

Familial Hypercholesterolemia Panel, Sequencing

Familial hypercholesterolemia (FH) is the most common inherited cardiovascular disease. It is characterized by markedly elevated low-density lipoprotein cholesterol (LDL-C) in the absence of an apparent secondary cause and premature atherosclerotic cardiovascular disease (ASCVD). Manifestations include coronary artery disease (CAD), cardiovascular disease (CVD), angina, myocardial infarction, xanthomas, and corneal arcus. Those with one parent with FH have a 50% chance of inheriting the condition, known as heterozygous FH (HeFH or FH).

Homozygous FH (HoFH) is a less common but more severe disorder, resulting from biallelic variants in a dominant FH-associated gene. If both parents have FH, their offspring have a 50% chance of having HeFH and a 25% chance of HoFH, which results from receiving two altered chromosomes. HoFH is characterized by severe early-onset CAD, aortic stenosis, and a high rate of coronary bypass surgery or death by teenage years. Treatment of FH commonly includes statins or lipid-lowering therapy with lifestyle modifications. FH is designated as a tier-1 genetic disorder by the CDC with proven benefit for case identification and family-based cascade screening.¹

Molecular testing may be used to confirm a diagnosis of FH in symptomatic individuals or for identification of at-risk relatives to ensure treatment prior to onset of ASCVD. Treatment guidelines for FH and HoFH have been published.²

Disease Overview

Associated Disorders

Heterozygous Familial Hypercholesterolemia

- LDL-C levels in untreated adults generally >190 mg/dL or total cholesterol >310 mg/dL
- LDL-C levels in untreated children or adolescents >160 mg/dL or total cholesterol >230 mg/dL
- History of premature CAD or other CVD
- Skin or tendon xanthomas
- Corneal arcus
- Family history of FH or clinical findings of FH
- Untreated men are at 50% risk for a coronary event by age 50 and untreated women are at 30% risk by age 60³
- FH accounts for approximately 2-3% of myocardial infarctions in those <60 years of age³
- Individuals with FH (LDL-C >190 mg/dL) and no FH variant are at an approximate sixfold increased risk for CAD, and those with FH and pathogenic FH mutation have an approximate 22-fold increased risk.⁴

Homozygous Familial Hypercholesterolemia

- LDL-C levels in untreated adults often >400 mg/dL
- LDL-C levels in untreated children or treated adults often lower and may not be sufficient to confirm diagnosis
- Xanthomas on tendons, around eyelids, between digits
- Severe CAD by mid-20s
- Aortic stenosis is common
- Treatment may include LDL apheresis

Tests to Consider

Familial Hypercholesterolemia Panel, Sequencing 3002110

Method: Massively Parallel Sequencing

Use to confirm a diagnosis of FH.

Familial Targeted Sequencing 3005867

Method: Massively Parallel Sequencing

- Testing for a known familial sequence variant by sequencing gene of interest. A copy of the family member's test result documenting the familial gene variant is REQUIRED.
- To determine if the variant(s) of interest are detectable by this assay, contact an ARUP genetic counselor at 800-242-2787.

See [Related Tests](#)

Typical Testing Strategy

Clinical diagnostic criteria for FH are established.^{5,6}

Screening can be performed via cholesterol testing, molecular testing, or both.

- LDL-C levels may overlap in FH and non-FH individuals, especially in adults.
- An estimated 20% of affected individuals may remain undiagnosed if only LDL-C levels are obtained.¹

Genetic testing should be offered when there is a strong clinical suspicion of FH based on clinical and/or a family history or to assess for a known pathogenic familial variant.⁴

Genetics

Genes

APOB, *LDLR*, *LDLRAP1*, *PCSK9*

Etiology

Approximately 7% of adults in the United States have severe hypercholesterolemia (untreated LDL-C >190 mg/dL) and approximately 2% of these individuals have a pathogenic identifiable FH variant.⁷

Mechanisms of pathogenesis by gene:

- *LDLR* variants cause impaired LDL receptor function or absence of LDL receptor.
- *APOB* gain-of-function variants affect binding of LDL particle to LDL receptor resulting in elevated LDL-C. This condition is also referred to as familial defective apoB and is clinically indistinguishable from FH. Loss-of-function variants in *APOB* are associated with hypobetalipoproteinemia.
- *PCSK9* gain-of-function variants may enhance affinity of PCSK9 protein binding with the LDL receptor, interfere with disassociation of LDL receptor/LDL complex, prevent recycling of receptor, or increase degradation of the LDL receptor. Loss-of-function variants are associated with hypocholesterolemia.
- *LDLRAP1* loss-of-function variants lead to absence of or nonfunctional LDL receptor adaptor protein 1, which prevents LDL receptor/LDL complex to be transported into the cell. This prevents the LDL receptor from effectively removing circulating LDL.

Penetrance

Estimated at 73-90% in individuals with molecularly confirmed FH

Influenced by gene, variant, and nongenetic factors

Prevalence

- FH: 1/250 in the general population
- HoFH: 1/200,000 in the general population
- Higher in specific founder populations

Inheritance

Autosomal dominant for *LDLR*-, *APOB*-, and *PCSK9*-associated FH; de novo variants are rare

Autosomal recessive for *LDLRAP1*-associated FH

HoFH results from biallelic variants in an autosomal dominant FH gene

Genotype-Phenotype Correlations

- LDL-C levels may be slightly lower with a pathogenic *APOB* variant compared to an *LDLR* variant.
- *LDLR* variants causing complete loss-of-function are associated with more severe disease and higher LDL-C levels than partial loss-of-function variants.
- *LDLRAP1*-associated disease typically has lipid levels between FH heterozygotes and HoFH.

Test Description

Clinical Sensitivity

Up to 85% for FH⁸

Influenced by pretest probability of FH using clinical diagnostic criteria

Contribution of genes to FH:

- *LDLR*: 60-80%
- *APOB*: <5%
- *PCSK9*: <1%
- *LDLRAP1*: very rare

Analytical Sensitivity

Majority of causative variants in the tested genes are sequence changes.

Large deletions/duplications in the tested genes account for ~5% of causative variants in many populations.

- In French Canadians, a large >15 kb *LDLR* deletion may account for 60% of FH cases and a 5 kb deletion for an additional 5%.

Variant Class	Analytical Sensitivity (PPA) Estimate ^a %	Analytical Sensitivity (PPA) 95% Credibility Region ^a (%)
SNVs	99.2	96.9-99.4
Deletions 1-10 bp	93.8	84.3-98.2
Deletions 11-44 bp	99.9	87.8-100
Insertions 1-10 bp	94.8	86.8-98.5
Insertions 11-23 bp	99.9	62.1-100

^aGenes included on this test are a subset of a larger methods-based validation from which the PPA values are derived.

bp, base pairs; PPA, positive percent agreement; SNVs, single nucleotide variants

Limitations

- A negative result does not exclude a diagnosis of FH.
- Diagnostic errors can occur due to rare sequence variations.
- Interpretation of this test result may be impacted if this patient has had an allogeneic stem cell transplantation.
- The following will not be evaluated:
 - Variants outside the coding regions and intron-exon boundaries of targeted gene(s)
 - Variant in regulatory and deep intronic regions
 - Large deletions/duplications/inversions in any of the tested genes

- Noncoding transcripts
- The following may not be detected:
 - Deletions/duplications/insertions of any size by massively parallel sequencing
 - Some variants due to technical limitations in the presence of pseudogenes, repetitive, or homologous regions
 - Low-level somatic variants

Genes Tested			
Gene	MIM #	Associated Disorder(s)	Inheritance
APOB	107730	Familial hypercholesterolemia 2	AD
		Familial hypobetalipoproteinemia 1	AR
LDLR	606945	Familial hypercholesterolemia 1	AD
LDLRAP1	605747	Familial hypercholesterolemia 4	AR
PCSK9	607786	Familial hypercholesterolemia 3	AD

AD, autosomal dominant; AR, autosomal recessive

References

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6. Lozano P, Henrikson NB, Dunn J, et al. [Lipid screening in childhood and adolescence for detection of familial hypercholesterolemia: a systematic evidence review for the U.S. Preventive Services Task Force](#). Rockville (MD): Agency for Healthcare Research and Quality (US); 2016. (Evidence Syntheses, No. 141.) Appendix D, Diagnostic Criteria for Familial Hypercholesterolemia. [Accessed: Mar 2020]
7. Khera AV, Won HH, Peloso GM, et al. [Diagnostic yield and clinical utility of sequencing familial hypercholesterolemia genes in patients with severe hypercholesterolemia](#). *J Am Coll Cardiol*. 2016;67(22):2578-2589.
8. Goldberg AC, Hopkins PN, Toth PP, et al. [Familial hypercholesterolemia: screening, diagnosis and management of pediatric and adult patients: clinical guidance from the National Lipid Association Expert Panel on Familial Hypercholesterolemia](#). *J Clin Lipidol*. 2011;5(3 Suppl):S1-S8.

Related Information

[Atherosclerotic Cardiovascular Disease Risk Markers](#)

Related Tests

[Lipid Panel 0020421](#)

Method: Quantitative Enzymatic

