagnostic Medicine (2014) issued evidenced-based guidelines for the diagnosis and treatment of limb-girdle and distal dystrophies. These guidelines included a systematic review which identified common features of limb-girdle muscular dystrophy (LGMD) which included slowly progressive symmetrical weakness (presenting at highly variable ages). The guidelines also note that although limb-girdle pattern of weakness affecting proximal muscles of the arms and legs is the most common presentation, other patterns, including scapulooperoneal weakness and distal weakness, are not rare. (p. 1454) These guidelines note that “serum CK levels vary widely between patients with the same disorder, ranging from normal to greater than 10 times above normal levels, and can be as much as 100 times normal in some cases.” (p. 1455

Myotonic Dystrophy

DMPK and/or CNBP (ZNF9) Repeat Analysis

Myotonic Dystrophy Foundation

More than 65 leading myotonic dystrophy (DM) clinicians in Western Europe, the UK, Canada and the US joined in a process started in Spring 2015 and concluded in Spring 2017 to create the Consensus-based Care Recommendations for Adults with Myotonic Dystrophy Type 1, which included this recommendation for genetic testing:

“DM1 via molecular genetic testing as the first line of investigation for any patient suspected of having DM1. Muscle biopsy should no longer be performed as a diagnostic test when there is clear clinical suspicion of DM1. Patients with more than 50 CTG repeats in the 3’ untranslated region of the DMPK gene on chromosome 19 are considered to have DM1. False-negative genetic testing results can occur, even in a family with an established DM1 diagnosis; expert referral is recommended”. (p. 32)

Fifteen leading myotonic dystrophy (DM) clinicians from western Europe, Canada and the United States have created the Consensus-based Care Recommendations for Adults with Myotonic Dystrophy Type 2, which included this recommendation for genetic testing:

“DM2 via DNA-based genetic testing as the first line of investigation for any patient suspected of having DM2. When there is clear clinical suspicion of DM2, muscle biopsy should no longer be performed as a diagnostic test. Patients with more than 75 CCTG in intron 1 of the CNBP gene in chromosome 3q21.3 can be considered to have DM2. Patients with repeats in the 28-75 range gray zone are unclear. DM2 repeat sizing in tissues other than blood and/or segregation studies in the family may be valuable in addressing potential pathogenicity. False-negative genetic testing results can occur, even in a family with an established DM2 diagnosis. Expert referral is recommended.” (page 22).

American College of Medical Genetics

ACMG published technical standards and guidelines for myotonic dystrophy type 1 in 2021. In it, they state: “Indications for genetic testing: This test is often used for symptomatic confirmatory diagnostic testing and predictive testing, after the identification of the mutation in an affected family member. The test is also useful for prenatal diagnosis for at-risk pregnancies after ultrasound evidence of fetal hypotonia, reduced fetal movements, positional abnormalities, and/or polyhydramnios. The testing is also extremely helpful in identifying individuals who are asymptomatic or exhibit equivocal symptoms, such as cataracts. For counseling purposes, it becomes important to identify which side of the family the mutation is segregating. When comparing unrelated affected individuals with small to moderate differences in repeat sizes, it is generally difficult to accurately predict the severity of the disease in each case. It is strongly recommended that genetic counseling be offered to not only the affected patient but also to other at-risk interested family members” (p. 553).

GeneReviews-Myotonic Dystrophy Type 1 and Myotonic Dystrophy Type 2

GeneReviews is an expert-authored review of current literature on a genetic disease, and goes through a rigorous editing and peer review process before being published online. They suggest that Myotonic dystrophy type 1 (DM1) should be suspected in adults with the following:

- Muscle weakness, especially of the distal leg, hand, neck, and face
- Myotonia (sustained muscle contraction), which often manifests as the inability to quickly release a hand grip (grip myotonia)
- Posterior subcapsular cataracts detectable as red and green iridescent opacities on slit lamp examination

DM1 should be suspected in neonates with some combination of the following:

- Hypotonia
- Facial muscle weakness
- Generalized weakness
- Positional malformations including clubfoot
- Respiratory insufficiency

DM2 should be suspected in individuals with the following findings:

- Muscle weakness
- Myotonia (sustained muscle contraction) that can manifest as:
 - grip myotonia (the inability to release a tightened fist quickly) occurring as early as the first decade of life
 - percussion myotonia (sustained contraction after tapping a muscle with a reflex hammer)
 - leg myotonia, especially while climbing a staircase or trying to run fast
 - electrical myotonia (repetitive spontaneous discharges observed on EMG).
 - Note: The myotonia in individuals with DM2 is not always detectable by EMG and may require an extensive EMG examination of several muscle groups including proximal and paraspinal muscles
- Posterior subcapsular cataracts detectable as nonspecific vacuoles and opacities on direct ophthalmoscopy or as pathognomonic posterior subcapsular red and green iridescent opacities on slit lamp examination
- Cardiac conduction defects or progressive cardiomyopathy
- Insulin insensitivity
- Hypogammaglobulinemia

“For asymptomatic minors at risk for adult-onset conditions for which early treatment would have no beneficial effect on disease morbidity and mortality, predictive genetic testing is considered inappropriate, primarily because it negates the autonomy of the child with no compelling benefit. Further, concern exists regarding the potential adverse effects that such information may have on family dynamics, the risk of discrimination and stigmatization in the future, and the anxiety that such information may cause.”

Hereditary Dystonia Multigene Panel

GeneReviews-Hereditary Dystonia Overview

GeneReviews is an expert-authored review of current literature on a genetic disease, and

goes through a rigorous editing and peer review process before being published online. The recommended testing for hereditary dystonia is as follows:

Per GeneReviews “Hereditary Dystonia Overview” (last update: June 22, 2017), dystonia is defined as “a movement disorder characterized by sustained or intermittent muscle contractions causing abnormal, often repetitive movements and/or postures. Dystonic movements are typically patterned and twisting, and may be associated with tremor. Dystonia is often initiated or worsened by voluntary action and associated with overflow muscle activation. Most forms of dystonia tend to worsen initially.” Multiple genes have been implicated in hereditary dystonia, representing a variety of inheritance patterns such as autosomal dominant, autosomal recessive, mitochondrial, and X-linked inheritance.

Parkinson Disease - *LRRK2* Sequencing and/or Deletion/Duplication Analysis and Parkinson Disease Multigene Panel

GeneReviews - Parkinson Disease

GeneReviews is an expert-authored review of current literature on a genetic disease, and goes through a rigorous editing and peer review process before being published online.

Per the Parkinson Disease GeneReviews, establishing a specific genetic cause of Parkinson disease:

- Can aid in discussions of causation, recurrence risks, and research eligibility.
- May provide some information about phenotype including prognosis of a particular monogenic cause of Parkinson disease.
- Usually involves evaluation of medical and family histories, and molecular genetic testing. Physical examination may be less helpful in suggesting a specific genetic cause because of the overlap of clinical features.

Usefulness of Genetic Testing in PD and PD Trials: A Balanced Review (Gasser, etc)

Per this review of the clinical utility of genetic testing in Parkinson Disease, “Overall, *LRRK2* mutations account for 5-15% of dominant familial, and 1-3% of sporadic PD cases”. (p. 211)

Hereditary Spastic Paraplegia Multigene Panel

GeneReviews-Hereditary Spastic Paraplegia Overview

GeneReviews is an expert-authored review of current literature on a genetic disease, and goes through a rigorous editing and peer review process before being published online. The predominant signs and symptoms of hereditary spastic paraplegia (HSP) are lower-extremity weakness and spasticity.

Neurologic examination. Individuals with HSP demonstrate the following:

- Bilateral lower-extremity spasticity (especially in hamstrings, quadriceps, adductors, and gastrocnemius-soleus muscles)
- Weakness (especially in the iliopsoas, hamstring, and tibialis anterior muscles)
- Spasticity and weakness are variable. Some individuals have spasticity and no demonstrable weakness, whereas others have spasticity and weakness in approximately the same proportions.
- Lower-extremity hyperreflexia and extensor plantar responses
- Impaired vibration sensation in the distal lower extremities

They suggest a multi-gene panel as the genetic testing strategy most likely to identify the genetic cause of the condition at the most reasonable cost while limiting identification of variants of [uncertain significance](#) and pathogenic variants in genes that do not explain the underlying [phenotype](#).

Congenital Myasthenic Syndrome - Congenital Myasthenic Syndromes Multigene Panel

GeneReviews-Congenital Myasthenic Syndromes Overview

GeneReviews is an expert-authored review of current literature on a genetic disease, and goes through a rigorous editing and peer review process before being published online.

An individual with a congenital myasthenic syndrome (CMS) typically presents with a history of fatigable weakness involving ocular, bulbar, and limb muscles with onset at or shortly after birth or in early childhood, usually in the first two years.

EMG testing is helpful to establish a defect in neuromuscular transmission.

- In the majority of CMS subtypes, a decremental EMG response of the compound muscle action potential (CMAP) can be evoked on low-frequency (2-3 Hz) stimulation.
 - In some subtypes of CMS, a positive response to acetylcholinesterase (AChE) inhibitors may occur. Response to AChE inhibitors is usually assessed by a controlled/supervised trial of oral AChE inhibitors and monitoring of fatigable muscle weakness and obvious clinical symptoms (e.g., ptosis, bulbar weakness). Of note, immunosuppressive therapy does not improve clinical symptoms in CMS, whereas it does in myasthenia gravis.

Myotonia Congenita - *CLCN1* Sequencing and/or Deletion/Duplication Analysis

GeneReviews-Myotonia Congenita

GeneReviews is an expert-authored review of current literature on a genetic disease, and goes through a rigorous editing and peer review process before being published online.

Myotonia congenita should be suspected in individuals with the following clinical and laboratory findings.

Clinical findings and medical history

- Episodes of muscle stiffness (myotonia) or cramps beginning in early childhood
- Alleviation of stiffness by brief exercise (known as the "warm-up" effect)
- Myotonic contraction elicited by percussion of muscles

Laboratory findings

- Serum creatine kinase concentration is usually elevated (less than or equal to 3-4x the upper limits of normal).
- Electromyography performed with needle electrodes discloses characteristic showers of spontaneous electrical activity (myotonic bursts).

Hypokalemic Periodic Paralysis - *CACNA1S* and *SCN4A* Sequencing and/or Deletion/Duplication Analysis

GeneReviews - Hypokalemic Periodic Paralysis

GeneReviews is an expert-authored review of current literature on a genetic disease, and goes through a rigorous editing and peer review process before being published online.

The diagnosis of hypoPP is established in a proband who meets the consensus diagnostic criteria for primary hypokalemic periodic paralysis:

- Two or more attacks of muscle weakness with documented serum potassium less than 3.5 mEq/L
OR
- One attack of muscle weakness in the proband and one attack of weakness in one relative with documented serum potassium less than 3.5 mEq/L
OR
- Three or more of the following six clinical/laboratory features:
 - Onset in the first or second decade
 - Duration of attack (muscle weakness involving at least 1 limbs) longer than two hours
 - The presence of triggers (previous carbohydrate rich meal, symptom onset during rest after exercise, stress)
 - Improvement in symptoms with potassium intake
 - A family history of the condition or genetically confirmed skeletal calcium or sodium channel mutation
 - Positive long exercise test AND
- Exclusion of other causes of hypokalemia (renal, adrenal, thyroid dysfunction; renal tubular acidosis; diuretic and laxative abuse)

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