Concert Genetic Testing: ~~Cardiac Disorders~~Cardiovascular

Reference Number: LA.CP.CG.02
Date of Last Revision ~~01/25~~03/26
Revision Log

Coding implications

See Important Reminder at the end of this policy for important regulatory and legal information.

OVERVIEW

~~Arrhythmias and cardiomyopathies can be multifactorial, hereditary, or caused by a known environmental factor, such as a drug. Hereditary arrhythmias and cardiomyopathies are primarily diagnosed clinically, and symptoms can be variable even within the same family. Most hereditary cardiac conditions are associated with multiple genes and while genetic test results may not guide medical management for those with a clinical diagnosis, identification of a pathogenic or likely pathogenic variant can allow for cascade testing of asymptomatic family members who might benefit from life-saving treatment.~~ This policy addresses the use of tests for the diagnosis and management of inherited and sporadic cardiovascular conditions, including structural or electrical defects, disorders of the blood vessels, cholesterol disorders, and lipid profiling. Genetic evaluation for other types of EDS are addressed within this policy.

Due to the complexity of genetic testing for hereditary cardiomyopathies and arrhythmias and the potential for misinterpretation of results, the decision to test and the interpretation of test results should be performed by, or in consultation with, an expert in the area of cardiac genetics. Pre-test and post-test genetic counseling that facilitates informed decision-making, addresses the possibility of secondary or incidental findings, and a plan for returning results before testing occurs is strongly advised.

~~Congenital heart defects (CHDs) are structural heart defects that are present at birth. CHDs affect 1-1.2% of live births and can be caused by genetic and environmental factors. Determining an underlying genetic cause for CHD can aid in assessing recurrence risks for at-risk family members, evaluating for associated extracardiac involvement, assessing for neurodevelopmental delays, and providing a more accurate prognosis for the patient.~~

~~Gene expression profiles and cell-free DNA testing are emerging as additional tools to use following a heart transplant to assess for risk and/or presence of organ rejection. While some of these testing options involve an invasive procedure to collect a tissue sample, others are performed using a peripheral blood sample.~~

~~This document addresses genetic testing for cardiac disorders, focusing on cardiomyopathy, arrhythmia, congenital heart defects, cholesterol disorders, and assessment of organ rejection following a heart transplant.~~

For additional information see the Rationale sections.

POLICY REFERENCE TABLE

Coding Implications

This clinical policy references Current Procedural Terminology (CPT®). CPT is a registered trademark of the American Medical Association. All CPT codes and descriptions are copyrighted ~~2023~~2024, American Medical Association. All rights reserved. CPT codes and CPT descriptions are from the current manuals and those included herein are not intended to be all-inclusive and are included for informational purposes only. Codes referenced in this clinical policy are for informational purposes only and may not support medical necessity. Inclusion or exclusion of any codes does not guarantee coverage. Providers should reference the most up-to-date sources of professional coding guidance prior to the submission of claims for reimbursement of covered services.

> **NOTE: Coverage is subject to each requested code's inclusion on the corresponding LDH fee schedule. Non-covered codes are denoted (*) and are reviewed for Medical Necessity for members under 21 years of age on a per case basis. The non-covered codes will only be denoted in the table below and not throughout the policy. Please only reference the policy reference table for covered and non-covered codes.**

The tests, ~~associated laboratories,~~ CPT codes, and ICD codes ~~contained within~~referenced in this ~~document serve only as examples to help users navigate claims and corresponding criteria; as such, they~~policy are not comprehensive, and ~~are~~their inclusion does not represent a guarantee of coverage or non-coverage. Please see the Concert Platform for ~~a comprehensive list of~~additional registered tests.

~~Criteria Sections~~ CRITERIA SECTIONS	~~Example Tests (Labs)~~EXAMPLE TESTS (LABS)	~~Common CPT Codes~~COMMON BILLING CODES	~~Common ICD Codes~~REF	~~Ref~~
~~Comprehensive Cardiomyopathy Panels~~**Comprehensive Cardiomyopathy and/or Arrhythmia Multigene Panels**	~~Cardiomyopathy Panel (GeneDx)~~	~~81439*~~	~~I42.0, I42.1, I42.2, I42.5, I42.8, I42.9,~~	~~1, 5~~

			~~Z13.71~~ ~~,~~ ~~Z82.41~~ ~~,~~ ~~Z82.49~~ ~~,~~ ~~Z84.81~~ ~~,~~ ~~Z84.89~~
Comprehensive Cardiomyopathy Panels	Cardiomyopathy ~~Comprehensive Panels (Invitae~~Panel (GeneDx)	81439*, I42.0, I42.1, I42.2, I42.5, I42.8, I42.9, Z13.71, Z82.41, Z82.49, Z84.81, Z84.89	1, 5
	Cardiomyopathy Comprehensive Panels (Invitae)~~CMNext (Ambry Genetics)~~		
~~Comprehensive Arrhythmia Panels~~	CMNext (Ambry Genetics)~~Arrhythmia Panel (GeneDx)~~	~~81~~	~~I45.81, I49.8, Z13.71 , Z82.41 , Z82.49 , Z84.81 , Z84.89~~
Comprehensive Arrhythmia Panels	Arrhythmia Panel (GeneDx)~~RhythmNext (Ambry Genetics)~~	81413*, 81414*, 0237U*,	11

		I45.81, I49.8, Z13.71, Z82.41, Z82.49, Z84.81, Z84.89		
	RhythmNext (Ambry Genetics)~~Arrhythmia Comprehensive Panel (Invitae)~~			
	Arrhythmia Comprehensive Panel (Invitae)~~Genomic Unity Cardiac Ion Channelopathies Analysis (Variantyx Inc)~~	~~0237U *~~		
~~Comprehensive Arrhythmia & Cardiomyopathy (Sudden Cardiac or Unexplained Death) Panels~~	Genomic Unity Cardiac Ion Channelopathies Analysis - 0237U (Variantyx Inc)~~Arrhythmia and Cardiomyopathy Comprehensive Panel (Invitae)~~		~~I42.0, I42.1, I42.2, I42.5, I45.81, I49.8, I42.9, Z13.71, Z82.41, Z82.49, Z84.81, Z84.89~~	~~5~~
Comprehensive Arrhythmia and Cardiomyopathy (Sudden Cardiac or Unexplained Death) Panels	Arrhythmia and Cardiomyopathy Comprehensive Panel (Invitae)~~CardioNext~~	81413*, 81414*, 81439*, I42.0,	5	

	~~(Ambry Genetics)~~	I42.1, I42.2, I42.5, I45.81, I49.8, I42.9, Z13.71, Z82.41, Z82.49, Z84.81, Z84.89		
	CardioNext (Ambry Genetics)~~Cardiomyopathy and Arrhythmia Panel, Sequencing and Deletion/Duplication (ARUP Laboratories)~~			
~~**Hypertrophic Cardiomyopathy (HCM)**~~	Cardiomyopathy and Arrhythmia Panel, Sequencing and Deletion/Duplication (ARUP Laboratories)			
~~Hypertrophic Cardiomyopathy Panels~~**Hypertrophic Cardiomyopathy (HCM)**	~~Hypertrophic Cardiomyopathy Panel (Invitae)~~	~~81~~	~~I42.1, I42.2, I42.9, Z13.71, Z82.41, Z82.49, Z84.81, Z84.89~~	~~2, 7~~
Hypertrophic Cardiomyopathy Panels	Hypertrophic Cardiomyopathy Panel (Invitae)~~HCMNext (Ambry Genetics)~~	81439*, S3865*, I42.1, I42.2, I42.9,	2, 7	

		Z13.71, Z82.41, Z82.49, Z84.81, Z84.89		
	HCMNext (Ambry Genetics)~~Hypertrophic Cardiomyopathy (HCM) Panel (GeneDx)~~			
~~Dilated Cardiomyopathy (DCM)~~	Hypertrophic Cardiomyopathy (HCM) Panel (GeneDx)			
~~Dilated Cardiomyopathy Panels~~**Dilated Cardiomyopathy (DCM)**	~~Dilated Cardiomyopathy Panel (GeneDx)~~	~~81439*~~	~~I42.0, I42.9, Z13.71, Z82.41, Z82.49, Z84.81, Z84.89~~	~~1, 11~~
Dilated Cardiomyopathy Panels	Dilated Cardiomyopathy Panel (PreventionGenetics, part of Exact Sciences)	81439*, I42.0, I42.9, Z13.71, Z82.41, Z82.49, Z84.81, Z84.89	1, 10, 11	
	DCMNext (Ambry Genetics)			
~~Arrhythmogenic Cardiomyopathy~~Arrhythmogenic Cardiomyopathy				

~~Arrhythmogenic Cardiomyopathy Panels~~Arrhythmogenic Cardiomyopathy Panels	Arrhythmogenic Right Ventricular Cardiomyopathy Panel (GeneDx)	~~81439*~~	81439*, I42.8, I42.9, Z82.41, Z82.49, Z84.81, Z84.89	~~16~~15
	Arrhythmogenic Cardiomyopathy Panel (Invitae)			
~~Restrictive Cardiomyopathy (RCM)~~Restrictive Cardiomyopathy (RCM)				
~~Restrictive Cardiomyopathy Panels~~Restrictive Cardiomyopathy Panels	Restrictive Cardiomyopathy (RCM) Panel (Cincinnati Children's Hospital Medical Center - Molecular Genetics and Cytogenetics Laboratories)	~~81439*~~	81439*, I42.5, I42.8, I42.9, Z82.41, Z82.49	4
~~Long QT Syndrome (LQTS)~~Long QT Syndrome (LQTS)				
~~Long QT Syndrome Panels~~Long QT Syndrome Panels	Long QT Syndrome Panel (Invitae)	~~81403*, 81406*, 81407*, 81413*, 81414*, 81479~~	81403*, 81406*, 81407*, 81413*, 81414*, 81479*, I45.81, Z13.71,	3, ~~10, 13~~9, 11

	LQTS Panel (GeneDx)		Z82.41, Z82.49, Z84.81, Z84.89	
~~Short QT Syndrome (SQTS)~~Short QT Syndrome (SQTS)				
~~Short QT Syndrome Panels~~Short QT Syndrome Panels	Short QT Syndrome Panel (Invitae)	~~81403*, 81406*, 81413*, 81414*, 81479~~	81403*, 81406*, 81413*, 81414*, 81479, Z13.71, Z82.41, Z82.49, Z84.81, Z84.89	11, 12~~, 13~~
	Short QT Syndrome Panel (PreventionGenetics, part of Exact Sciences)			
~~Brugada Syndrome (BrS)~~Brugada Syndrome (BrS)				

~~Brugada Syndrome Panels or *SCN5A* Variant Analysis~~Brugada Syndrome Panels or *SCN5A* Variant Analysis	Brugada Panel (GeneDx)	~~81404*, 81406*, 81407*, 81413*, 81414*, 81479~~	81404*, 81406*, 81407*, 81413*, 81414*, 81479, S3861*, I49.8, Z13.71, Z82.41, Z82.49, Z84.81, Z84.89	~~12, 14~~11, 13
	Brugada Syndrome Panel (Invitae)			
	Brugada Panel (GeneDx)			
Catecholaminergic Polymorphic Ventricular Tachycardia (CPVT)				
Catecholaminergic Polymorphic Ventricular Tachycardia Panels	Catecholaminergic Polymorphic Tachycardia Panel (Invitae)		~~81407*, S3861*~~81403*, 81405*, 81408*, 81413*, 81414*, 81479, Z13.71, Z82.41, Z82.49, Z84.81, Z84.89	14
	~~Brugada Panel (GeneDx)~~CPVTNext (Ambry Genetics)			
~~Catecholaminergic Polymorphic Ventricular Tachycardia (CPVT)~~Familial Hypercholesterolemia (FH)				
Familial Hypercholesterolemia (FH) Panels	~~Catecholaminergic Polymorphic Tachycardia~~Familial Hypercholesterolemia (FH) Panel (~~Invitae~~GeneDx)	~~81403*,~~ 81401*, 81405~~**~~, ~~81408*, 81413*,~~	~~Z13.71, Z82.41, Z82.49, Z84.81, Z84.898~~, 16	~~15~~

	~~CPVTNext (Ambry Genetics)~~ Invitae Familial Hypercholesterolemia Panel (Invitae)	~~81414*,~~ 81406*, 81407*, 81479, E78, E78.01		
~~Familial Hypercholesterolemia (FH) Panels~~**Congenital Heart Malformations**	~~Familial Hypercholesterolemia (FH) Panel (GeneDx)~~	~~81401*, 81405*, 81406*, 81407*, 81479~~	~~E78, E78.01~~	~~9, 18~~
Congenital Heart Malformation Panels	Nonsyndromic Congenital Heart Disease Panel (PreventionGenetics, part of Exact Sciences)~~Invitae Familial Hypercholesterolemia Panel (Invitae)~~	81405*, 81406*, 81407*, 81408*, 81479, Q20, Q21, Q22, Q23, Q24	6	
	Congenital Heart Disease Panel (Invitae)			
~~**Congenital Heart Malformations**~~**Familial Thoracic Aortic Aneurysm and Dissection (TAAD)**				
Familial Thoracic Aortic Aneurysm and Dissection (TAAD) Multigene Panel	Thoracic Aortic Aneurysm Panel (Cincinnati Children's Hospital Medical Center- Molecular Genetics and Cytogenetics Laboratories)	81405**, 81406**, ~~81407*,~~ 81408**, 81410*,	~~Q20~~, ~~Q21~~, ~~Q22~~	~~6~~

	TAAD Panel Next Generation Sequencing (DDC Clinic Laboratory)	81411*, 81479, I71.00-I71.9, Q87.5	~~,~~ ~~C~~ ~~2~~ ~~3~~ ~~,~~ ~~C~~ ~~2~~ ~~4~~ 17, 18, 19	
	TAADNext (Ambry Genetics)			
	~~AlloMap (CareDx)~~Marfan syndrome, Loeys-Dietz syndrome, Familial thoracic aortic aneurysms & dissections, and Related disorders NGS Panel - Comprehensive (CTGT)		~~Z94.1, Z48.21~~	~~8~~
	Marfan Syndrome and Thoracic Aortic Aneurysm and Dissection NGS Panel (Sequencing & Deletion/Duplication) (Fulgent Genetics)			
	~~Molecular Microscope MMDX - Heart (Kashi Clinical Laboratories)~~Marfan/TAAD Panel (GeneDx)		~~Z94.1, Z48.21~~	~~8~~
	Aortopathy Comprehensive Panel			

	(Invitae)			
~~Donor-Derived Cell-Free DNA for Heart Transplant Rejection~~**Hereditary Hemorrhagic Telangiectasia (HHT)**	~~AlloSure (CareDx)~~	~~81479~~	~~Z94.1, Z48.21~~	~~17~~
Hereditary Hemorrhagic Telangiectasia Multigene Panel	~~Prospera (Natera)~~HHTNext (Ambry Genetics)	~~0493U*~~ 81405*, 81406*, 81479, R04.0, Q27.30-Q27.39	20, 21	
	~~Viracor TRAC Heart dd-cfDNA (Eurofins)~~Hereditary Hemorrhagic Telangiectasia (HHT) Panel (Blueprint Genetics)			

~~OTHER~~ RELATED POLICIES

This policy document provides criteria for ~~genetic~~ testing ~~for cardiovascular~~related to cardiac disorders. Please refer to:

- ~~***Specialty Testing: Multisystem*** ***Genetic Testing: Aortopathies and Connective Tissue Disorders***~~***Conditions*** for criteria related to ~~other genetic disorders affecting the heart and connective tissue.~~
- ~~***Genetic Testing: Multisystem Inherited Disorders, Intellectual Disability, and Developmental Delay*** for criteria related to genetic~~ diagnostic tests for genetic disorders that affect multiple organ systems~~.~~ (e.g. whole exome and genome sequencing, chromosomal microarray, and multigene panels for broad phenotypes).
- ~~***Genetic***~~***Reproductive Testing: Prenatal Diagnosis*** ~~***(via amniocentesis, CVS, or PUBS) and Pregnancy Loss***~~ for ~~coverage~~criteria related to ~~prenatal and~~fetal diagnostic testing for genetic disorders during pregnancy and following a pregnancy loss~~ diagnostic genetic testing~~.
- ~~***Genetic***~~***Reproductive Testing:*** ~~***Preimplantation Genetic Testing***~~***Fertility*** for criteria related to ~~genetic testing of embryos prior to in vitro fertilization~~preimplantation diagnosis.
- ~~***Genetic Testing:*** ~~***General Approach to Genetic and Molecular***~~***Laboratory Testing*** for criteria related to ~~cardiac disorders~~cardiovascular conditions, including known familial

variant testing, that is not specifically discussed in this or another non-general policy~~, including known familial variant testing.~~.

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CRITERIA

It is the policy of Louisiana Healthcare Connections that the specific genetic testing noted below is **medically necessary** when meeting the related criteria:

COMPREHENSIVE CARDIOMYOPATHY AND/OR ARRHYTHMIA MULTIGENE PANELS

Comprehensive Cardiomyopathy Panels

I. Comprehensive cardiomyopathy panels ~~(81439)~~ are considered **medically necessary** when:

A. The member/enrollee has a diagnosis of cardiomyopathy, **OR**

~~A. The member has a first-degree relative with sudden cardiac death (SCD) or sudden unexplained death (SUD), **AND**~~

B. The member/enrollee has a first-degree relative with sudden cardiac death (SCD) or sudden unexplained death (SUD), **AND**

1. This relative's autopsy revealed unspecified cardiomyopathy (e.g., cardiomegaly or cardiomyopathy), **OR**

2. This relative's autopsy revealed an anatomically normal heart, **AND**

a) The autopsy did not reveal a cause of death.

II. ~~Comprehensive~~Current evidence does not support comprehensive cardiomyopathy panels ~~(81439) are considered **investigational**~~ for all other indications.

NOTE: Multigene panels that are targeted to the cardiomyopathy phenotype observed are recommended by professional guidelines

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~~COMPREHENSIVE ARRHYTHMIA PANELS~~

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Comprehensive Arrhythmia Panels

I. Comprehensive arrhythmia panels ~~(0237U, 81413, 81414)~~ are considered **medically necessary** when:

A. The member/enrollee meets one of the following:

~~1. The member has a first-degree relative with sudden cardiac death (SCD) or sudden unexplained death (SUD) before age 50 years, **OR**~~

1. The member/enrollee has a first-degree relative with sudden cardiac death (SCD) or sudden unexplained death (SUD) before age 50 years, **OR**

~~1.~~2. The member/enrollee has a ~~first-degree relative~~first-degree relative with ~~sudden cardiac death (SCD)~~sudden cardiac death (SCD) at age 50 years or older, **AND**

a) The deceased individual had family history of premature ~~SCD~~SCD, **OR**

b) The deceased individual's death is suspicious for genetic heart disease, **OR**

B. The member/enrollee has unexplained ~~sudden cardiac arrest~~sudden cardiac arrest, **AND**

1. Clinical tests were non-diagnostic for reversible, ischemic, or structural causes (e.g., ECG, cardiac stress tests, echocardiogram, intravenous pharmacologic provocation testing).

II. ~~Comprehensive~~ Current evidence does not support comprehensive arrhythmia panels ~~(0237U, 81413, 81414) are considered **investigational**~~ for all other indications.

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~~COMPREHENSIVE ARRHYTHMIA AND CARDIOMYOPATHY (SUDDEN CARDIAC OR UNEXPLAINED DEATH) PANELS~~

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Comprehensive ~~panels including genes for both cardiomyopathies~~Arrhythmia and Cardiomyopathy (Sudden Cardiac or Unexplained Death) Panels

I. Comprehensive panels including genes for both cardiomyopathies and arrhythmias ~~(81413, 81414, 81439)~~ are considered **medically necessary** when:

~~A.~~ The member ~~meets clinical criteria for Comprehensive Cardiomyopathy Panels, AND~~

A. ~~The member~~/enrollee meets clinical criteria for ~~Comprehensive Arrhythmia Panels.~~Comprehensive Cardiomyopathy Panels, **AND**

B. ~~Comprehensive~~The member/enrollee meets clinical criteria for Comprehensive Arrhythmia Panels.

II. Current evidence does not support comprehensive panels including genes for both cardiomyopathies and arrhythmias ~~(81413, 81414, 81439) are considered **investigational**~~ for all other indications.

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HYPERTROPHIC CARDIOMYOPATHY (HCM)

Hypertrophic Cardiomyopathy Panels

I. Genetic testing for hypertrophic cardiomyopathy via a multigene panel ~~(81439, S3865)~~ is considered **medically necessary** when:

A. The member/enrollee has unexplained left ventricular hypertrophy (LVH), as defined by myocardial wall thickness of 15mm or greater (in adults), or a z-score of 2 or greater (in children) based on echocardiogram or cardiac MRI~~, **OR**~~.

~~A. The member has a first-degree relative with sudden cardiac death (SCD), **AND**~~

~~1. Autopsy revealed an HCM phenotype.~~

II. ~~Genetic~~Current evidence does not support genetic testing for hypertrophic cardiomyopathy via a multigene panel ~~(81439, S3865) is considered **investigational**~~ for all other indications.

NOTE: If a panel is performed, the appropriate panel code should be used

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DILATED CARDIOMYOPATHY (DCM)

Dilated Cardiomyopathy Panels

I. Genetic testing for dilated cardiomyopathy (DCM) via a multigene panel ~~(81439)~~ is considered **medically necessary** when:

A. The member/enrollee has findings characteristic of DCM including all of the following:

1. Left ventricular enlargement or biventricular dilatation based on echocardiogram or cardiac MRI, **AND**

2. Systolic dysfunction (e.g., ejection fraction less than 50%) based on echocardiogram, cardiac MRI, or left ventricular angiogram, **AND**

3. Non-genetic causes of DCM have been ruled out, such as prior myocardial infarction from coronary artery disease, valvular and congenital heart disease, toxins (most commonly, anthracyclines or other chemotherapeutic agents; various drugs with idiosyncratic reactions), thyroid disease, inflammatory or infectious conditions, severe long-standing hypertension, and radiation~~, **OR**~~.

~~A. The member has a first-degree relative with sudden cardiac death (SCD), **AND**~~

~~1. Autopsy revealed a DCM phenotype.~~

II. ~~Genetic~~Current evidence does not support genetic testing for dilated cardiomyopathy (DCM) via a multigene panel ~~(81439) is considered **investigational**~~ for all other indications.

~~**NOTE:** If a panel is performed, the appropriate panel code should be used~~

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NOTE: If a panel is performed, the appropriate panel code should be used

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ARRHYTHMOGENIC CARDIOMYOPATHY

Arrhythmogenic Cardiomyopathy Panels

I. Genetic testing for arrhythmogenic cardiomyopathy via a multigene panel ~~(81439)~~ is considered **medically necessary** when:

A. The member/enrollee has any one of the following:

1. On echo:

a) Regional right ventricular (RV) akinesia or dyskinesia, **OR**

(1) Aneurysm, **AND**

b) At least one of the following (end diastole):

(1) PLAX RVOT ≥32 mm (PLAX/BSA ≥19 mm/m2), **OR**

(2) PSAX RVOT ≥36 mm (PSAX/BSA ≥21 mm/m2), **OR**

(3) Fractional area change ≤33%, **OR**

2. On MRI:

a) Regional RV akinesia or dyskinesia, **OR**

(1) Dyssynchronous RV contraction, **AND**

b) At least one of the following:

(1) Rao RVEDV/BSA ≥110 mL/m2 (male), ≥100 mL/m2 (female), **OR**

(2) RVEF ≤40%, **OR**

3. On RV Angiography:

a) Regional RV akinesia, dyskinesia, or aneurysm, **OR**

4. Endomyocardial biopsy showing fibrous replacement of the RV free wall myocardium in more than 1 sample, with or without fatty replacement, **AND**:

a) Residual myocytes <60% by morphometric analysis (or <50% if estimated), **OR**

5. On ECG:

    a) Inverted T waves in right precordial leads (V1, V2, and V3) or beyond in individuals >14 years of age (in the absence of complete RBBB QRS ≥120ms), **OR**

    b) Epsilon wave (reproducible low-amplitude signals between end of QRS complex to onset of the T wave) in the right precordial leads (V1 to V3), **OR**

    c) Nonsustained or sustained VT of LBBB with superior axis (negative or indeterminate QRS in leads II, III, and aVF and positive in lead aVL), **OR**

6. On Family History:

    a) ARVC confirmed in a ~~first-degree relative~~first-degree relative who meets current Task Force Criteria, **OR**

    b) ARVC confirmed pathologically at autopsy or surgery in a first-degree relative, **OR**

    c) Identification of a pathogenic mutation categorized as associated or probably associated with ARVC in the ~~patient~~member/enrollee under evaluation, **OR**

B. The member/enrollee has any two of the following:

1. On echo, either:

    a) Regional RV akinesia or dyskinesia, **OR**

        (1) Aneurysm, **AND**

    b) At least one of the following (end diastole):

        (1) PLAX RVOT ≥29 mm to <32 mm (PLAX/BSA ≥16 to <19 mm/m2), **OR**

        (2) PSAX RVOT ≥32 to <36 mm (PSAX/BSA ≥18 to <21 mm/m2), **OR**

        (3) Fractional area change >33 to ≤40%, **OR**

2. On MRI, either:

    a) Regional RV akinesia or dyskinesia, **OR**

        (1) Dyssynchronous RV contraction, **AND**

b) At least one of the following:

(1) Rao RVEDV/BSA ≥100 to <110 mL/m2 (male), ≥90 to 100 mL/m2 (female), **OR**

(2) RVEF >40 to ≤45%, **OR**

3. Endomyocardial biopsy showing fibrous replacement of the RV free wall myocardium in more than 1 sample, with or without fatty replacement, **AND**

a) Residual myocytes 60% to 75% by morphometric analysis (or 50% to 65% if estimated), **OR**

4. On ECG:

a) Inverted T waves in leads V1 and V2 in individuals >14 years of age (in the absence of complete RBBB), or in V4, V5, or V6, **OR**

b) Inverted T waves in leads V1, V2, V3, and V4 in individuals >14 years of age in the presence of complete RBBB, **OR**

c) Late potentials by SAECG in ≥1 of 3 parameters in the absence of QRS duration of ≥110ms on the standard ECG:

(1) Filtered QRS duration (fQRS) ≥114 ms, **OR**

(2) Duration of terminal QRS <40 μV (low-amplitude signal duration) ≥38 ms, **OR**

(3) Root-mean-square voltage of terminal 40 ms ≤20 μV, **OR**

d) Terminal activation duration of QRS ≥55 ms measured from the nadir of the S wave to the end of the QRS, including R' in V1, V2, or V3 in the absence of complete RBBB, **OR**

e) Nonsustained or sustained VT or RV outflow configuration, LBBB morphology with inferior axis (positive QRS in II, III and aVF and negative in lead aVL) or of unknown axis, **OR**

f) >500 ventricular extrasystoles per 24 hours (Holter), **OR**

5. On ~~family~~Family History:

a) History of ARVC in a ~~first-degree relative~~first-degree relative in whom it is not possible or practical to determine whether the family member/enrollee meets current Task Force Criteria, **OR**

b) Premature sudden death (<35 years of age) due to suspected ARVC in a first-degree relative, **OR**

c) ARVC confirmed pathologically or by current Task Force Criteria in second-degree relative.

II. ~~Genetic~~Current evidence does not support genetic testing for arrhythmogenic cardiomyopathy via a multigene panel ~~(81439) is considered **investigational** ~~for all other indications.

NOTE: If a panel is performed, the appropriate panel code should be used

~~***NOTE:*** If a panel is performed, the appropriate panel code should be used~~

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RESTRICTIVE CARDIOMYOPATHY (RCM)

Restrictive Cardiomyopathy Panels

I. ~~Genetic~~Current evidence does not support genetic testing for restrictive cardiomyopathy (RCM) via a multigene panel ~~(81439) is considered **investigational**~~for all indications.

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LONG QT SYNDROME (LQTS)

Long QT Syndrome Panels

I. Genetic testing for long QT syndrome (LQTS) via multigene panel ~~(81403, 81406, 81407, 81413, 81414, 81479) ~~is considered **medically necessary** when:

A. The member/enrollee is asymptomatic, **AND**

1. The member/enrollee has a confirmed prolonged QTc (greater than 460ms prepuberty, greater than 480 ms for adults) on resting ECG and/or provocative stress testing with exercise or during intravenous pharmacologic provocation testing (eg, with epinephrine), **OR**

2. The member/enrollee has a ~~close relative~~close relative with a clinical diagnosis of LQTS, whose genetic status is unknown~~,~~,[1] **OR**

B. The member/enrollee is symptomatic (~~for example:~~e.g., a history of syncope, cardiac arrest, and/or aborted sudden death), **AND**

1. The member/enrollee meets either of the following:

a) A cardiologist has established a strong clinical suspicion for LQTS based on examination of the ~~patient's~~member/enrollee's clinical history, family history, and expressed electrographic phenotype, **OR**

b) The member/enrollee has a Schwartz score of 3.0 or more, **AND**

2. Non-genetic causes of a prolonged QTc interval have been ruled out, such as QT-prolonging drugs, hypokalemia, structural heart disease, or certain neurologic conditions including subarachnoid bleed.

II. ~~Genetic~~Current evidence does not support genetic testing for long QT syndrome (LQTS) via multigene panel ~~(81403, 81406, 81407, 81413, 81414, 81479) is considered **investigational**~~ for all other indications.

NOTE: If a panel is performed, the appropriate panel code should be used

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[1]If a pathogenic or likely pathogenic variant has been identified in an explanatory gene in the affected family member, refer to the *General Criteria for Known Familial Variant Analysis for a Genetic Condition* within the *General Approach to Laboratory Testing.*

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SHORT QT SYNDROME (SQTS)

Short QT Syndrome Panels

I. Genetic ~~Testing~~testing for short QT syndrome (SQTS) via multigene panel ~~(81403, 81406, 81413, 81414, 81479)~~ is considered **medically necessary** when:

A. The member/enrollee has a QTc of 330ms or less, **OR**

B. The member/enrollee has a SQTS diagnostic score of 4 or greater utilizing the criteria below, **OR**

C. The member/enrollee is asymptomatic, **AND**

1. The member/enrollee has a ~~first-degree relative~~first-degree relative with a clinical diagnosis of SQTS, whose genetic status is unknown~~.~~.[1]

II. ~~Genetic~~Current evidence does not support genetic testing for short QT syndrome (SQTS) via multigene panel ~~(81403, 81406, 81413, 81414, 81479) is considered **investigational**~~ for all other indications.

~~**NOTE:** If a panel is performed, the appropriate panel code should be used~~

NOTE*:* If a panel is performed, the appropriate panel code should be used

[1]If a pathogenic or likely pathogenic variant has been identified in an explanatory gene in the affected family member, refer to the *General Criteria for Known Familial Variant Analysis for a Genetic Condition* within the *General Approach to Laboratory Testing.*

Criteria	**Points**
Electrocardiogram[a]	
QTc less than 370 ms	1
QTc less than 350 ms	2
QTc less than 330 ms	3
J point-T peak interval[b] less than 120 ms	1
Clinical history[c]*	
History of sudden cardiac arrest	2
Documented polymorphic VT or VF	2
Unexplained syncope	1
Atrial fibrillation	1
Family history[d]*	

First- or second-degree relative with high-probability SQTS	2
First- or second-degree relative with autopsy-negative SCD	1
Sudden infant death syndrome	1
Genotype*	
Genotype positive	2
Mutation of undetermined significance in a culprit gene	1

SQTS score: High-probability SQTS: greater than or equal to 4 points, intermediate-probability SQTS: 3 points, low-probability SQTS: less than or equal to 2 points.
[a] Electrocardiogram: must be recorded in the absence of modifiers known to shorten the QT.
[b] Jpoint-Tpeak interval must be measured in the precordial lead with the greatest amplitude T-wave.
[c] Clinical history: events must occur in the absence of an identifiable etiology, including structural heart disease. Points can only be received for 1 of cardiac arrest, documented polymorphic VT, or unexplained syncope.
[d] Family history: points can only be received once in this section.
*A minimum of 1 point must be obtained in the electrocardiographic section in order to obtain additional points.

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BRUGADA SYNDROME (~~BrS~~BRS)

Brugada Syndrome Panels or *SCN5A* Variant Analysis

I. Genetic testing for Brugada syndrome (BrS) via *SCN5A* variant analysis ~~(81407, S3861)~~ is considered **medically necessary** when:

A. The member/enrollee meets one of the following:

1. Type 1 ECG (elevation of the J wave greater than or equal to 2 mm with a negative T wave and ST segment that is coved type and gradually descending) in more than one right precordial lead with or without administration of a sodium channel blocker (e.g., flecainide, pilsicainide, ajmaline, or procainamide), **OR**

2. Type 2 ECG (elevation of the J wave greater than or equal to 2 mm with a positive or biphasic T wave; ST segment with saddle-back configuration and elevated greater than or equal to 1 mm) in more than one right precordial lead under baseline conditions with conversion to type 1 ECG following challenge with a sodium channel blocker, **OR**

3. Type 3 ECG (elevation of the J wave greater than or equal to 2 mm with a positive T wave; ST segment with saddle-back configuration and elevated less than 1 mm) in more than one lead under baseline conditions with conversion to type 1 ECG following challenge with a sodium channel blocker, **AND**

B. Conditions causing a Brugada syndrome ~~phenocopy~~phenocopy (e.g., as myocardial ischaemia, electrolyte disturbances, and drug intoxications) have been ruled out, **AND**

C. Any of the following:

1. Recurrent syncope, **OR**
2. Ventricular fibrillation, **OR**
3. Self-terminating polymorphic ventricular tachycardia, **OR**
4. Cardiac arrest, **OR**
5. A family history of ~~sudden cardiac death.~~sudden cardiac death (SCD).

II. ~~Genetic~~Current evidence does not support genetic testing for Brugada syndrome (BrS) via *SCN5A* variant analysis ~~(81407, S3861) is considered **investigational** ~~for all other indications.

III. ~~Genetic~~Current evidence does not support genetic testing for Brugada syndrome (BrS) via genes other than *SCN5A*, including multigene panel analysis ~~(81404, 81406, 81407, 81413, 81414, 81479), is considered **investigational**~~.

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CATECHOLAMINERGIC POLYMORPHIC VENTRICULAR TACHYCARDIA (CPVT)

Catecholaminergic Polymorphic Ventricular Tachycardia Panels

I. Genetic testing for catecholaminergic polymorphic ventricular tachycardia (CPVT) ~~(81403, 81405, 81408, 81413, 81414, 81479)~~ via multigene panel is considered **medically necessary** when:

   A. The member/enrollee has no known structural cardiac abnormalities, **AND**

   B. The member/enrollee has any of the following:

      1. Syncope occurring during physical activity or acute emotion, **OR**
      2. History of exercise- or emotion-related palpitations and dizziness, **OR**
      3. Sudden unexpected cardiac death triggered by acute emotional stress or exercise, **OR**
      4. Family history of juvenile ~~sudden cardiac death~~ sudden cardiac death (SCD) triggered by exercise or acute emotion, **OR**
      5. Exercise-induced bidirectional or polymorphic ventricular arrhythmias, **OR**
      6. Ventricular fibrillation occurring in the setting of acute stress.

II. ~~Genetic~~Current evidence does not support genetic testing for catecholaminergic polymorphic ventricular tachycardia (CPVT) ~~(81403, 81405, 81408, 81413, 81414, 81479)~~ via multigene panel ~~is considered **investigational**~~ for all other indications.

NOTE: If a panel is performed, the appropriate panel code should be used

~~**NOTE:** If a panel is performed, the appropriate panel code should be used~~

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FAMILIAL HYPERCHOLESTEROLEMIA (FH)

Familial Hypercholesterolemia (FH) Panels

I. Genetic testing for familial hypercholesterolemia (FH) via multigene panel ~~(81401, 81405, 81406, 81407, 81479)~~ to establish or confirm a diagnosis of familial hypercholesterolemia (FH) is considered **medically necessary** when:

A. The member/enrollee has at least two or more elevated LDL-C measurements, including assessment after intensive lifestyle modification, **AND**

B. There is no apparent secondary cause of hypercholesterolemia (e.g., hypothyroidism, diabetes, renal disease, nephrotic syndrome, liver disease, medications), **AND**

1. The member/enrollee is a child with LDL-C levels greater than or equal to 190 mg/dl, **OR**

2. The member/enrollee is a child with LDL-C levels greater than or equal to 160 mg/dl with one of the following:

a) At least one ~~first-degree relative~~first-degree relative with elevated LDL-C, **OR**

b) At least one ~~first-degree relative~~first-degree relative with ~~premature CAD,~~premature coronary artery disease (CAD), **OR**

c) Limited family history (e.g., adoption), **OR**

d) A family history of both hypercholesterolemia and ~~premature CAD,~~premature coronary artery disease (CAD), **OR**

3. The member/enrollee is an adult with LDL-C levels greater than or equal to 250 mg/dl, **OR**

4. The member/enrollee is an adult with LDL-C levels greater than or equal to 190 mg/dl with one of the following:

a) At least one ~~first-degree relative~~first-degree relative with elevated LDL-C, **OR**

b) At least one ~~first-degree relative~~first-degree relative with ~~premature CAD,~~premature coronary artery disease (CAD), **OR**

c) Limited family history (e.g. adoption), **OR**

5. The member/enrollee is an adult with LDL-C levels greater than or equal to 160 mg/dl with one of the following:

a) A family history of both hypercholesterolemia and ~~premature CAD,~~premature coronary artery disease (CAD), **OR**

b) A personal history of ~~premature CAD,~~premature coronary artery disease (CAD), **OR**

C. The member/enrollee is an adult with ~~premature CAD,~~premature coronary artery disease (CAD), **AND**

1. A family history of both hypercholesterolemia and ~~premature CAD.~~premature coronary artery disease (CAD).

II. ~~Genetic~~Current evidence does not support genetic testing for familial hypercholesterolemia (FH) via multigene panel ~~(81401, 81405, 81406, 81407, 81479)~~ to establish or confirm a diagnosis of familial hypercholesterolemia (FH) ~~is considered **investigational**~~ for all other indications.

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CONGENITAL HEART MALFORMATIONS

Congenital Heart Malformation Panels

I. Genetic testing for congenital heart malformations via multigene panel analysis ~~(81405, 81406, 81407, 81408, 81479)~~ may be considered **medically necessary** when:

A. The member/enrollee has a complex congenital heart malformation (e.g., hypoplastic left heart, transposition of the great vessels, tetralogy of Fallot, etc), **AND**

B. The ~~member's~~member/enrollee's clinical features do not fit a known genetic disorder for which targeted testing could be performed (e.g., 22q11.2 deletion syndrome, Down syndrome/Trisomy 21, Williams syndrome, etc.), **AND**

C. Prenatal teratogen exposure has been considered, and ruled out when possible.

II. ~~Genetic~~Current evidence does not support genetic testing for congenital heart malformations via multigene panel analysis ~~(81405, 81406, 81407, 81408, 81479) is considered **investigational**~~ for all other indications, including "simple" congenital heart defects (e.g. ventricular septal defects, atrial septal defects, patent ductus arteriosus).

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~~POST HEART TRANSPLANT GENE EXPRESSION PANELS FOR REJECTION RISK VIA PERIPHERAL BLOOD~~

~~The use of post heart transplant gene expression panels~~view rationale

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FAMILIAL THORACIC AORTIC ANEURYSM AND DISSECTION (TAAD)

Familial Thoracic Aortic Aneurysm and Dissection (TAAD) Multigene Panel

I. Familial thoracic aortic aneurysm and dissection (TAAD) multigene panel analysis to establish a genetic diagnosis for ~~rejection risk via peripheral blood to determine management of patients after heart transplantation (81595)~~TAAD is considered **medically necessary** when:

A. The member ~~has undergone heart transplant and is at low-risk~~/enrollee has a history of any of the following:

1. Aortic root enlargement, **OR**

2. Thoracic aneurysm, **OR**

3. Type A aortic dissection or type B aortic dissection, **AND**

~~A.~~B. The member/enrollee does not otherwise meet diagnostic criteria for ~~organ rejection~~another connective tissue disorder, **AND**

~~A. The member's heart transplant was performed at least 2 months ago and less than 5 years ago.~~

C. ~~The use of post heart transplant gene expression panels~~The member/enrollee has a family history of dilation or dissection of the aortic root, consistent with autosomal dominant inheritance.

II. Current evidence does not support thoracic aortic aneurysm and dissection (TAAD) multigene panel analysis to establish a genetic diagnosis for ~~rejection risk via peripheral blood to determine management of patients after heart transplantation (81595) is considered **investigational**~~TAAD for all other indications.

NOTE: If a panel is performed, the appropriate panel code should be used

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~~POST HEART TRANSPLANT GENE EXPRESSION PANELS FOR REJECTION RISK VIA TISSUE~~

~~The use~~view rationale

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HEREDITARY HEMORRHAGIC TELANGIECTASIA (HHT)

Hereditary Hemorrhagic Telangiectasia Multigene Panel

~~I.~~ Hereditary hemorrhagic telangiectasia (HHT) multigene panel analysis to establish or confirm a diagnosis of ~~post heart transplant gene expression panels for rejection risk via tissue (0087U) is considered **investigational.**~~

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~~DONOR-DERIVED CELL-FREE DNA FOR HEART TRANSPLANT REJECTION~~

I. ~~The use of peripheral blood measurement of donor-derived cell-free DNA in the management of patients after heart transplantation (0118U, 0493U, 81479)~~HHT is considered **medically necessary** when:

A. The member/enrollee has ~~undergone a heart transplant,~~any of the following clinical features of HHT:

1. Spontaneous and recurrent nosebleeds (epistaxis), **OR**

2. Mucocutaneous telangiectases at characteristic sites, including lips, oral cavity, fingers, and nose, **OR**

~~1.~~3. Visceral arteriovenous malformation (AVM) (either pulmonary, cerebral, spinal, gastrointestinal or pancreatic), **AND**

B. ~~Peripheral blood measurement of donor-derived cell-free DNA testing has~~The panel includes, at a minimum, the following genes: *ACVRL1*, *ENG*.

~~A.~~ Current evidence does not ~~been performed in the past twelve months.~~

II. ~~The use of peripheral blood measurement~~support hereditary hemorrhagic telangiectasia (HHT) multigene panel analysis to establish or confirm a diagnosis of ~~donor-derived cell-~~

~~free DNA in the management of patients after heart transplantation (0118U, 81479) is considered **investigational**~~HHT for all other indications.

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~~DEFINITIONS~~

1. ~~**Close relatives** include first, second, and third degree blood relatives:~~

   a. ~~**First-degree relatives** are parents, siblings, and children~~

   b.a. ~~**Second-degree relatives** are grandparents, aunts, uncles, nieces, nephews, grandchildren, and half-siblings~~

   c.a. ~~**Third-degree relatives** are great-grandparents, great-aunts, great-uncles, great grandchildren, and first cousins~~

1. ~~A **phenocopy** is a trait or disease that resembles the trait expressed by a certain genotype, but in an individual that is not a carrier of that genotype~~

2.1. ~~**Sudden cardiac death (SCD)** is death due to a cardiovascular cause that occurs within one hour of the onset of symptoms.~~

2. ~~**Sudden unexplained death (Sudden unexplained death syndrome, SUDS)** refers to a sudden cardiac death that occurs in an apparently healthy and often young individual within an hour of the onset of symptoms and for no apparent reason.~~

3. ~~**Premature coronary artery disease (CAD)** is defined as male subjects at or under 55 years of age, female subjects at or under 65 years of age; adapted from the American Heart Association phenotype definition of HeFH. (Sturm, et al)~~

4. ~~**Sudden cardiac arrest** is defined as "the sudden cessation of cardiac activity so that the victim becomes unresponsive, with no normal breathing and no signs of circulation. If corrective measures are not taken rapidly, this condition progresses to sudden death. Cardiac arrest should be used to signify an event as described above, that is reversed, usually by CPR and/or defibrillation or cardioversion, or cardiac pacing." (Buxton, et al)~~

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RATIONALE

Comprehensive Cardiomyopathy Panels

Heart Failure Society of America and American College of Medical Genetics and Genomics (ACMG)

The Heart Failure Society of America published joint guidelines with the American College of Medical Genetics and Genomics (Hershberger et al, 2018) and made the following recommendations:

- Guideline 4: Genetic testing is recommended for patients with cardiomyopathy (Level of evidence A)
    - 4a: Genetic testing is recommended for the most clearly affected family member/enrollee.
    - 4b: Cascade genetic testing of at-risk family members is recommended for pathogenic and likely pathogenic variants.
    - 4c: In addition to routine newborn screening tests, specialized evaluation of infants with cardiomyopathy is recommended, and genetic testing should be considered~~.~~ (p. 289~~)~~).

Per the guideline, multigene panel genetic testing is recommended over a serial single-gene testing approach owing to the genetically and heterogeneous nature of cardiomyopathy~~.~~ (p. 290~~)~~).

Asia Pacific Heart Rhythm Society (APHRS) and Heart Rhythm Society (HRS)

The Asia Pacific Heart Rhythm Society (APHRS) and Heart Rhythm Society (HRS) published an expert consensus statement (Stiles et al, 2020) on the investigation of decedents with sudden unexplained death and patients with sudden cardiac arrest, and of their families that includes the following "take-home messages" related to genetic testing:

- For survivors of sudden cardiac arrest (SCA), victims of sudden unexplained death (SUD), and their relatives, a multidisciplinary team is central to thorough investigation, so as to maximize the opportunity to make a diagnosis. Where there has been an SCD or resuscitated SCA and a genetic cause is suspected, genetic testing and counseling is essential for families, to ensure that risks, benefits, results, and the clinical significance of genetic testing can be discussed~~.~~ (p. e3~~)~~).
- A comprehensive autopsy is an essential part of the investigation of SUD and should include collection and storage of tissue suitable for genetic analysis. When the autopsy suggests a possible genetic cause, or no cause and the heart is normal, referral to a multidisciplinary team for further investigation is indicated~~.~~ (p. e3~~)~~).
- For victims of SCD or survivors of cardiac arrest where the phenotype is known, genetic testing of the proband focused on likely candidate genes, along with clinical evaluation of

family members, aids in identifying family members with, or at risk of developing, the same condition~~.~~ (p. e3~~)~~).

- For the investigation of SCA survivors, essential inquiry includes detailed personal and family history, witness accounts, physical examination, multiple electrocardiograms (ECGs), and cardiac imaging. Ambulatory monitoring and/or provocative testing (exercise, pharmacological, and invasive electrophysiological) may provide additional useful information. A sample suitable for future DNA testing should be taken early in the patient's course and stored~~.~~ (p. e4~~)~~).
- Genetic investigation of SCA survivors is best undertaken at a center with multidisciplinary care infrastructure and should focus on likely candidate genes known to be causally related to the suspected phenotype. In some cases, genetic evaluation without a suspected phenotype may be undertaken with appropriate genetic counseling, although genetic evaluation of patients with a known nongenetic cause of cardiac arrest is discouraged~~.~~ (p. e4~~)~~).

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Comprehensive Arrhythmia Panels

European Heart Rhythm Association, Heart Rhythm Society, Asia Pacific Heart Rhythm Society, Latin American Hearth Rhythm Society

The EHRA/HRS/APHRS/LAHRS 2022 expert consensus statement on the state of genetic testing for cardiac diseases provided guidance on the investigation of decedents with sudden unexplained death and patients / families with sudden cardiac arrest.

"In relatives of UCA [unexplained cardiac arrest] survivors or SCD [sudden cardiac death] decedents, clinical evaluation of first degree family members should be performed, and targeted to the index case's phenotype if present~~."~~" (p. 1350~~)~~).

These guidelines also provide a flowchart for workup for a sudden cardiac death or non-fatal cardiac arrest, recommending that for individuals who died from a SUD or UCA in which no autopsy was performed, and were less than age 50 years, and/or had a family history of premature SCD and/or genetic heart disease, and/or circumstances of death were suspicious for genetic heart disease, clinical evaluation of first degree family members is indicated~~.~~ (p. 1351~~)~~).

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Comprehensive Arrhythmia ~~&~~and Cardiomyopathy (Sudden Cardiac or Unexplained Death) Panels

Asia Pacific Heart Rhythm Society (APHRS) and Heart Rhythm Society (HRS)

The Asia Pacific Heart Rhythm Society (APHRS) and Heart Rhythm Society (HRS) published an expert consensus statement (Stiles et al, 2020) on the investigation of decedents with sudden unexplained death and patients with sudden cardiac arrest, and of their families, which states that hypothesis-free genetic testing is not indicated in cases of SCD where the phenotype remains unknown. ~~-~~Genetic testing using any range from large unfocused gene panels to whole-exome or whole-genome sequencing in the absence of a clinical phenotype or diagnosis may be considered in the context of a scientific effort but is not recommended for routine patient care and counseling~~.~~ (p. e26~~)~~).

Concert Note

While large unfocused gene panels are generally discouraged for this indication, because there is a path to coverage for both Comprehensive Arrhythmia Panels and Comprehensive Cardiomyopathy Panels (both phenotypically-focused tests), it is the philosophy of Concert that, if a member/enrollee meets criteria for both individual panels, that member/enrollee should also meet criteria for the combined test.

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Hypertrophic Cardiomyopathy Panels

American College of Cardiology and American Heart Association (ACC/AHA)

The American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines published an updated guideline for the diagnosis and treatment of patients with hypertrophic cardiomyopathy (2020), which stated the following with regard to genetic testing for HCM:

> "Counseling patients with HCM regarding the potential for genetic transmission of HCM is one of the corner-stones of care. Screening first-degree family members of patients with HCM, using either genetic testing or an imaging/electrocardiographic surveillance protocol, can begin at any age and can be influenced by specifics of the patient/family history and family preference. As screening recommendations for family members hinge on the pathogenicity of any detected variants, the reported pathogenicity should be reconfirmed every 2 to 3 years~~.~~"~~"~~" (p. e161~~)~~).

The ACC/AHA says HCM is "characterized predominantly by LVH in the absence of another cardiac, systemic, or metabolic disease capable… A clinical diagnosis of HCM in adult patients can therefore be established by imaging, with 2D echocardiography or cardiovascular magnetic resonance (CMR) showing a maximal end-diastolic wall thickness of greater than or equal to 15 mm anywhere in the left ventricle, in the absence of another cause of hypertrophy in adults. More limited hypertrophy (13–14 mm) can be diagnostic when present in family members of a patient with HCM or in conjunction with a positive genetic test. For children, the diagnostic criteria are

confounded by needing to adjust for body size and growth. Traditionally, a body surface area adjusted z-score of 2 or more standard deviations above the mean has been used~~.~~"" (p. e167~~)~~).

"Postmortem testing for HCM-associated variants using blood or tissue collected at autopsy has been reported, particularly in instances where the family variant is unknown and no other affected family members are still living….identification of a likely pathogenic or pathogenic variant not only confirms the diagnosis of HCM but allows cascade genetic testing of other at-risk relatives as outlined previously~~.~~"" (p. e184~~)~~).

American College of Cardiology Foundation and American Heart Association

The American College of Cardiology Foundation (ACCF) and the American Heart Association (AHA) (2011) issued joint guidelines on the diagnosis and treatment of hypertrophic cardiomyopathy. They state that hypertrophic cardiomyopathy is clinically recognized by a maximal left ventricular wall thickness of 15mm or greater in adults, and the equivalent relative to body surface area in children. They also recommended that screening (with or without genetic testing) be performed in first-degree relatives of individuals with hypertrophic cardiomyopathy~~.~~ (p. e792~~)~~).

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Dilated Cardiomyopathy Panels

European Heart Rhythm Association, Heart Rhythm Society, Asia Pacific Heart Rhythm Society, Latin American Hearth Rhythm Society

In their 2022 expert consensus statement, the European Heart Rhythm Association, Heart Rhythm Society, Asia Pacific Heart Rhythm Society, and Latin American Hearth Rhythm Society ~~state:~~defines dilated cardiomyopathy as left ventricle or biventricular dilatation and systolic dysfunction in the absence of abnormal loading conditions or coronary artery disease (p. 1342). The expert consensus states the following:

"Genetic testing is…useful in all DCM [dilated cardiomyopathy] patients, is recommended in DCM patients with the highest yield of pathogenic variant screening and should be considered even in the absence of familial contest or associated clinical features~~.~~"" (p. ~~525)~~1343).

Heart Failure Society of America

Hershberger, et al published guidelines in 2018 on cardiomyopathy genetic evaluation. They state the following:

> "That familial dilated cardiomyopathy (DCM) has a genetic basis is also well accepted. (The term DCM is used herein instead of the more technical attribution, "idiopathic dilated cardiomyopathy", where the other common and easily clinically detected causes of systolic dysfunction such as coronary artery disease, primary valvular or

congenital heart disease, or previous exposure to cancer chemotherapy or other injurious drugs, have been excluded~~).”~~)” (p. 282~~)~~).

GeneReviews: Dilated Cardiomyopathy 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 diagnostic screening for dilated cardiomyopathy is as follows:

DCM is established when a patient has both left ventricular enlargement and systolic dysfunction. “An ejection fraction of less than 50% is considered systolic dysfunction. The left ventricular ejection fraction is the most commonly used clinical measure of systolic function, and is usually estimated from a two-dimensional echocardiogram or from cardiac MRI. … Ejection fractions can also be estimated from a left ventricular angiogram.”

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Arrhythmogenic Cardiomyopathy Panels

Towbin et al 2019

Modification of the Task Force Criteria for the diagnosis of arrhythmogenic right ventricular cardiomyopathy (ARVC) were published in 2010 and outlined clinical criteria for individuals with possible ARVC, which the Task Force defined as individuals with one major criteria or two minor criteria from different categories. The major and minor criteria are as follows:

Major Criteria

I. Echo:
    A. Regional RV akinesia dyskinesia, or aneurysm and 1 of the following (end diastole):
        1. PLAX RVOT ≥32 mm (PLAX/BSA ≥19 mm/m2)
        2. PSAX RVOT ≥36 mm (PSAX/BSA ≥21 mm/m2)
        3. Fractional area change ≤33%
II. MRI
    A. Regional RV akinesia or dyskinesia, or dyssynchronous RV contraction and 1 of the following:
        1. Rao RVEDV/BSA ≥110 mL/m2 (male), ≥100 mL/m2 (female)
        2. RVEF ≤40%
III. RV Angiography
    A. Regional RV akinesia, dyskinesia, or aneurysm
IV. Endomyocardial biopsy showing fibrous replacement of the RV free wall myocardium in more than 1 sample, with or without fatty replacement and with:
    A. Residual myocytes <60% by morphometric analysis (or <50% if estimated)

V. ECG
   A. Inverted T waves in right precordial leads (V1, V2, and V3) or beyond in individuals >14 years of age (in the absence of complete RBBB QRS ≥120ms)
   B. Epsilon wave (reproducible low-amplitude signals between end of QRS complex to onset of the T wave) in the right precordial leads (V1 to V3)
   C. Nonsustained or sustained VT of LBBB with superior axis (negative or indeterminate QRS in leads II, III, and aVF and positive in lead aVL)

VI. Family History
   A. ARVC confirmed in a first-degree relative who meets current Task Force Criteria
   B. ARVC confirmed pathologically at autopsy or surgery in a first-degree relative
   C. Identification of a pathogenic mutation categorized as associated or probably associated with ARVC in the patient under evaluation

Minor Criteria

I. Echo
   A. Regional RV akinesia, dyskinesia, or aneurysm and 1 of the following (end diastole):
      1. PLAX RVOT ≥29 mm to <32 mm (PLAX/BSA ≥16 to <19 mm/m2)
      2. PSAX RVOT ≥32 to <36 mm (PSAX/BSA ≥18 to <21 mm/m2)
      3. Fractional area change >33 to ≤40%

II. MRI
   A. Regional RV akinesia or dyskinesia, OR
   B. Dyssynchronous RV contraction and 1 of the following:
      1. Rao RVEDV/BSA ≥100 to <110 mL/m2 (male), ≥90 to 100 mL/m2 (female)
      2. RVEF >40 to ≤45%

III. Endomyocardial biopsy showing fibrous replacement of the RV free wall myocardium in more than 1 sample, with or without fatty replacement and with:
   A. Residual myocytes 60% to 75% by morphometric analysis (or 50% to 65% if estimated)

IV. ECG
   A. Inverted T waves in leads V1 and V2 in individuals >14 years of age (in the absence of complete RBBB), or in V4, V5, or V6.
   B. Inverted T waves in leads V1, V2, V3, and V4 in individuals >14 years of age in the presence of complete RBBB
   C. Late potentials by SAECG in ≥1 of 3 parameters in the absence of QRS duration of ≥110ms on the standard ECG:
      1. Filtered QRS duration (fQRS) ≥114 ms
      2. Duration of terminal QRS <40 μV (low-amplitude signal duration) ≥38 ms
      3. Root-mean-square voltage of terminal 40 ms ≤20 μV
   D. Terminal activation duration of QRS ≥55 ms measured from the nadir of the S wave to the end of the QRS, including R’ in V1, V2, or V3 in the absence of complete RBBB

E. Nonsustained or sustained VT or RV outflow configuration, LBBB morphology with inferior axis (positive QRS in II, III and aVF and negative in lead aVL) or of unknown axis
F. >500 ventricular extrasystoles per 24 hours (Holter)

V. Family History
A. History of ARVC in a first-degree relative in whom it is not possible or practical to determine whether the family member meets current Task Force Criteria
B. Premature sudden death (<35 years of age) due to suspected ARVC in a first-degree relative
C. ARVC confirmed pathologically or by current Task Force Criteria in second-degree relative (p. 311)

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Restrictive Cardiomyopathy Panels

American College of Medical Genetics and Genomics (ACMG)

The American College of Medical Genetics and Genomics (ACMG) (2018) published clinical practice recommendations for the genetic evaluation of cardiomyopathy. The following recommendations were made for RCM:

> In regard to selecting genes to test in association with the cardiomyopathy, "Consider HCM or DCM panel."
>
> "Genetic causes of RCM continue to be identified, but because RCM is a relatively rare form of cardiomyopathy, numbers remain limited. A recent study identified a pathogenic variant in 60% of subjects, primarily occurring in genes known to cause HCM. Family members were frequently identified with HCM or HCM with restrictive physiology… Cardiac amyloidosis resulting from pathogenic variants in TTR needs to be differentiated from other forms of RCM due to the age demographic in which this occurs, the slowly progressive nature of this disease, and therefore different management strategies. The TTR allele p.Val142Ile (commonly referred to as Val122Ile based on nomenclature for the circulating protein after N-terminal peptide cleavage) has been found in 10% of African Americans older than age 65 with severe congestive heart failure. Substantial recent progress with amyloidosis, both in imaging strategies, including cardiac magnetic resonance and pyrophosphate scanning, and therapeutic interventions in ongoing clinical trials, provide new incentives for genetic diagnosis.~~"~~" (p. 904~~)~~).

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Long QT Syndrome Panels

European Heart Rhythm Association (EHRA)/Heart Rhythm Society (HRS)/Asia Pacific Heart Rhythm Society (APHRS)/Latin American Heart Rhythm Society (LAHRS)

This expert consensus statement on the state of genetic testing for cardiac diseases published in 2022 by Wilde et al. states the following:

"Molecular genetic testing for definitive disease associated genes (currently KCNQ1, KCNH2, SCN5A, CALM1, CALM2, and CALM3) should be offered to all index patients with a high probability diagnosis of LQTS, based on examination of the patient's clinical history, family history, and ECG characteristics obtained at baseline, during ECG Holter recording and exercise stress test (Schwartz Score 3.5~~)".)~~" (p. e15~~)~~).

"In patients with an intermediate probability of LQTS (e.g. prolonged QTc with a Schwartz score 1.5–3.0), testing of genes with limited, disputed and refuted evidence should not be performed, while testing of the established genes may be considered, mostly to help rule out the diagnosis after extensive phenotypic investigation~~."""~~ (p. e17~~)~~).

Heart Rhythm Society (HRS) and European Heart Rhythm Association (EHRA)

The HRS and the EHRA (Ackerman, et al 2011) published joint recommendations and made the following recommendations for LQTS genetic testing in asymptomatic individuals:

- "Comprehensive or LQT1-3 (*KCNQ1, KCNH2*, and *SCN5A*) targeted LQTS genetic testing is recommended for any patient in whom a cardiologist has established a strong clinical index of suspicion for LQTS based on examination of the patient's clinical history, family history, and expressed electrocardiographic (resting 12-lead ECGs and/or provocative stress testing with exercise or catecholamine infusion) phenotype. (Class I)
- Comprehensive or LQT1-3 (*KCNQ1, KCNH2, SCN5A*) targeted LQTS genetic testing is recommended for any asymptomatic patient with QT prolongation in the absence of other clinical conditions that might prolong the QT interval (such as electrolyte abnormalities, hypertrophy, bundle branch block, etc, ie, otherwise idiopathic) on serial 12-lead ECGs defined as QTc greater than 480 ms (prepuberty) or greater than 500 ms (adults). (Class I)

- Comprehensive or LQT1-3 (*KCNQ1, KCNH2, SCN5A*) targeted LQTS genetic testing may be considered for any asymptomatic patient with otherwise idiopathic QTc values greater than 460 ms (prepuberty) or greater than 480 ms (adults) on serial 12-lead ECGs. (Class IIB~~)".)~~" (p. 1311~~)~~).

Schwartz, Crotti; 2011

Schwartz and Crotti published a scoring system in which to diagnose LQTS. They suggest using the Schwartz score for "selection of those patients who should undergo molecular screening (everyone with a score greater than or equal to 3.0) and in the use of 'cascade screening' for the identification of all affected family members including the silent mutation carriers~~".~~" (p. 5~~)~~).

SCORE:

- Less than or equal to 1 point: low probability of LQTS
- 1.5 to 3 points: intermediate probability of LQTS
- 3.5 points or more: high probability~~.~~ (p. 23)

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Short QT Syndrome Panels

Heart Rhythm Society, European Heart Rhythm Society, Asia Pacific Heart Rhythm Society

Priori et al HRS/EHRA/APHRS published an expert consensus statement in 2013 with the following Class 1 clinical diagnostic criteria (which are later referenced in Wilde AAM, Semsarian C, Márquez MF, et al. European Heart Rhythm Association/Heart Rhythm Society/Asia Pacific Heart Rhythm Society/Latin American Heart Rhythm Society expert consensus statement on the state of genetic testing for cardiac diseases. *Journal of Arrhythmia*. 2022;38(4):491-553) for short QT syndrome (SQTS):

"This group has reached a consensus that a cutoff value less than or equal to 330ms should be used for the diagnosis~~.""~~" (p. 1943~~)~~).

European Heart Rhythm Association, Heart Rhythm Society, Asia Pacific Heart Rhythm Society, Latin American Hearth Rhythm Society

In 2022, Wilde et al published the following guidelines regarding SQTS:

"In any patient satisfying the diagnostic criteria for SQTS (such as Class 1 clinical diagnosis [see Priori et al HRS/EHRA/APHRS 2013 expert consensus statement] or SQTS diagnostic score greater [than or equal to] 4), molecular genetic testing is recommended for the definitive disease associated genes (currently *KCNH2*, *KCNQ1*). Testing of *KCNJ2* and *SLC4A3* may be performed in all index patients in whom a cardiologist has established with a high probability a diagnosis of SQTS, based on examination of the patient's clinical history, family history, and ECG characteristics obtained at baseline or during ECG Holter recording and exercise stress test (SQTS diagnostic score greater than or equal to 4~~).""~~)" (p. 515~~)~~).

"Cascade testing for at-risk family members is recommended when a disease-causing mutation is identified~~.""~~" (p. 516~~)~~).

Supplementary Table 9. Diagnostic score cards for short QT syndrome (4)

Criteria	**Points**
Electrocardiogram[a]	

QTc less than 370 ms	1
QTc less than 350 ms	2
QTc less than 330 ms	3
J point-T peak interval[b] less than 120 ms	1
Clinical history[c]*	
History of sudden cardiac arrest	2
Documented polymorphic VT or VF	2
Unexplained syncope	1
Atrial fibrillation	1
Family history[d]*	
First- or second-degree relative with high-probability SQTS	2
First- or second-degree relative with autopsy-negative SCD	1
Sudden infant death syndrome	1
Genotype*	
Genotype positive	2
Mutation of undetermined significance in a culprit gene	1

SQTS score: High-probability SQTS: greater than or equal to 4 points, intermediate-probability SQTS: 3 points, low-probability SQTS: less than or equal to 2 points.

[a] Electrocardiogram: must be recorded in the absence of modifiers known to shorten the QT.

[b] Jpoint-Tpeak interval must be measured in the precordial lead with the greatest amplitude T-wave.

[c] Clinical history: events must occur in the absence of an identifiable etiology, including structural heart disease. Points can only be received for 1 of cardiac arrest, documented polymorphic VT, or unexplained syncope.
[d] Family history: points can only be received once in this section.
*A minimum of 1 point must be obtained in the electrocardiographic section in order to obtain additional points.

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Brugada Syndrome Panels or *SCN5A* Variant Analysis

GeneReviews: Brugada Syndrome

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 diagnostic screening for Brugada syndrome is as follows:

"Brugada syndrome [BrS] should be suspected in individuals with any of the following findings:

- Recurrent syncope
- Ventricular fibrillation
- Self-terminating polymorphic ventricular tachycardia
- Cardiac arrest
- Family history of sudden cardiac death

AND one of the following EKG patterns:

Type 1 EKG (elevation of the J wave greater than or equal to 2 mm with a negative T wave and ST segment that is coved type and gradually descending) in more than one right precordial lead (V1-V3)*... with or without administration of a sodium channel blocker (e.g., flecainide, pilsicainide, ajmaline, or procainamide)

Type 2 EKG (elevation of the J wave greater than or equal to 2 mm with a positive or biphasic T wave; ST segment with saddleback configuration and elevated greater than or equal to 1 mm) in more than one right precordial lead under baseline conditions with conversion to type 1 EKG following challenge with a sodium channel blocker

Type 3 EKG (elevation of the J wave greater than or equal to 2 mm with a positive T wave; ST segment with saddleback configuration and elevated less than 1 mm) in more than one lead under baseline conditions with conversion to type 1 EKG following challenge with a sodium channel blocker."

European Heart Rhythm Association, Heart Rhythm Society, Asia Pacific Heart Rhythm Society, Latin American Hearth Rhythm Society (2022)

"Brugada syndrome phenocopies such as myocardial ischaemia, electrolyte disturbances and drug intoxications should be excluded before a diagnosis of BrS can be made.~~"~~" (p. 510-511~~)~~).

"Other genes [besides *SCN5A*] have been implicated in BrS. However, the gene-disease validity of most of those genes (other than *SCN5A*) has been disputed following rigorous assessment of available data using the ClinGen framework. Although a disputed ClinGen status does not challenge a role of the gene product in BrS pathophysiology, it strongly argues against reporting those genes in the diagnostic setting.~~"~~" (p. 511~~)~~).

*~~-~~No other factor(s) should account for the EKG abnormality.

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Catecholaminergic Polymorphic Ventricular Tachycardia Panels

GeneReviews: Catecholaminergic Polymorphic Ventricular Tachycardia

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 diagnostic screening for catecholaminergic polymorphic ventricular tachycardia is as follows:

"Catecholaminergic polymorphic ventricular tachycardia (CPVT) should be suspected in individuals who have one or more of the following:

- Syncope occurring during physical activity or acute emotion; mean onset is age seven to 12 years. Less frequently, first manifestations may occur later in life; individuals with a first event up to age 40 years have been reported.
- History of exercise- or emotion-related palpitations and dizziness in some individuals
- Sudden unexpected cardiac death triggered by acute emotional stress or exercise
- Family history of juvenile sudden cardiac death triggered by exercise or acute emotion
- Exercise-induced bidirectional or polymorphic ventricular arrhythmias…
- Ventricular fibrillation occurring in the setting of acute stress

The diagnosis of CPVT is established in the presence of a structurally normal heart, normal resting EKG, and exercise- or emotion-induced bidirectional or polymorphic ventricular tachycardia…"

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Familial Hypercholesterolemia (FH) Panels

Journal of the American College of Cardiology (2018)

"Genetic testing for FH should be offered to individuals of any age in whom a strong clinical index of suspicion for FH exists based on examination of the patient's clinical and/or family histories. This index of suspicion includes the following:

1. Children with persistent* LDL-C levels ≥160 mg/dl or adults with persistent* LDL-C levels ≥190 mg/dl without an apparent secondary cause of hypercholesterolemia† and with at least 1 first-degree relative similarly affected or with premature CAD‡ or where family history is not available (e.g., adoption)
2. Children with persistent* LDL-C levels ≥190 mg/dl or adults with persistent* LDL-C levels ≥250 mg/dl without an apparent secondary cause of hypercholesterolemia,† even in the absence of a positive family history.

Evidence Grade: Class of Recommendation IIa, Strength of Evidence B-NR.

Genetic testing for FH may be considered in the following clinical scenarios:

1. Children with persistent* LDL-C levels ≥160 mg/dl (without an apparent secondary cause of hypercholesterolemia†) with an LDL-C level ≥190 mg/dl in at least 1 parent or a family history of hypercholesterolemia and premature CAD‡
2. Adults with no pre-treatment LDL-C levels available but with a personal history of premature CAD‡ and family history of both hypercholesterolemia and premature CAD‡
3. Adults with persistent* LDL-C levels ≥160 mg/dl (without an apparent secondary cause of hypercholesterolemia†) in the setting of a family history of hypercholesterolemia and either a personal history or a family history of premature CAD‡

Evidence Grade: Class of Recommendation IIb, Strength of Evidence C-EO"

If LDL-C values are unavailable, total cholesterol values ≥320, 260, and 230 mg/dl (corresponding to LDL-C levels ≥250, 190, and 160 mg/dl, respectively) could be used.

*~~-~~Two or more measurements, including assessment after intensive lifestyle modification.

† Hypothyroidism, diabetes, renal disease, nephrotic syndrome, liver disease, medications.

‡ Premature coronary artery disease (CAD) = male subjects ≤55 years of age, female subjects ≤65 years of age; adapted from the American Heart Association phenotype definition of HeFH~~.~~"" (p. 674~~)~~).

"Genetic testing for patients with suspected FH should, at a minimum, include analysis of LDLR, APOB, and PCSK9. This analysis should include for LDLR and PCSK9 sequencing of all exons and exon/intron boundaries, as well as LDLR deletion/duplication analysis, and for APOB the exons encoding the LDLR ligand-binding region… Larger, more inclusive, lipid disorder NGS panels are also available that provide evaluation of not only the main FH genes but also the genes causing conditions with phenotypic overlap previously described. These expanded panels should be considered to improve the diagnosis of patients with these "phenocopy" conditions that may require specific therapies, and they should include the following genes: *LDLR, APOB, PCSK9, LDLRAP1, LIPA, ABCG5, ABCG8,* and *APOE*~~.~~"" (p. 674~~)~~).

Musunuru et al, (2020)

"An international expert panel convened by the FH Foundation wrote a scientific statement on clinical genetic testing for FH. This statement generally recommends genetic testing of FH genes (*LDLR, APOB, PCSK9*, and potentially other genes if warranted by the patient phenotype…) for individuals with hypercholesterolemia for which an inherited variant is a likely cause. The statement highlights individuals with some combination of persistent elevated low-density lipoprotein cholesterol levels, personal history of premature coronary artery disease, family history of hypercholesterolemia, and family history of premature coronary artery disease who should be offered or may be considered for genetic testing… In addition, cascade genetic testing should be offered to all at-risk family members of an individual found to have a pathogenic variant in a FH gene. Genetic testing for FH is expected to result in a higher rate of diagnosis among patients with FH, more effective cascade testing, the initiation of therapies at earlier ages, and more accurate risk stratification~~."~~" (p. 381~~)~~).

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Congenital Heart Malformation Panels

American Heart Association

The American Heart Association published a statement entitled "Genetic Basis for Congenital Heart Disease: Revisited" in September 2018 (correction published in November 2018) which states the following:

"Uncovering a genetic pathogenesis for congenital HD is increasingly clinically relevant, in part because of the aforementioned improved survival. For the clinician caring for a child or adult with congenital HD, important reasons for determining the genetic cause can include (1) assessing recurrence risks for the offspring of the congenital HD survivor, additional offspring of the parents, or other close relatives; (2) evaluating for associated extracardiac involvement; (3) assessing risk for neurodevelopmental delays for newborns and infants; and (4) providing more accurate prognosis for the congenital HD and outcomes for congenital HD–related interventions~~.""~~" (p. 3~~)~~).

~~Post Heart Transplant Gene Expression Panels for Rejection Risk via Peripheral Blood~~

~~International Society of Heart and Lung Transplantation~~

~~The 2022 International Society of Heart and Lung Transplantation (ISHLT) Guidelines for the Care of Heart Transplant Patients have the following recommendations for the non-invasive monitoring of acute cellular rejection after heart transplant [HT], and specifically addresses Allomap:~~

~~"Gene Expression Profiling (GEP) (i.e., Allomap) of peripheral blood can be used in low-risk patients between 2 months and 5 years after HT to identify adult recipients who have low~~

~~risk of current ACR [acute cellular rejection] to reduce the frequency of EMB [endomyocardial biopsy]…Class IIa, Level of Evidence: B. (Journal pre-proof p. 69)~~

~~Post Heart Transplant Gene Expression Panels for Rejection Risk via Tissue~~

~~International Society of Heart and Lung Transplantation~~

~~The 2022 International Society of Heart and Lung Transplantation (ISHLT) guidelines for the Care of Heart Transplant Patients state the following regarding post heart transplant gene expression panels for rejection risk via tissue testing: "...the assessment of gene expression within allograft tissue and the identification of rejection-associated gene transcripts (e.g., Molecular Microscope, MMDx) has permitted improved discrimination between T-cell mediated or antibody mediated rejection and tissue injury, but this technology may not be clinically available outside of North America and is currently not in widespread use as a routine diagnostic test." (p. e33-34)~~

~~Donor-Derived Cell-Free DNA for Heart Transplant Rejection~~

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Familial Thoracic Aortic Aneurysm and Dissection (TAAD) Multigene Panel

American ~~Society of Transplant Surgeons~~College of Medical Genetics and Genomics (ACMG)

American College of Medical Genetics and Genomics (2012) issued guidelines on the evaluation of adolescents or adults with some features of Marfan syndrome (MFS) (including TAAD), which recommendations included the following (p. 174-175):

Genetic testing for TAAD can aid in the diagnosis in addition to physical exam, family history, dilated eye exam, echocardiography and vasculature imaging. Diagnostic criteria for TAAD include autosomal dominant history of dilatation or dissection of the aortic root, ascending aorta or descending aorta in the absence of major criteria for the diagnosis of Marfan syndrome or other connective tissue disease.

American Heart Association/American College of Cardiology

The AHA and ACC published a joint guideline (2022) in which genetic testing is recommended for patients with aortic root/ascending aortic aneurysms or aortic dissection and risk factors for hereditary thoracic aortic disease (strong recommendation, moderate quality of evidence). These risk factors include:

- Thoracic aortic disease (TAD) and syndromic features of Marfan, Loeys-Dietz or vascular Ehlers-Danlos syndrome
- TAD presentation under 60 years of age
- Family history of either TAD or peripheral/intracranial aneurysms in first or second degree relative
- History of unexplained sudden death at a relatively young age in first or second degree relative (p. e361).
- A multigene panel comprising all genes suspected to cause HTAD [heritable thoracic aortic disease] is the most cost-effective and clinically useful approach to testing (p. e362).

GeneReviews: Heritable Thoracic Aortic Disease 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.

Per the Heritable Thoracic Aortic Disease GeneReviews article, "A multigene panel that includes genes associated with HTAD [heritable thoracic aortic disease] is recommended." Per Table 1 of this article, these genes include: *ACTA2, COL3A, FBN1, MYH11, MYLK, SMAD3, TGFB2, TGFBR1, TGFBR2, LOX, PRKG1, EFEMP2, FOXE3, MFAP5, SMAD2, BGN, CBS, COL4A5, ELN, FBN2, FLNA, HCN4, NOTCH1, MAT2A, PKD1, PKD2, SKI, SLC2A10, SMAD4, TGFB3*.

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Hereditary Hemorrhagic Telangiectasia Multigene Panel

Second International Guidelines for the Diagnosis and Management of Hereditary Hemorrhagic Telangiectasia

The goal of the Second International HHT Guidelines process was to develop evidence-based consensus guidelines for the management and prevention of HHT-related symptoms and complications. The expert panel generated and approved new recommendations. With regard to diagnosis, the following was recommended:

The expert panel recommends that clinicians refer patients for diagnostic genetic testing for HHT (page 992):

- to identify the causative mutation in a family with clinically confirmed HHT;
- to establish a diagnosis in relatives of a person with a known causative mutation, including:
    - individuals who are asymptomatic or minimally symptomatic and
    - individuals who desire prenatal testing; and
- to assist in establishing a diagnosis of HHT in individuals who do not meet clinical diagnostic criteria.

The expert panel recommends that for individuals who test negative for *ENG* and *ACVRL1* coding sequence mutations, *SMAD4* testing should be considered to identify the causative mutation.

GeneReviews: Hereditary Hemorrhagic Telangiectasia

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.

Diagnostic testing for HHT is recommended when the following clinical findings are seen:

- Spontaneous and recurrent nosebleeds (epistaxis).
  - With night-time nosebleeds heightening the concern for HHT.
- Multiple telangiectases at characteristic sites.
  - Lips, oral cavity, fingers, and nose
- Visceral arteriovenous malformation (AVM).
  - Typically pulmonary, cerebral, hepatic, spinal, gastrointestinal, or pancreatic. AVMs outside these locations are uncommon and not suggestive of HHT.
- Family history. A first-degree relative in whom HHT has been diagnosed according to these Curaçao criteria.
- The clinical diagnosis of HHT can be established in a proband using the Curaçao criteria, which requires three or more of the above suggestive findings, or the molecular diagnosis can be established in a proband with suggestive findings and a heterozygous pathogenic variant in one of the highly associated genes.

GeneReviews also states that concurrent gene testing can be considered using an HHT multigene panel that includes *ACVRL1*, *ENG*, *SMAD4*, and other genes of interest.

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DEFINITIONS

1. **Close relatives** include first, second, and third degree blood relatives:

   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. **Phenocopy** is a trait or disease that resembles the trait expressed by a certain genotype, but in an individual that is not a carrier of that genotype

3. **Premature coronary artery disease (CAD)** is defined as male subjects at or under 55 years of age, female subjects at or under 65 years of age; adapted from the American Heart Association phenotype definition of HeFH (Sturm, et al).

4. **Sudden cardiac arrest** is defined as “the sudden cessation of cardiac activity so that the victim becomes unresponsive, with no normal breathing and no signs of circulation. If

corrective measures are not taken rapidly, this condition progresses to sudden death. Cardiac arrest should be used to signify an event as described above, that is reversed, usually by CPR and/or defibrillation or cardioversion, or cardiac pacing" (Buxton, et al).

5.

Sudden unexplained death (~~In their position statement approved in March 2023, the American Society of Transplant Surgeons stated the following: "We recommend that dd-cfDNA [donor-derived cell-free DNA] may be utilized to rule out subclinical rejection for heart transplant recipients." (p. 3)~~

~~*Concert Note*~~

~~For routine monitoring of patients post-transplant, absent clear, specific and evidence-based guideline recommendations for a particular regimen of screening, a default frequency of coverage of once every 12 months will be adopted.~~

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6. **SUD)** (also known as Sudden unexplained death syndrome or SUDS) refers to a sudden cardiac death that occurs in an apparently healthy and often young individual within an hour of the onset of symptoms and for no apparent reason

7. **Type A aortic dissection** occurs at the ascending part of the aorta, just as it branches off of the heart

8. **Type B aortic dissection** occurs at the descending part of the aorta, and may extend into the abdomen

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Reviews, Revisions, and Approvals	Revision Date	Approval Date	Effective Date
Converted corporate to local policy.	08/23	11/27/23	
Semi-annual review. Overview, coding reference table, background and references updated Throughout policy: replaced "coverage criteria" with "criteria. Throughout the criteria, For Comprehensive Cardiomyopathy Panels: in I.B. changed "sudden unexplained cardiac death" to "sudden cardiac death or sudden unexplained death"; added in I.B.2. that the heart is normal. In Comprehensive Arrhythmia panels: I.A.1. and I.A.2., removed "unexplained" from "sudden unexplained cardiac death" and changed age 40 or younger to "before age 50 years; in I.A.2, removed verbiage of "additional family history of sudden unexplained cardiac death" and requirement that autopsy did not reveal a cause of death; added requirement that the deceased individual had family history of premature SCD or their death was suspicious for genetic heart disease; In I.B.1., added that the clinical tests were non-diagnostic "for reversible, ischemic, or structural causes." For Hypertrophic Cardiomyopathy Panels; Dilated Cardiomyopathy Panels: in I.B. changed "sudden unexplained cardiac death (SUDS) and autopsy AND" to "sudden cardiac death AND": I.B.2. added "Autopsy". Title of Panel "Right	12/23	2/27/24	

Reviews, Revisions, and Approvals	Revision Date	Approval Date	Effective Date
Ventricular Cardiomyopathy (ARVC)" changed to "Arrhythmogeic Cardiomyopathy". For Arrhythmogenic Cardiomyopathy Panels: in I. changed "right ventricular cardiomyopathy" to "cardiomyopathy"; in I.A. removed "a possible diagnosis of ARVC…" and added "any one of the following…". For Restrictive Cardiomyopathy Panels: in I. removed CPT code "81404"; in I.A. added "The member/enrollee has a confirmed…"; in I.A.2. changed "has a close blood relative with a clinical diagnosis of LQTS, whose genetic status is unknown" to "The member/enrollee had a blood relative with a clinical diagnosis of LQTS, whose genetic status is unknown"; in I.B. added "for example…"; in I.B.1. removed "The member/enrollee has a confirmed prolonged QTc…" and added "A cardiologist has established a strong clinical suspicion…"; in II. removed CPT code "81404". In Short QT Syndrome Panel: in I. removed "Short" and added "short QT syndrome (SQTS)…"; in II. added "other indications". For Brugada Syndrome: in I. removed "or multigene panel analysis…"; in I.A. replaced "has" with "meets" and removed "ECG patterns:"; in I.A.1., I.A.2 and I.A.3. changed "2 mm or larger" to "greater than or equal to 2 mm"; in I.B. added "Conditions causing a Brugada…"; in I.C.1. removed "documented ventricular" and added "Recurrent syncope, OR"; in I.B.2. added "ventricular"; in I.B.4. added "Cardiac arrest, OR"; in I.B.3. removed "OR"; in I.B.4. removed "Coved type…"; in I.B.5. removed "electrophysiologic…" and "Cardiac arrest"; in I.B.6. removed "Syncope…"; in II. added "Genetic testing for Brugada syndrome…"; in III. Removed "*SCN5A* variant…" and added "genese other than *SCN5A…"* and removed "for all other indications"; in III. Removed "Note: If a panel…". For Catecholaminergic Polymorphic Ventricular Tachycardia (CPVT) Panels: in I.A.2. removed "some individuals"; in I.A.5. added "bidirectional…". In Familial Hypercholesterolemia (FH) Panels: in I.A. added (see Background…)"; in I.A.3. added "***"; in II. removed statement regarding "**Dutch Lipid Clinic Network Criteria…"; in II. removed statement "***Make Early Diagnosis…". In Post Heart Transplant Gene Expression Panels for Rejection Risk Via Peripheral Blood Panels: in I.A. removed "is low risk…" and added "has undergone heart transplant…"; in I.B. added "The member/enrollee's heart transplant…"; in II. added "via peripheral blood". Added Post Heart Transplant Gene Expression Panels for Rejection Risk via Tissue and criteria. For Donor-Derived Cell-Free DNA for Heart Transplant Panels: removed contents from section I.A and I.B.. "The use of peripheral blood measurement…" and replaced with "The use of peripheral blood…"; added II. "The use of peripheral blood measurement…". Under Notes and Definitions: added 2. "A phenocopy…". Under Background and Rationale: removed "inheritance patterns" and replaced with "genetic testing". For Comprehensive Arrythmia Panels: removed "Asian Pacific and replaced with "European"; removed "*Society (APHRS)…*"; and added "*Association, Heart Rhythm Society*…" and added "The EHRA/HRS/APHRS/LAHRS 2022 expert…". For Comprehensive Arrhythmia & Cardiomyopathy (Sudden Cardiac or Unexplained Death) Panels: removed "For victims of sudden cardiac death (SCD)…"; added "While large unfocused gene panels are generally…". For Dilated Cardiomyopathy Panels: removed "American College of Medical Genetics and Genomics (ACMG)…" and added "*A European Heart Rhythm Association*…"; removed "Practice Guideline (2018)"; added "DCM is			

Reviews, Revisions, and Approvals	Revision Date	Approval Date	Effective Date
established when a patient has both left ventricular enlargement…". Arrhythmogenic Right Ventricular Panel replaced with Arrhythmogenic Cardiomyopathy Panels. For Arrhythmogenic Cardiomyopathy Panels: reference "Marcus" and "2010" removed and replaced with "Towbin" and "2019"; Major criteria I. removed "By 2D echo…" and replaced with "Echo…"; II. removed "By MRI…" and replaced with "MRI…"; added III. "RV Angiography…"; and removed III. "On endomyocardial biopsy…"; IV. removed "on EKG" and replaced with "and with…"; added V. "ECG"; under Minor Criteria I. removed "By 2D echo…" and added "Echo…"; in III. Added "Endomyocardial biopsy showing…" and removed " at least one" and replaced with "more than 1"; in IV. Added "ECG…"; in IV.B. removed "Late potential by signal averaged…"; in IV.C. added "Late potentials by SAECG…"; in IV.D. removed "Arrhythmia (any of the following):" and replaced with "RBBB". In Restrictive Cardiomyopathy Panels, Left Ventricular Non-Compaction Cardiomyopathy Panels and Long QT Syndrome Panels: removed "Heart Rhythm Society…". In Long QT Syndrome Panels: added "*American Heart Association*…"; removed "Mutation specific genetic testing…". In Short QT Syndrome Panels: removed "The Heart Rhythm Society…". Added Supplementary Table 9. Added Brugada Syndrome Panels along with clinical guidance, Catecholaminergic Polymorphic Ventricular Tachycardia Panels along with clinical guidance, Familial Hypercholesterolemia (FH) Panels along with clinical guidance. Removed "National Heart, Lung and Blood Institute…"; removed Table 1. Recommendations on Cardiovascular Health and Risk Reduction in Children and Adolescents. Post Heart Transplant Gene Expression Panels for Rejection Risk name updated to Post Heart Transplant Gene Expression Panels for Rejection Risk via Peripheral Blood. For Post Heart Transplant Gene Expression Panels for Rejection Risk via Peripheral Blood: removed "Guidelines"; added "2022"; removed "(Constanzo et al, 2010)" and added "for the Care of Heart Transplant Patients have"; removed "(Allomap) can be used to…". Added Post Heart Transplant Gene Expression Panels for Rejection Risk via Tissue. For Donor-Derived Cell-Free DNA for Heart Transplant RejectionL added "American Society of Transplant Surgeons…".			
Semi-annual review. Updated title to reflect V2.2024 version. For Known Familial Variant Analysis for Cardiac Disorders, moved criteria to policy "Genetic Testing: General Approach to Genetic and Molecular Testing" to consolidate criteria for known familial variant tests. For Left Ventricular Non-Compaction Cardiomyopathy Panels, retired criteria set based on rarity of testing. For Familial Hypercholesterolemia, removed criteria point requiring a definitive genetic diagnosis prior to medication eligibility. Minor rewording for clarity throughout. Coding, reference-table, background and references updated.	06/24	9/4/24	10/4/24
Semi-annual review. Updated title to reflect V1.2025 version. Restrictive Cardiomyopathy Panels: Removed panel testing note as this criteria is investigational. Post Heart Transplant Gene Expression Panels For Rejection Risk via Tissue: Updated page numbers for the ISHLT reference in the Background and Rationale from p. 62 and p. e33-34. Familial Hypercholesterolemia (FH) Panels: Removed "Genetic testing for FH should	1/25	3/31/25	5/1/25

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be offered to individuals of any age in whom a strong clinical index of suspicion for FH exists based on examination of the patient's clinical and/or family histories." from Background and Rationale section; Changed reference to 2018 American College of Cardiology Guidelines and created new criteria based on these guidelines; No changes to coverage; Updated formatting of coverage criteria to separate children and adults for ease of medical review; Updated Background and Rationale to include new reference information; Removed out of date reference. Long QT Syndrome (LQTS) Panels: Added reference: "Wilde AAM, Semsarian C, Márquez MF, et al. European Heart Rhythm Association/Heart Rhythm Society/Asia Pacific Heart Rhythm Society/Latin American Heart Rhythm Society expert consensus statement on the state of genetic testing for cardiac diseases. [published correction appears in Europace. 2022 Aug 30;:]. Europace. 2022;24(8):1307-1367. doi:10.1093/europace/euac030"; Removed reference: Al-Khatib SM, Stevenson WG, Ackerman MJ, et al. 2017 AHA/ACC/HRS Guideline for Management of Patients With Ventricular Arrhythmias and the Prevention of Sudden Cardiac Death: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines and the Heart Rhythm Society [published correction appears in Circulation. 2018 Sep 25;138(13):e419-e420]. Circulation. 2018;138(13):e272-e391. doi:10.1161/CIR.0000000000000549; Added to Background and Rationale: "European Heart Rhythm Association (EHRA)/Heart Rhythm Society (HRS)/Asia Pacific Heart Rhythm Society (APHRS)/Latin American Heart Rhythm Society (LAHRS); This expert consensus statement on the state of genetic testing for cardiac diseases published in 2022 by Wilde et al. states the following: "Molecular genetic testing for definitive disease associated genes (currently KCNQ1, KCNH2, SCN5A, CALM1, CALM2, and CALM3) should be offered to all index patients with a high probability diagnosis of LQTS, based on examination of the patient's clinical history, family history, and ECG characteristics obtained at baseline, during ECG Holter recording and exercise stress test (Schwartz Score 3.5)". (p. e.15) "In patients with an intermediate probability of LQTS (e.g. prolonged QTc with a Schwartz score 1.5–3.0), testing of genes with limited, disputed and refuted evidence should not be performed, while testing of the established genes may be considered, mostly to help rule out the diagnosis after extensive phenotypic investigation." Donor-Derived Cell-Free DNA for Heart Transplant Rejection: Updated Policy Reference Table to include 0493U - Prospera (Natera); Updated Concert Note in the Background and Rationale to state the following, "For routine monitoring of patients post-transplant, absent clear, specific and evidence-based guideline recommendations for a particular regimen of screening, a default frequency of coverage of once every 12 months will be adopted." Comprehensive Arrhythmia Panels: Updated language from, "The member has aborted sudden cardiac death" to, "The member has unexplained sudden cardiac arrest"; Added definition for Sudden cardiac arrest in Definitions section; Updated title of SUDS definition to "Sudden unexplained death (Sudden unexplained death syndrome, SUDS)"; Updated page numbers in Background and Rationale to reflect new numbering due to published correction; Updated references to include published correction of Wilde et al., 2022. Dilated Cardiomyopathy Panels: Updated reference to: "Wilde			

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AAM, Semsarian C, Márquez MF, et al. European Heart Rhythm Association/Heart Rhythm Society/Asia Pacific Heart Rhythm Society/Latin American Heart Rhythm Society expert consensus statement on the state of genetic testing for cardiac diseases. [published correction appears in Europace. 2022 Aug 30;:]. Europace. 2022;24(8):1307-1367. doi:10.1093/europace/euac030". Comprehensive Arrhythmia & Cardiomyopathy (Sudden Cardiac or Unexplained Death) Panels: Updated example test in Policy Reference Table. Brugada Syndrome Panels or SCN5A Variant Analysis: Updated reference in Policy Reference Table; Updated GeneReviews copyright dates in Reference list. Hypertrophic Cardiomyopathy Panels: Removed reference: "Authors/Task Force members, Elliott PM, Anastasakis A, et al. 2014 ESC Guidelines on diagnosis and management of hypertrophic cardiomyopathy: the Task Force for the Diagnosis and Management of Hypertrophic Cardiomyopathy of the European Society of Cardiology (ESC). Eur Heart J. 2014;35(39):2733-2779. doi:10.1093/eurheartj/ehu284"; Added language to Background and Rationale: "The ACC/AHA says HCM is “characterized predominantly by LVH in the absence of another cardiac, systemic, or metabolic disease capable… A clinical diagnosis of HCM in adult patients can therefore be established by imaging, with 2D echocardiography or cardiovascular magnetic resonance (CMR) showing a maximal end-diastolic wall thickness of greater than or equal to 15 mm anywhere in the left ventricle, in the absence of another cause of hypertrophy in adults. More limited hypertrophy (13–14 mm) can be diagnostic when present in family members of a patient with HCM or in conjunction with a positive genetic test. For children, the diagnostic criteria are confounded by needing to adjust for body size and growth. Traditionally, a body surface area adjusted z-score of 2 or more standard deviations above the mean has been used.” (p. e167); Postmortem testing for HCM-associated variants using blood or tissue collected at autopsy has been reported, particularly in instances where the family variant is unknown and no other affected family members are still living….identification of a likely pathogenic or pathogenic variant not only confirms the diagnosis of HCM but allows cascade genetic testing of other at-risk relatives as outlined previously.” (p. e184)". Catecholaminergic Polymorphic Ventricular Tachycardia (CPVT) Panels: Rearranged order of criteria for ease of use; Updated GeneReviews copyright dates in Reference list. Comprehensive Cardiomyopathy Panels: Formatting changes made to criteria based on client feedback; Updated Reference number in Policy Reference Table. Short QT Syndrome (SQTS) Panels: Formatting changes made to criteria based on client feedback; Updated reference to: "Wilde AAM, Semsarian C, Márquez MF, et al. European Heart Rhythm Association/Heart Rhythm Society/Asia Pacific Heart Rhythm Society/Latin American Heart Rhythm Society expert consensus statement on the state of genetic testing for cardiac diseases. [published correction appears in Europace. 2022 Aug 30;:]. Europace. 2022;24(8):1307-1367. doi:10.1093/europace/euac030".			
Annual review. Policy title updated from Concert Genetic Testing: Cardiac Disorders to Concert Genetic Testing: Cardiovascular. Minor rewording throughout without clinical significance. Hypertrophic Cardiomyopathy Panels: Removed criterion I.B allowing testing for members based on an	03/26		

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affected first-degree relative. Dilated Cardiomyopathy Panels: The criterion 1.B "The member has a first-degree relative with sudden cardiac death (SCD), AND Autopsy revealed a DCM phenotype." was removed; added the phrase "biventricular dilatation" to criterion A.1. Long QT Syndrome Panels and Short QT Syndrome Panels: Added the following footnote to clarify criteria IA2: "If a pathogenic or likely pathogenic variant has been identified in an explanatory gene in the affected family member, refer to the General Criteria for Known Familial Variant Analysis for a Genetic Condition within the General Policy for Laboratory Testing." Changed "Investigational" policy statements to note that "current evidence does not support…" Coding table, rationale and references updated			

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Important Reminder

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