2.04.107	Carrier Screening for Genetic Diseases		
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Section:	2.0 Medicine	**Page:**	Page 1 of 29

Policy Statement

Targeted Risk-Based Carrier Screening

Targeted carrier screening for X-linked and autosomal recessive genetic diseases for members who are pregnant or are considering pregnancy and are at increased risk of having offspring with an X-linked or autosomal recessive disease may be considered **medically necessary** when **one or more** of the following criteria is met:

I. One or both individuals have a first- or second-degree relative who is affected
II. One individual is known to be a carrier
III. One or both individuals are members of a population known to have a carrier rate that exceeds a threshold considered appropriate for testing for a particular condition

Note: Known autosomal dominant genetic diseases can usually be predicted for inheritance without testing, but may be needed when the situation is unclear.

AND **all** of the following are met:

A. The natural history of the disease is well understood and there is a reasonable likelihood that the disease is one with high morbidity or early mortality in the homozygous or compound heterozygous state (see Policy Guidelines)
B. Alternative biochemical or other clinical tests to definitively diagnose carrier status are not available, or, if available, provide an indeterminate result or are individually less efficacious than genetic testing
C. The genetic test has adequate clinical validity to guide clinical decision-making and residual risk is understood
D. An association of the marker with the disorder has been established
E. If targeted testing is performed by a panel, the panel should also either meet the criteria for non-targeted testing, or be limited to a single gene or small panel in addition to a non- targeted panel in unusual circumstances (see Policy Guidelines). Non-targeted panels can be used instead of targeted testing when the genes of interest are included in the non-targeted panel (see below)
F. Previous carrier screening or individual targeted gene testing for the gene variant(s) of interest has not been performed (see Policy Guidelines)

All targeted carrier screening not meeting any of the above criteria is considered **not medically necessary**.

Non-Targeted Carrier Screening

Expanded non-targeted or similar carrier screening panels for autosomal recessive and X-linked genetic disorders may be considered **medically necessary** as an alternative to testing of individual genes (e.g., *SMN1* gene and *CFTR* gene) for members who are pregnant or are considering pregnancy when **all** of the following criteria are met:

I. The natural history of each disease is well understood and there is reasonable likelihood that the disease is one with high morbidity or early mortality in the homozygous or compound homozygous state (see Policy Guidelines)
II. Alternative biochemical or other clinical tests to definitively diagnose carrier status are not available, or, if available, provide an indeterminate result or are individually less efficacious than genetic testing
III. The genetic test has adequate clinical validity to guide clinical decision-making and residual risk is understood
IV. An association of the markers with the disorders has been established
V. Previous carrier screening has not been performed (see Policy Guidelines)
VI. All testing must include CFTR and SMN1 genes

Non-targeted carrier screening panels other than meeting the criteria for and billed as 81443 (see Policy Guidelines and Coding Sections) are considered **investigational** in all other situations when above criteria are not met (see Policy Guidelines).

NOTE: Refer to Appendix A to see the policy statement changes (if any) from the previous version.

Policy Guidelines

Note: First-degree relatives include biological parent, brother, sister, or child; second-degree relatives include biologic grandparent, aunt, uncle, niece, nephew, grandchildren, and half-sibling.

The expanded panel should include carrier testing for spinal muscular atrophy (SMN1 gene) and cystic fibrosis (CFTR gene). Such panels are preferred as an alternative to testing of individual genes for all women who are pregnant or are considering pregnancy. Some larger panels can also be approved if the request is only for CPT 81443. Claims for panel testing should reflect the CPT code closest to the panel being ordered. Claims submitted using individual gene codes rather than the appropriate panel code is considered to be unbundling and improper coding.

Screening for Cystic Fibrosis (CTFR, CPT code 81220) and Spinal Muscular Atrophy (SMN1, CPT code 81401 or G0452) are recommended for all women who are pregnant or considering pregnancy (see Policy Guidelines).

Screening for Tay-Sachs disease (HEXA) and Fragile X syndrome (FMR1) can be based on the risk from the family history. HEXA is usually part of the 81443 panel, SMN1 and FMR1 can be excluded from the 81443 panel (by CPT guidelines) but are required as part of any large panel using 81443 and are not to be billed separately.

In addition, 8 of the 9 genes in the panel 81412 for Ashkenazi Jewish associated disorders are included in the usual panel 81443. Since 81412 does not include CFTR, SNM1 or other genes needed for a carrier panel , 81412 should not be used either instead of or in addition to 81443 for carrier screening.

See Appendix 1 for definitions and related genetic testing nomenclature. A list of higher volume tests and the associated laboratories with commonly associated CPT and ICD-10 codes is provided in Appendix 2.

Carrier screening (targeted or non-targeted) is only medically necessary once per lifetime. Exceptions may be considered if advances in technology support medical necessity for retesting.

Targeted carrier screening for autosomal recessive or X-linked conditions can also be called risk-based test or ethnic-based testing. If targeted testing is performed by a panel, the most appropriate panel code available should be used. The testing should include what would usually be offered for non-targeted testing (including CFTR and SNM1) and additional targeted testing would only be added if an appropriate non-targeted panel does not include the genes of interest. If the carrier screening test is a panel less than 15 genes and does not include *CFTR* or *SMN1*, but would be 15 or more genes if including *CFTR* or *SMN1*, then it should be coded with 81443 (see Codes section). Panels closely resembling 81443 should be billed using 81443 rather than billing individually (i.e., unbundling).

Non-targeted carrier screening applies to persons of any risk including average risk. Panels should typically use 81443 for non-targeted carrier screening and must include the *CFTR* and *SMN1* genes. Non-targeted carrier screening panels should usually include the minimum number of genes but not exceed the maximum number of genes recommended by professional guidelines from the American College of Obstetricians and Gynecologists (ACOG; 2-22

conditions) or the American College of Medical Genetics and Genomics (ACMG; 113 genes) but there is no specific limitation.

The ACOG Committee Opinion 690 (reaffirmed in 2020) states that "Ethnic-specific, panethnic, and expanded carrier screening are acceptable strategies for prepregnancy and prenatal carrier screening" and offered the following summary pertaining to expanded carrier screening: "Given the multitude of conditions that can be included in expanded carrier screening panels, the disorders selected for inclusion should meet several of the following consensus-determined criteria: have a carrier frequency of 1 in 100 or greater, have a well-defined phenotype, have a detrimental effect on quality of life, cause cognitive or physical impairment, require surgical or medical intervention, or have an onset early in life. Additionally, screened conditions should be able to be diagnosed prenatally and may afford opportunities for antenatal intervention to improve perinatal outcomes, changes to delivery management to optimize newborn and infant outcomes, and education of the parents about special care needs after birth. Carrier screening panels should not include conditions primarily associated with a disease of adult onset."[1.]

The ACOG guideline includes a list of 22 conditions deemed reasonable to include in a carrier screening panel (see Appendix 2). While there is no agreed upon definition of severity across professional societies, these 22 conditions have severity that would be deemed profound or severe per publication based on previous work by ACMG and cited by the most recent ACMG guidelines.[2.3.] All but one condition deemed reasonable by ACOG (alpha-thalassemia) would be classified as profound or severe based on collaborative clinical expert application of a trait-based algorithm;[4.] however, in this work it is not clear if the alpha-thalassemia genes *HBA1/HBA2* were classified based on hemoglobin Bart hydrops fetalis syndrome or hemoglobin H disease. Carrier testing of autosomal recessive genes associated with severe disease with carrier frequency of greater than 1/100 is estimated to identify 82% of at-risk couples.[5.]

In 2021, the ACMG recommended that the phrase "expanded carrier screening" be replaced by "carrier screening" as expanded carrier screening is not well or precisely defined by professional organizations.[3.] Previously, ACMG has defined expanded panels as those that use next-generation sequencing to screen for variants in many genes, as opposed to gene-by-gene screening (e.g., ethnic-specific screening or panethnic testing for cystic fibrosis). The use of "code stacking" or submitting requests for multiple single genes (instead of using the panel code 81443) will be considered an expanded panel and therefore treated as investigational. Individual genes that might otherwise be approved will not be covered when submitted in this fashion with multiple other CPT codes that indicate a panel is being used. Only 81220 (for CFTR) and 81401 (molecular pathology level 2 used for SMN1 or G0452) can be allowed when requested as separate single gene testing. Other single gene testing is only allowed when all the criteria in the Policy Statement above are met to show high risk for a particular disease.

Expanded panels may include the diseases that are present with increased frequency in specific populations, but typically include testing for a wide range of diseases for which the patient is not at risk of being a carrier.

The updated ACMG guideline now recommends a multi-tier approach to carrier screening for autosomal recessive and X-linked conditions,[3.] incorporating recommendations from the ACOG Committee Opinion 691 (2017),[6.] to enhance communication and precision while advancing equity in carrier screening (see Table PG1).[3.] The consensus group recognized no accepted standard in defining the severity of various conditions; and, based off previously published work[2.] use the following definitions: (1) profound: shortened lifespan during infancy or childhood, intellectual disability; (2) severe: death in early adulthood, impaired mobility or a [disabling] malformation involving an internal organ; (3) moderate: neurosensory impairment, immune deficiency or cancer, mental illness, dysmorphic features; and (4) mild: not meeting one of those described.

The ACMG consensus group recommends offering Tier 3 carrier screening (≥1/200 carrier frequency + Tier 2; see Table PG1) to all pregnant patients and those planning a pregnancy. Carrier testing of autosomal recessive genes associated with severe disease with carrier frequency greater than 1/100 is estimated to identify 82% of at-risk couples, and identify 93% of at-risk couples when testing for genes with greater than 1/200 carrier frequency.[5] The ACMG Tier 3 recommendations were based on estimates that moving from Tier 2 (≥1/100 carrier frequency) to Tier 3 (1/200 carrier frequency) provided additional identification of 4-9/10,000 at-risk couples depending on the endogamous population examined. When the population evaluated was weighted by U.S. census data, at-risk couples identified increased by 6 per 10,000 couples when moving from the Tier 2 (≥1/100) carrier frequency to that of Tier 3 (≥1/200). Assuming ~4 million births per year, this translates to an annual increase of identifying 2,400 additional U.S. couples.

The ACMG consensus group specified gene recommendations which include testing for 97 autosomal recessive genes and 16 X-linked genes, all of which associate with disorders of moderate, severe, or profound severity and are of 1/200 or greater carrier frequency. Non-targeted carrier screening panels that test for genes beyond this provide diminishingly small results, and pleiotropy, locus heterogeneity, variant interpretation, and poor genotype-phenotype correlation may disproportionately impact the ability to provide accurate prognostic information.[3]

Additionally, the recommendations include that male partners of pregnant women and those planning a pregnancy may be offered Tier 3 carrier screening for autosomal recessive conditions when carrier screening is performed simultaneously with their female partner. Tier 4 screening may be offered when a pregnancy stems from a known or possible consanguineous relationship (second cousins or closer) or when family or personal medical history warrants. The ACMG does not recommend offering Tier 1 and/or Tier 2 screening, because these do not provide equitable evaluation of all racial/ethnic groups, or the routine offering of Tier 4 panels.

Testing Strategy
After testing the proband, targeted testing on the reproductive partner is preferred. Testing only applies to genes meeting criteria outlined above. If a lab does a more extensive test, then testing for other findings in the reproductive partner would not meet criteria. In general, carrier screening can be done once per lifetime. However, if only targeted or limited testing was done previously, then a more general non-targeted panel could be performed, particularly in cases where there is a new reproductive partner. In this case it is likely that genes could be re-tested.

Table PG1. American College of Medical Genetics and Genomics Tiered Approach to Carrier Screening[3]

Tier	Screening Recommendations
1	Cystic fibrosis + spinal muscular atrophy + risk-based screening
2	≥1/100 carrier frequency + Tier 1
3	≥1/200 carrier frequency + Tier 2 (includes X-linked conditions)
4	<1/200 carrier frequency + Tier 3 (genes and conditions will vary by laboratory)

ACMG: American College of Medical Genetics and Genomics

X-linked genes considered appropriate for carrier screening in Tier 3 include: *ABCD1, AFF2, ARX, DMD, F8, F9, FMR1, GLA, L1CAM, MID1, NR0B1, OTC, PLP1, RPGR, RS1, and SLC6A8.* Refer to Tables 1 through 5 in the ACMG position statement for additional details regarding appropriate autosomal recessive conditions and their associated carrier frequencies. Additional details are available in the Supplemental Information section.

Carrier screening should only be performed in adults.

Targeted Risk-Based Screening Recommendations
ACOG and ACMG have issued numerous guidelines on targeted risk-based screening (see Table PG2).

Table PG2. ACOG and ACMG Recommendations for Risk-Based Screening

Society	Recommendation	Year
Cystic fibrosis[a] (*CTFR*)		
ACOG	"Cystic fibrosis carrier screening should be offered to all women considering pregnancy or are pregnant."[9]	2017
ACMG	Current ACMG guidelines use a 23-variant panel and were developed after assessing the initial experiences on implementation of cystic fibrosis screening into clinical practice. Using the 23-variant panel, the detection rate is 94% in the Ashkenazi Jewish population and 88% in the non-Hispanic white general population.[10]	2013
Spinal muscular atrophy[b] (*SMN1*)		
ACOG	"Screening for spinal muscular atrophy should be offered to all women considering pregnancy or are pregnant. In patients with a family history of spinal muscular atrophy, molecular testing reports of the affected individual and carrier testing of the related parent should be reviewed, if possible, before testing. If the reports are not available, SMN1 deletion testing should be recommended for the low-risk partner."[9]	2017
ACMG	Because spinal muscular atrophy is present in all populations, carrier testing should be offered to all couples regardless of race or ethnicity.[11]	2013
Tay-Sachs disease (*HEXA*)		
ACOG	"Screening for Tay-Sachs disease should be offered when considering pregnancy or during pregnancy if either member of a couple is of Ashkenazi Jewish, French-Canadian, or Cajun descent. Those with a family history consistent with Tay-Sachs disease should also be screened"[9]	2017
Fragile X syndrome (*FMR1*)		
ACOG	"Fragile X premutation carrier screening is recommended for women with a family history of fragile X-related disorders or intellectual disability suggestive of fragile X syndrome and who are considering pregnancy or are currently pregnant. If a woman has unexplained ovarian insufficiency or failure or an elevated follicle-stimulating hormone level before age 40 years, fragile X carrier screening is recommended to determine	2017

Society	Recommendation	Year
	whether she has an FMR1 premutation."[9]	

ACMG: American College of Medical Genetics and Genomics; ACOG: American College of Obstetricians and Gynecologists.[a] Carrier rates: Ashkenazi Jews 1/24, non-Hispanic white 1/25, Hispanic white 1/58, African American 1/61, Asian American 1/94.
[b] General population carrier rate: 1/40 to 1/60.
Gene names provided by the following:

- The National Institutes of Health (NIH), a part of the U.S. Department of Health and Human Services. Genetics Home Reference: Your Guide to Understanding Genetic Conditions; Health Conditions. https://ghr.nlm.nih.gov/
- OMIM® - Online Mendelian Inheritance in Man®. http://omim.org/about

ACOG[9] and ACMG[12] provided recommendations specific to individuals of Ashkenazi Jewish descent due to high carrier rates for multiple conditions in this population (see Table PG3). According to ACMG, if only 1 member of the couple is Jewish, ideally, that individual should be tested first. If the Jewish partner has a positive carrier test result, the other partner (regardless of ethnic background) should be screened for that particular disorder. One Jewish grandparent is sufficient to offer testing.

Table PG3.ACMG (2008, 2013) and ACOG (2017) Carrier Screening Recommendations for Individuals of Ashkenazi Jewish Descent[9, 12]

Condition	Incidence (Lifetime)	Carrier Rate	ACMG (2008, 2013)	ACOG (2017)
Tay-Sachs disease (*HEXA*)	1/3000	1/30	R	R
Canavan disease (*ASPA*)	1/6400	1/40	R	R
Cystic fibrosis (*CTFR*)	1/2500-3000	1/29	R	R
Familial dysautonomia (*ELP1*)	1/3600	1/32	R	R
Fanconi anemia (group C) (*FANCC*)	1/32,000	1/89	R	C
Niemann-Pick disease type A (*SMPD1*)	1/32,000	1/90	R	C
Bloom syndrome (*BLM*)	1/40,000	1/100	R	C
Mucolipidosis IV (*MCOLN1*)	1/62,500	1/127	R	C
Gaucher disease (*GBA*)	1/900	1/15	R	C
Familial hyperinsulinism (*ABCC8, KCNJ11*)		1/52		C
Glycogen storage disease type I (*G6PC, SLC37A4*)		1/71		C
Joubert syndrome (*AHI1, ARL3, ARL13B, ARMC9, B9D1, B9D2, C2CD3, C5ORF42, CC2D2A , CEP41, CEP104, CEP120, CEP290, CPLANE1,*		1/92		C

Condition	Incidence (Lifetime)	Carrier Rate	ACMG (2008, 2013)	ACOG (2017)
***CSPP1, CXORF5, IFT172, INPP5E, KIAA0556, KIAA0586, KIF7, MKS1, NPHP1, OFD1, PDE6D, PIBF1, POC1B, RPGRIP1L, SUFU, TCTN1, TCTN2, TCTN3, TMEM67, TMEM107, TMEM138, TMEM216, TMEM231, TMEM237, TTC21B, ZNF423*)**				
Maple syrup urine disease (*BCKDHA, BCKDHB, DBT*)		1/81		C
Usher syndrome (*MYO7A, CDH23, USH2A, CLRN1)*		<= 1/40		C

ACMG: American College of Medical Genetics and Genomics; ACOG: American College of Obstetricians and Gynecologists; C: should be considered; R: recommended.
Gene names provided by the following:

- The National Institutes of Health (NIH), a part of the U.S. Department of Health and Human Services. Genetics Home Reference: Your Guide to Understanding Genetic Conditions; Health Conditions. https://ghr.nlm.nih.gov/

OMIM® - Online Mendelian Inheritance in Man®. http://omim.org/about

Genetic Counseling

Genetic counseling is primarily aimed at patients who are at risk for inherited disorders, and experts recommend formal genetic counseling in most cases when genetic testing for an inherited condition is considered. The interpretation of the results of genetic tests and the understanding of risk factors can be very difficult and complex. Therefore, genetic counseling will assist individuals in understanding the possible benefits and harms of genetic testing, including the possible impact of the information on the individual's family. Genetic counseling may alter the utilization of genetic testing substantially and may reduce inappropriate testing. Genetic counseling should be performed by an individual with experience and expertise in genetic medicine and genetic testing methods. Carrier screening with appropriate genetic counseling is performed in adults.

Genetics Nomenclature Update

Human Genome Variation Society (HGVS) nomenclature is used to report information on variants found in DNA and serves as an international standard in DNA diagnostics. It is being implemented for genetic testing medical evidence review updates starting in 2017 (see Table PG4). HGVS nomenclature is recommended by HGVS, the Human Variome Project, and the Human Genome Organization (HUGO).

The ACMG and Association for Molecular Pathology (AMP) standards and guidelines for interpretation of sequence variants represent expert opinion from ACMG, AMP, and the College of American Pathologists. These recommendations primarily apply to genetic tests used in

clinical laboratories, including genotyping, single genes, panels, exomes, and genomes. Table PG5 shows the recommended standard terminology-"pathogenic," "likely pathogenic," "uncertain significance," "likely benign," and "benign"-to describe variants identified that cause Mendelian disorders.

Table PG4. Nomenclature to Report on Variants Found in DNA

Previous	Updated	Definition
Mutation	Disease-associated variant	Disease-associated change in the DNA sequence
	Variant	Change in the DNA sequence
	Familial variant	Disease-associated variant identified in a proband for use in subsequent targeted genetic testing in first-degree relatives

Table PG5. American College of Medical Genetics and Genomics-Association for Molecular Pathology Standards and Guidelines for Variant Classification

Variant Classification	Definition
Pathogenic	Disease-causing change in the DNA sequence
Likely pathogenic	Likely disease-causing change in the DNA sequence
Variant of uncertain significance	Change in DNA sequence with uncertain effects on disease
Likely benign	Likely benign change in the DNA sequence
Benign	Benign change in the DNA sequence

Coding

Please see the Codes table for details.
The following CPT code describes Genetic testing for severe inherited conditions:

- **81443**: Genetic testing for severe inherited conditions (e.g., cystic fibrosis, Ashkenazi Jewish-associated disorders [e.g., Bloom syndrome, Canavan disease, Fanconi anemia type C, mucolipidosis type VI, Gaucher disease, Tay-Sachs disease], beta hemoglobinopathies, phenylketonuria, galactosemia), genomic sequence analysis panel, **must include** sequencing of at least 15 genes (e.g., ACADM, ARSA, ASPA, ATP7B, BCKDHA, BCKDHB, BLM, CFTR, DHCR7, FANCC, G6PC, GAA, GALT, GBA, GBE1, HBB, HEXA, IKBKAP, MCOLN1, PAH)

If CPT tier 1 or tier 2 molecular pathology codes are available for the specific test, they should be used. If the test has not been codified by CPT, the following code would be used:

- **81479**: Unlisted molecular pathology procedure

The following is a specific CPT code for a genomic sequencing panel for Ashkenazi Jewish–associated disorders:

- **81412:** Ashkenazi Jewish associated disorders (e.g., Bloom syndrome, Canavan disease, cystic fibrosis, familial dysautonomia, Fanconi anemia group C, Gaucher disease, Tay-Sachs disease), genomic sequence analysis panel, **must include** sequencing of at least 9 genes, including *ASPA*, *BLM*, *CFTR, FANCC*, *GBA*, *HEXA*, *IKBKAP*, *MCOLN1*, *and SMPD1*

Description

Carrier screening is performed to identify individuals at risk of having offspring with inherited recessive single-gene disorders. Carriers are usually not at risk of developing the disease but can pass pathogenic variants to their offspring. Carrier testing may be performed in the prenatal or preconception periods.

Related Policies

- Genetic Testing for Mitochondrial Disorders
- Germline Genetic Testing for BRCA1 or BRCA2 for Hereditary Breast/Ovarian Cancer Syndrome and Other High-Risk Cancers

- Invasive Prenatal (Fetal) Diagnostic Testing
- Preimplantation Genetic Testing

Benefit Application

Benefit determinations should be based in all cases on the applicable contract language. To the extent there are any conflicts between these guidelines and the contract language, the contract language will control. Please refer to the member's contract benefits in effect at the time of service to determine coverage or non-coverage of these services as it applies to an individual member.

Some state or federal mandates (e.g., Federal Employee Program [FEP]) prohibits plans from denying Food and Drug Administration (FDA)-approved technologies as investigational. In these instances, plans may have to consider the coverage eligibility of FDA-approved technologies on the basis of medical necessity alone.

Regulatory Status

Clinical laboratories may develop and validate tests in-house and market them as a laboratory service; laboratory-developed tests must meet the general regulatory standards of the Clinical Laboratory Improvement Amendments. Laboratories that offer laboratory-developed tests must be licensed by Clinical Laboratory Improvement Amendments for high-complexity testing. To date, the U.S. Food and Drug Administration has chosen not to require any regulatory review of this test.

A number of commercially available genetic tests exist for carrier screening. They range from testing for individual diseases to small panels designed to address testing based on ethnicity as recommended by practice guidelines (ACOG, ACMG), to large non-targeted panels that test for numerous diseases.

Rationale

Background

Inherited Recessive Disorders

There are more than 1300 inherited recessive disorders (autosomal or X-linked) that affect 30 out of every 10,000 children.[7,] Some diseases have limited impact on either length or quality of life, while others are uniformly fatal in childhood.

Targeted Carrier Screening

Carrier screening tests asymptomatic individuals in order to identify those who are heterozygous for serious or lethal single-gene disorders. The purpose of screening is to determine the risk of conceiving an affected child and "to optimize pregnancy outcomes based on ... personal preferences and values."[8,] Risk-based carrier screening is performed in individuals having an increased risk based on population carrier prevalence, or personal or family history. Conditions selected for screening can be based on ethnicities at high-risk or may be panethnic. An example of effective ethnicity-based screening involves Tay-Sachs disease, with a 90% reduction in the disease following the introduction of carrier screening in the 1970s in the U.S. and Canada.[9,] An example of panethnic screening involves cystic fibrosis when the American College of Obstetricians and Gynecologists (ACOG) noted that ethnic intermarriage was increasing in the U.S.[10,11,] and recommended panethnic cystic fibrosis carrier screening in 2005.[12,]

Non-targeted Carrier Screening

Non-targeted carrier screening involves screening individuals or couples for disorders in many genes (up to 100s) by next-generation sequencing. Non-targeted carrier screening panels may screen for diseases that are present with increased frequency in specific populations but also

include a wide range of diseases for which the patient is not at increased risk of being a carrier. Arguments for non-targeted carrier screening include the potential to assess ethnicity, identify more potential conditions, efficiency, and cost. The conditions included in non-targeted carrier screening panels are not standardized and the panels may include many conditions not routinely evaluated and for which there are no existing professional guidelines.

This evidence review applies only if there is no separate evidence review that outlines specific criteria for carrier screening. If a separate evidence review exists, then criteria for medical necessity in that evidence review supersede the guidelines herein.

Carrier screening for mitochondrial disorders associated with autosomal recessive inheritance of nuclear DNA variants is addressed in this review. Diagnostic genetic testing for mitochondrial disorders and carrier testing of known familial variants associated with mitochondrial disorders are addressed in Blue Shield of California Medical Policy: Genetic Testing for Mitochondrial Disorders

Literature Review
Evidence reviews assess whether a medical test is clinically useful. A useful test provides information to make a clinical management decision that improves the net health outcome. That is, the balance of benefits and harms is better when the test is used to manage the condition than when another test or no test is used to manage the condition.

The first step in assessing a medical test is to formulate the clinical context and purpose of the test. The test must be technically reliable, clinically valid, and clinically useful for that purpose. Evidence reviews assess the evidence on whether a test is clinically valid and clinically useful. Technical reliability is outside the scope of these reviews, and credible information on technical reliability is available from other sources.

Targeted Risk-based Carrier Screening
Clinical Context and Test Purpose
The purpose of targeted risk-based carrier screening is to identify asymptomatic individuals who are heterozygous for serious or lethal single-gene disorders with the purpose of determining the risk of conceiving an affected child and inform reproductive decisions.

The question addressed in this evidence review is: Does the use of targeted risk-based carrier screening improve the net health outcome of asymptomatic individuals at risk of having offspring with inherited gene disorders?

The following PICO was used to inform literature selection.

Populations
The relevant population of interest are individuals or couples at risk for having offspring with inherited genetic disorders due to family history, ethnicity, or race.

Interventions
The intervention of interest is targeted risk-based carrier screening with genes or focused gene panels specific to risk, for example, a Jewish Askenazi panel.

Comparators
The comparator of interest is no carrier screening.

Outcomes
The primary outcome of interest is reproductive decision making.

A beneficial outcome of a true test result is an informed reproductive decision that is consistent with the prospective parent(s)' personal preferences and values. Informed reproductive

decisions can include those concerning preimplantation genetic diagnosis, in vitro fertilization, not having a child, invasive prenatal testing, adoption, or pregnancy termination.

A harmful outcome is a reproductive decision based on an incorrect test or assessment of the genotype-phenotype relationship. A false-positive result or incorrect genotype-phenotype association could lead to avoiding or terminating a pregnancy unnecessarily. A false-negative test could lead to an affected offspring.

Study Selection Criteria

For the evaluation of the clinical utility of targeted risk-based carrier screening for genetic disorders, studies would need to use the test to inform reproductive decisions in asymptomatic individuals who are at risk of having an offspring with inherited recessive single-gene disorders. In addition, because the American College of Obstetricians and Gynecologists (ACOG) and the American College of Medical Genetics and Genomics (ACMG) consider risk-based carrier screening an established practice, guideline recommendations from these organizations will also be included in the evidence discussion.

Clinically Valid

A test must detect the presence or absence of a condition, the risk of developing a condition in the future, or treatment response (beneficial or adverse). The clinical validity of a carrier screening test is evaluated by its ability to predict carrier status. Clinical validity is influenced by carrier prevalence, penetrance, expressivity, and environmental factors.[7,] Different variants in the same gene can result in different phenotypes (allelic heterogeneity) in most genetic disorders and impact clinical validity. Depending on the assay method (e.g., next-generation sequencing, microarray), clinical sensitivity and predictive values vary according to the proportion of known pathogenic variants evaluated. Clinical sensitivity will vary according to the number of known variants tested. Additionally, not all testing strategies rely solely on genetic testing-e.g., biochemical testing (hexosaminidase A) may be the initial test to screen for Tay-Sachs carrier status and blood counts for hemoglobinopathies. Finally, following a negative carrier screening test, the estimated residual risk of being a carrier reflects both the pretest probability (e.g., estimated carrier prevalence in the population) and clinical validity (test clinical sensitivity and specificity). Consequently, limitations in clinical validity are quantified in residual risk estimates.

Review of Evidence

Targeted Risk-Based Screening Recommendations

The ACOG and ACMG have issued numerous guidelines on targeted risk-based screening (see Table 1).

Table 1. American College of Obstetricians and Gynecologists and American College of Medical Genetics and Genomics Recommendations for Risk-Based Screening

Society	Recommendation	Year
Cystic fibrosis[a]		
ACOG	"Cystic fibrosis carrier screening should be offered to all women considering pregnancy or are pregnant."[6,]	2017
ACMG	Current ACMG guidelines use a 23-variant panel and were developed after assessing the initial experiences on implementation of cystic fibrosis screening into clinical practice. Using the 23-variant panel, the detection rate is 94% in the Ashkenazi Jewish population and 88% in the non-Hispanic white general population.[13,]	2013
Spinal muscular atrophy[b]		
ACOG	"Screening for spinal muscular atrophy should be offered to all women considering pregnancy or are pregnant. In patients with a family history of spinal muscular atrophy, molecular testing reports of the affected individual and carrier testing of the related parent should be reviewed, if possible, before testing. If the reports are not available, SMN1 deletion testing should be recommended for the low-risk partner."[6,]	2017

Society	Recommendation	Year
ACMG	Because spinal muscular atrophy is present in all populations, carrier testing should be offered to all couples regardless of race or ethnicity.[14]	2013
Tay-Sachs disease		
ACOG	"Screening for Tay-Sachs disease should be offered when considering pregnancy or during pregnancy, if either member of a couple is of Ashkenazi Jewish, French-Canadian, or Cajun descent. Those with a family history consistent with Tay-Sachs disease should also be screened"[6]	2017
Fragile X syndrome		
ACOG	"Fragile X premutation carrier screening is recommended for women with a family history of fragile X-related disorders or intellectual disability suggestive of fragile X syndrome and who are considering pregnancy or are currently pregnant. If a woman has unexplained ovarian insufficiency or failure or an elevated follicle-stimulating hormone level before age 40 years, fragile X carrier screening is recommended to determine whether she has an *FMR1* premutation."[6]	2017

ACMG: American College of Medical Genetics and Genomics; ACOG: American College of Obstetricians and Gynecologists.
[a] Carrier rates: Ashkenazi Jews 1/24, non-Hispanic white 1/25, Hispanic white 1/58, African American 1/61, Asian American 1/94.
[b] General population carrier rate: 1/40 to 1/60.

The ACOG[6] and the ACMG[15] provided recommendations specific to individuals of Ashkenazi Jewish descent due to high carrier rates for multiple conditions in this population (see Table 2). According to ACMG, if only one member of the couple is Jewish, ideally, that individual should be tested first. If the Jewish partner has a positive carrier test result, the other partner (regardless of ethnic background) should be screened for that particular disorder. One Jewish grandparent is sufficient to offer testing.

Table 2. American College of Medical Genetics and Genomics (2008, 2013) and American College of Obstetricians and Gynecologists (2017) Carrier Screening Recommendations for Individuals of Ashkenazi Jewish Descent[6,15]

Condition	Incidence (Lifetime)	Carrier Rate	ACMG (2008, 2013)	ACOG (2017)
Tay-Sachs disease	1/3000	1/30	R	R
Canavan disease	1/6400	1/40	R	R
Cystic fibrosis	1/2500-3000	1/29	R	R
Familial dysautonomia	1/3600	1/32	R	R
Fanconi anemia (group C)	1/32,000	1/89	R	C
Niemann-Pick disease type A	1/32,000	1/90	R	C
Bloom syndrome	1/40,000	1/100	R	C
Mucolipidosis IV	1/62,500	1/127	R	C
Gaucher disease	1/900	1/15	R	C
Familial hyperinsulinism		1/52		C
Glycogen storage disease type I		1/71		C
Joubert syndrome		1/92		C
Maple syrup urine disease		1/81		C
Usher syndrome		≤1/40		C

ACMG: American College of Medical Genetics and Genomics; ACOG: American College of Obstetricians and Gynecologists; C: should be considered; R: recommended.

Clinically Useful

A test is clinically useful if the use of the results informs management decisions that improve the net health outcome of care. The net health outcome can be improved if patients receive correct therapy, or more effective therapy, or avoid unnecessary therapy, or avoid unnecessary testing.

Direct Evidence

Direct evidence of clinical utility is provided by studies that have compared health outcomes for patients managed with and without the test. Because these are intervention studies, the preferred evidence would be from randomized controlled trials.

Chain of Evidence

Indirect evidence on clinical utility rests on clinical validity. If the evidence is insufficient to demonstrate test performance, no inferences can be made about clinical utility.

Review of Evidence

The clinical utility of carrier screening is defined by the extent to which reproductive decision making or choices are informed (i.e., increases "reproductive autonomy and choice"[7.]). Evidence to support the clinical utility of carrier screening for conditions with the highest carrier rates (e.g., Tay-Sachs disease, cystic fibrosis [CF]) among specific ethnic groups is robust concerning the effect on reproductive decision making.[9,16,17,18.] For example, early studies of Tay-Sachs carrier screening in Ashkenazi Jews demonstrated a marked impact on reproductive decisions[16,18.] and, after some 4 decades of ethnicity-based carrier screening, most Tay-Sachs disease cases occur in non-Jewish individuals.[17.] As another example, a 2014 systematic review of CF carrier screening found that while individual carrier status "did not affect reproductive intentions or behaviors," most couple carriers terminated affected fetuses.[19.] For inherited single-gene disorders where carrier rates are of similar magnitude, recommendations to offer screening have a convincing rationale, even if partially based indirectly on results from other conditions. One caveat is that family history, ethnicity, and race are self-reported, and may not be completely accurate, particularly in multi-ethnic and multi-racial societies.[20.],

Section Summary: Targeted Risk-Based Carrier Screening

Risk-based carrier screening involves testing for a defined set of pathogenic variants for specified conditions. The clinical validity is sufficiently defined and reflected in the estimated residual risk. Numerous studies have shown that reproductive decisions were affected by results from targeted risk-based carrier screening. In addition, ACOG and ACMG consider risk-based carrier screening an established practice and have issued guidance on targeted risk-based screening. There is sufficient evidence to support the clinical utility of targeted risk-based screening.

Non-targeted Carrier Screening

Clinical Context and Test Purpose

The purpose of non-targeted carrier screening is to identify asymptomatic individuals who are heterozygous for serious or lethal recessive single-gene disorders with the purpose of determining the risk of conceiving an affected child and inform reproductive decisions. Non-targeted carrier screening panels screen for carrier status in a prospective or expectant parent for multiple conditions for which that individual is not known to be at risk based on family history or ethnic background.

The question addressed in this evidence review is: Does the use of non-targeted carrier screening improve the net health outcome of asymptomatic individuals at either an increased risk or population risk of having offspring with inherited recessive single-gene disorders?

The following PICO was used to inform literature selection.

Populations

The relevant population of interest are individuals or couples either at increased risk or population risk for having offspring with inherited gene disorders. Individuals at elevated risk for the purposes of non-targeted carrier screening include:

- Individuals at increased risk due to race, ethnicity, or family history.
- Families that carry a single-gene variant indicative of impairment in DNA repair mechanism.
- Individuals with a history of pregnancy loss not explained by a physiologic condition.
- History of infertility (after standard work-ups to identify cause).

Interventions

The intervention of interest is non-targeted carrier screening.

Comparators
The comparator of interest is targeted carrier screening.

Outcomes
The primary outcome of interest is reproductive decision making.

A beneficial outcome of a true test result is an informed reproductive decision that is consistent with the prospective parent(s)' personal preferences and values. Informed reproductive decisions can include those concerning preimplantation genetic diagnosis, in vitro fertilization, not having a child, invasive prenatal testing, adoption, or pregnancy termination.

A harmful outcome is a reproductive decision based on an incorrect test or assessment of the genotype-phenotype relationship. A false-positive result or incorrect genotype-phenotype association could lead to avoiding or terminating a pregnancy unnecessarily. A false-negative test could lead to an affected offspring.

Study Selection Criteria
For the evaluation of the clinical utility of non-targeted carrier screening , studies would need to use the test to inform reproductive decisions in asymptomatic individuals who are at risk of having an offspring with inherited recessive single-gene disorders. In addition, because ACOG and ACMG consider risk-based carrier screening an established practice, guideline recommendations from these organizations will also be included in the evidence discussion.

Clinically Valid
A test must detect the presence or absence of a condition, the risk of developing a condition in the future, or treatment response (beneficial or adverse). For conditions where pathogenic variants would be included in an non-targeted carrier screening (expanded carrier screening) panel, clinical validity should be demonstrated. Outside those targeted variants, pathogenicity, penetrance, and expressivity together with disease severity require accurate definition.

Subsumed in clinical validity is the effect of a condition's severity on quality of life, impairments, and the need for intervention.

ACOG (2017) made the following recommendations on expanded carrier screening[1]:

"Ethnic-specific, panethnic, and expanded carrier screening are acceptable strategies for prepregnancy and prenatal carrier screening"
Based on consensus, ACOG recommended the following criteria:

- carrier frequency ≥1/100
- well-defined phenotype
- detrimental effect on the quality of life, cause cognitive or physical impairment, require surgical or medical intervention, or have an onset early in life
- not be primarily associated with a disease of adult-onset.

ACOG provided a detailed example of a panel that includes testing for 22 conditions that meet these criteria: α-thalassemia, β-thalassemia, Bloom syndrome, Canavan disease, CF, familial dysautonomia, familial hyperinsulinism, Fanconi anemia C, fragile X syndrome, galactosemia, Gaucher disease, glycogen storage disease type 1A, Joubert syndrome, medium-chain acyl-CoA dehydrogenase deficiency, maple syrup urine disease types 1A and 1B, mucolipidosis IV, Niemann-Pick disease type A, phenylketonuria, sickle cell anemia, Smith-Lemli-Opitz syndrome, spinal muscular atrophy, and Tay-Sachs disease.

In 2021, an updated position statement describing a multi-tier approach to carrier screening was published by ACMG.[3] See Supplemental Information for additional details.

Review of Evidence

Many of the genes included in non-targeted carrier screening panels from different laboratories do not meet the prevalence criterion in all ethnic groups.[21] However, self-reports of ethnicity may not be consistent with genetic ancestry in substantial proportion of individuals, particularly in countries with intermixed ethnicity such as the United States.[20,22,23] A study by Guo and Gregg (2019) found that screening for the 40 genes that met the criterion of at least 1% prevalence in any ethnic group identified nearly all of the 2.52% of couples who would have been identified as at-risk.[5]

Studies have been reported on larger non-targeted carrier screening panels (approximately 200 disorders) in the reproductive setting and are described in Tables 3 and 4. Terhaar et al (2018) compared positivity rates from 3 multi-gene carrier screening panels.[24] Positivity rates increased with the number of genes tested, with 7.2% positivity for trio testing, 13.2% for a standard screen, and 35.8% for a global panel. Peyser et al (2019) reported that a non-targeted carrier screening panel identified 1243 carriers out of 4232 infertility patients (29.4%), while an ethnicity based screen would have identified 359 (8.5%). The investigators calculated that out of the 1.2% of couples who carried the pathogenic variants for the same gene, 47% would have been missed with an ethnicity-based screen.[25] In another study of patients who received non-targeted carrier screening at a fertility clinic, 1.7% of couples were at-risk for a recessive or X-linked disorder.[26]

Several reports have been published on a commercially available 176 gene panel. The non-targeted carrier screening panel was designed for maximizing per-disease sensitivity for diseases categorized as severe or profound. Ben-Shachar et al (2019) considered all 176 conditions in a panel to meet ACOG criteria, except for the criterion of a carrier rate exceeding 1 in 100.[27] In another analysis, medical geneticists evaluated disease severity associated with the 176 genes in the panel.[4] After evaluation of published literature and mapping according to ACOG severity criteria, the investigators concluded that 65 of the genes (36.9%) were associated with profound symptoms (shortened lifespan in infancy/childhood/adolescence and intellectual disability), 65 genes (36.9%) were associated with severe symptoms (shortened lifespan in infancy/childhood/adolescence or intellectual disability; or at least one of the following: shortened lifespan in premature adulthood, impaired mobility, internal physical manifestation with 3 or more traits: shortened lifespan in premature adulthood, impaired mobility, internal physical manifestation, sensory impairment, immunodeficiency/cancer, mental illness, or dysmorphic features), and 42 genes were associated with moderate symptoms. Moderate severity was classified as shortened lifespan in premature adulthood, impaired mobility, or internal physical manifestation; or, at least one of the following: sensory impairment, immunodeficiency/cancer, mental illness, or dysmorphic features. It is unclear if these would meet the ACOG criteria of a well-defined phenotype, a detrimental effect on quality of life, cause cognitive or physical impairment, require surgical or medical intervention, or have an onset early in life.

Other modeling studies have also estimated the incremental number of potentially affected fetuses if non-targeted carrier screening replaced a risk-based approach. Carrier rates with non-targeted carrier screening ranged from 19% to 36% in individuals and from 0.2% to 1.2% of couples. Westmeyer et al (2020) calculated that approximately 1 in 175 pregnancies would be affected by a disorder in a 274-gene screening panel.[23] Generally, as the size of the panel increases (risk-based to different sizes of expanded panels), the percentage of patients who are identified as carriers for any recessive disease also increases. The downstream impact similarly increases with a need for partner testing and genetic counseling.

Table 3. Relevant Clinical Validity Studies, Study Characteristics

Study	Setting	Study Design	Study Population	No. Screened	No. of Couples Screened	Disorders Screened
Terhaar et al (2018)[24]	Referred for testing in a reproductive setting	Database review	51,584 samples analyzed with a trio panel	75,036	NR	Trio panel = 3 Standard panel = 23 Global panel = 218

Study	Setting	Study Design	Study Population	No. Screened	No. of Couples Screened	Disorders Screened
			19,550 samples analyzed with a standard panel 3,902 samples analyzed with a global panel			
Peyser et al (2019)[25.]	Infertility clinic	Case series	All female and male patients who did not opt out	4,232	1206	100
Hernandez-Nieto et al (2020)[26.]	Infertility clinics in Mexico and U.S.	Case series	Patients undergoing fertility treatments were offered genetic testing.	805	391	283

NR: not reported.
[a] By obstetricians, family practitioners, geneticists, genetics counselors, perinatologists, and reproductive endocrinologists.

Table 4. Relevant Clinical Validity Studies, Results

Study	Individual Carriers, n (%)[a]	Couple Carriers, n (%)	Incremental Findings Over Risk-Based Testing N (95% CI)	Incremental Findings Over ACOG Recommended Screen
Terhaar et al (2018)[24.]	(35.8%)	NA	35.8% vs. 7.2% for trio panel	35.8% vs. 13.2% for a 23 gene panel
Peyser et al (2019)[25.]	1243 (29.4%)	15 (1.2%)	884	584
Hernandez-Nieto et al (2020)[26.]	352 (43.7%)	17 (4.34%) 1.7% for X-linked or recessive disorders	NR	NR

ACOG: American College of Obstetricians and Gynecologists; CI: confidence interval; NA: not applicable; NR: not reported.
[a] One or more disorders.

Subsection Summary: Clinical Validity

Studies have found that non-targeted carrier screening identifies more carriers and potentially affected fetuses.. Many of the genes in non-targeted carrier screening do not meet the ACOG consensus-driven criteria of at least 1% carrier rate for all ethnic groups. However, panethnic testing has also been supported by ACOG, which may address the discrepancies between self-reported ethnicity and genetic ancestry, particularly in ethnically mixed populations such as the U.S. One study calculated that a panethnic panel of 40 genes with at least a 1% prevalence in any ethnicity would address nearly all of the at-risk couples. As panels become larger, the likelihood of being identified as a carrier of a rare genetic disorder increases, resulting in an at-risk couple rate of nearly 2% for a recessive or X-linked disorder. Many, though not all, of these rare genetic disorders are associated with severe or profound symptoms including shortened lifespan and intellectual or physical disability.

Clinically Useful
A test is clinically useful if the use of the results informs management decisions that improve the net health outcome of care. The net health outcome can be improved if patients receive correct therapy, or more effective therapy, or avoid unnecessary therapy, or avoid unnecessary testing.

Direct Evidence
Direct evidence of clinical utility is provided by studies that have compared health outcomes for patients managed with and without the test. Because these are intervention studies, the preferred evidence would be from randomized controlled trials. Although direct evidence of clinical utility is optimally provided by studies that compare health outcomes for patients managed with and without the test, this is not reasonably expected for carrier screening.

Chain of Evidence
Indirect evidence on clinical utility rests on clinical validity. If the evidence is insufficient to demonstrate test performance, no inferences can be made about clinical utility. A chain of evidence that non-targeted carrier screening offers greater clinical utility than recommended risk-based approaches, relies on clinical validity - a well-defined predictable risk that the offspring will be affected by severe phenotype - to non-targeted carrier screening and should correctly identify more carrier couples of severe phenotype conditions than recommended risk-based screening.

Several survey studies evaluated patients' perspectives and reproductive behaviors concerning non-targeted carrier screening (see Table 5 and 6). For couples in which both partners carried genes for the same recessive disorder, actions following non-targeted carrier screening were reported in 60% to 91% of couples; the exact percentage depended upon the severity of disease. Frequently reported actions are prenatal screening or in vitro fertilization with preimplantation genetic diagnosis.

Clinical utility is supported by studies noted in the section above on ethnicity-based carrier testing, for which there is strong evidence of the impact of carrier screening on reproductive decision making and its effect on the prevalence of severe recessive disorders.[9,16,17,18,] For non-targeted carrier screening , a modeling study of the 176 gene panel described above found that compared with testing just for CF and spinal muscular atrophy, there would be a clinical impact on lifetime costs and life-years lost for 290 out of 100,000 pregnancies.[28,]

Table 5. Characteristics of Observational Studies for Clinical Utility

Author (Year)	Study Type	Country	Dates	Participants	Number	Outcomes
Ghiossi et al (2018)[29,]	Retrospective survey	United States	2014 to 2015	Couples in which both partners carry genes for the same recessive disease (profound, severe, or moderate per Lazarin et al. 2014) who had received ECS	537 eligible couples,64 (12%) completed survey	• Action (defined as IVF with PGD or prenatal diagnosis) • No action
Johansen Taber et al (2018)[30,]	Retrospective survey	United States	2015 to 2017	Women for which both partners carry genes for the same recessive disease who had received ECS; 54% were for IVF	1701 eligible couples who were at risk (78 conditions), 391 women completed the survey	• Reproductive planning

ECS: expanded (i.e., non-targeted) carrier screening; IVF: in vitro fertilization; NR: not reported; PGD: preimplantation genetic diagnosis.

Table 6. Results of Observational Studies for Clinical Utility

Study (Year)	Results
Ghiossi et al (2018)[29.]	• 60% reported taking action (IVF with PGD or prenatal diagnosis) following ECS results • 40% reported taking no action following ECS results • Of at-risk couples carrying severe or profound conditions, 76% (32/42) reported alternative reproductive actions, versus 22% (4/18) at-risk couples carrying moderate conditions suggesting that disease severity has a significant effect on reproductive actions (p=.000145)
Johansen Taber et al (2018)[30.]	• 77% of patients screened before becoming pregnant planned or pursued actions to avoid having affected offspring (91% for a profound condition, 77% for a severe condition, and 65% for a moderate condition) • 37% of patients screened during pregnancy pursued prenatal diagnostic testing (49% if excluding those reporting they underwent IVF with pre-implantation genetic testing, those who reported testing performed too late to allow termination, and those reporting termination had occurred before test results returned), of which 8 affected pregnancies were terminated (1/8 for moderate disorders and 7/8 for severe or profound disorders) • Reasons for declining prenatal testing were fear of miscarriage, belief that termination would not be pursued in the event of a positive diagnosis or perception that the risk of an affected pregnancy was low.

ECS: expanded (i.e., non-targeted) carrier screening; IVF: in vitro fertilization; PGD: preimplantation genetic diagnosis.

Section Summary: Expanded Carrier Screening

Indirect evidence on clinical utility depends on the demonstration that the genes included in non-targeted carrier screening are associated with severe genetic disorders, as described in the section above on clinical validity. The clinical utility of non-targeted carrier screening is the ability to affect reproductive choices such as in vitro fertilization with preimplantation genetic diagnosis or prenatal genetic testing to avoid a severe genetic disorder in the offspring. Observational studies have shown that a majority of couples would consider intervention, with a percentage choosing intervention that depends on the severity of the condition. Modeling suggests that the clinical impact of avoiding severe genetic disorders, even if rare, is high.

Summary of Evidence

For individuals who are asymptomatic but at risk for having offspring with an inherited X-linked or autosomal recessive genetic disorder who receive targeted risk-based carrier screening, the evidence includes studies supporting clinical validity and clinical utility. Relevant outcomes are test validity and changes in reproductive decision making. Results of carrier testing can be used to inform reproductive decisions such as preimplantation genetic diagnosis, in vitro fertilization, not having a child, invasive prenatal testing, adoption, or pregnancy termination. The evidence is sufficient to determine that the technology results in an improvement in the net health outcome.

For individuals who are either at increased risk or population risk for having offspring with an inherited X-linked or autosomal recessive genetic disorder who receive a non-targeted carrier screening panel, , the evidence includes studies supporting clinical validity and clinical utility. Relevant outcomes are test validity and changes in reproductive decision making. Studies have found that non-targeted carrier screening identifies more carriers and more potentially affected fetuses. Many of the genes in carrier screening panels do not meet the ACOG consensus-driven criteria of at least 1% carrier rate for all ethnic groups. However, non-targeted testing can address the discrepancies between self-reported ethnicity and genetic ancestry in an ethnically mixed population. As panels become larger the likelihood of being identified as a carrier of a rare genetic disorder increases, leading to an at-risk couple rate of nearly 2% for having an offspring with a recessive or X-linked disorder. Many, though notably not all, of these rare genetic disorders are associated with severe or profound symptoms including shortened lifespan and intellectual or physical disability. With adequate genetic counseling, carrier screening panels can inform reproductive choices, and observational studies have shown that a majority of

couples would consider intervention that depends on the severity of the condition. Therefore, non-targeted carrier screening panels for severe recessive and X-linked genetic disorders can have a significant clinical impact. The evidence is sufficient to determine that the technology results in an improvement in the net health outcome.

Supplemental Information
The purpose of the following information is to provide reference material. Inclusion does not imply endorsement or alignment with the evidence review conclusions.

Practice Guidelines and Position Statements
Guidelines or position statements will be considered for inclusion in 'Supplemental Information' if they were issued by, or jointly by, a US professional society, an international society with US representation, or National Institute for Health and Care Excellence (NICE). Priority will be given to guidelines that are informed by a systematic review, include strength of evidence ratings, and include a description of management of conflict of interest.

American College of Obstetricians and Gynecologists
In 2017 (reaffirmed in 2020), the American College of Obstetricians and Gynecologists (ACOG) made the following recommendations on expanded (i.e., non-targeted) carrier screening [1]:

"Ethnic-specific, panethnic, and expanded carrier screening are acceptable strategies for prepregnancy and prenatal carrier screening. Each obstetrician-gynecologist or other health care provider or practice should establish a standard approach that is consistently offered to and discussed with each patient, ideally before pregnancy. After counseling, a patient may decline any or all carrier screening."

"Expanded carrier screening does not replace previous risk-based screening recommendations." Based on "consensus," characteristics of included disorders should meet the following criteria:

- carrier frequency ≥1/100
- well-defined phenotype
- detrimental effect on the quality of life, cause cognitive or physical impairment, require surgical or medical intervention, or have an onset early in life
- not be primarily associated with a disease of adult-onset.

The ACOG also noted that expanded carrier screening panels may not offer the most sensitive detection method for some conditions such as Tay-Sachs disease (i.e., they will miss carrier state in up to 10% of low-risk populations) or hemoglobinopathies.

In 2015, a joint statement on expanded carrier screening was issued by ACOG, the American College of Medical Genetics and Genomics (ACMG), the National Society of Genetic Counselors, the Perinatal Quality Foundation, and the Society for Maternal-Fetal Medicine.[8] The statement was not intended to replace current screening guidelines but to demonstrate an approach for health care providers and laboratories seeking to or currently offering expanded carrier screening panels. Some points considered included the following.

"Expanded carrier screening panels include most of the conditions recommended in current guidelines. However, molecular methods used in expanded carrier screening are not as accurate as methods recommended in current guidelines for the following conditions:

- Screening for hemoglobinopathies requires use of mean corpuscular volume and hemoglobin electrophoresis.
- Tay-Sachs disease carrier testing has a low detection rate in non-Ashkenazi populations using molecular testing for the 3 common Ashkenazi mutations. Currently, hexosaminidase A enzyme analysis on blood is the best method to identify carriers in all ethnicities."

"Patients should be aware that newborn screening is mandated by all states and can identify some genetic conditions in the newborn. However, newborn screening may include a different panel of conditions than expanded carrier screening. Newborn screening does not usually detect children who are carriers for the conditions being screened so will not necessarily identify carrier parents at increased risk."

The statement also included a set of recommendations for screened conditions:

- "The condition being screened for should be a health problem that encompasses one or more of the following:
  - Cognitive disability.
  - Need for surgical or medical intervention.
  - Effect on quality of life.
  - Conditions for which a prenatal diagnosis may result in:
    - Prenatal intervention to improve perinatal outcome and immediate care of the neonate.
    - Delivery management to optimize newborn and infant outcomes such as immediate, specialized neonatal care.
    - Prenatal education of parents regarding special needs care after birth; this often may be accomplished most effectively before birth."

American College of Medical Genetics and Genomics

In 2021, the ACMG issued a position statement on screening for autosomal recessive and X-linked conditions during pregnancy and preconception.[3.] This position statement replaces the 2013 ACMG position statement on prenatal and preconception expanded carrier testing, and incorporates ACOG Committee Opinion 691 recommendations.[6.]

The ACMG consensus group made the following recommendations:

- Replacing the term "expanded carrier screening" with "carrier screening" as no precise definition for "expanded" exists.
- Establishing a tier-based system of carrier screening, to enhance communication and precision while advancing equity in carrier screening (see Table 7 below).
- Carrier screening paradigms should be ethnic and population neutral and more inclusive of diverse populations to promote equity and inclusion.
- Offering Tier 3 carrier screening to all pregnant patients and those planning a pregnancy.
- Male partners of pregnant women and those planning a pregnancy may be offered Tier 3 carrier screening for autosomal recessive conditions when carrier screening is performed simultaneously with their female partner.
- Consider offering Tier 4 screening when a pregnancy stems from a known or possible consanguineous relationship (second cousins or closer) or when family or personal medical history warrants.

The ACMG does not recommend:

- Offering Tier 1 and/or Tier 2 screening, because these do not provide equitable evaluation of all racial/ethnic groups.
- Routine offering of Tier 4 panels.

Table 7. American College of Medical Genetics and Genomics Tiered Approach to Carrier Screening[3.]

Tier	Screening Recommendations
1	Cystic fibrosis + spinal muscular atrophy + risk based screening
2	≥1/100 carrier frequency + Tier 1
3	≥1/200 carrier frequency + Tier 2 (includes X-linked conditions)
4	<1/200 carrier frequency + Tier 3 (genes and conditions will vary by lab)

ACMG: American College of Medical Genetics and Genomics

X-linked genes considered appropriate for carrier screening in Tier 3 include: *ABCD1, AFF2, ARX, DMD, F8, F9, FMR1, GLA, L1CAM, MID1, NR0B1, OTC, PLP1, RPGR, RS1, and SLC6A8.* Refer to Tables 1 through 5 in the ACMG position statement for additional details regarding appropriate autosomal recessive conditions for screening and their associated carrier frequencies.

The ACMG recommends the following components regarding laboratory reporting of carrier screening panels:

- The content of carrier screen panels and corresponding ACMG tier must be described.
- The testing approach and detectable variant types should be clearly stated.
- Not reporting residual risk estimates.
- Only reporting pathogenic and likely pathogenic variants.
- Interpretation should consider genes and variants with multiple disease associations.
- Reporting of a variant of uncertain significance (VUS) only in the partners of identified carriers and only with consent of the patient.

U.S. Preventive Services Task Force Recommendations

The U.S. Preventive Services Task Force makes recommendations for carrier testing for *BRCA*-associated genetic diseases and for hereditary hemochromatosis, topics that are not included herein but are in evidence reviews for each condition (see 2.04.02 and 2.04.80, respectively).

Medicare National Coverage

There is no national coverage determination. In the absence of a national coverage determination, coverage decisions are left to the discretion of local Medicare carriers.

Ongoing and Unpublished Clinical Trials

Some currently unpublished trials that might influence this review are listed in Table 8.

Table 8. Summary of Key Trials

NCT No.	Trial Name	Planned Enrollment	Completion Date
NCT04157595	Mackenzie's Mission: The Australian Reproductive Carrier Screening Project	20,000	Dec 2022 (enrolling by invitation)
Unpublished			
NCT01902901	Clinical Implementation of Carrier Status Using Next Generation Sequencing	384	May 2018

NCT: national clinical trial.

Appendix 1 and 2

Appendix 1. Definitions

Carrier Screening

Carrier genetic screening is performed on people who display no symptoms for a genetic disorder but may be at risk for passing it on to their children.

A carrier of a genetic disorder has one abnormal allele for a disorder. When associated with an autosomal recessive or X-linked disorder, carriers of the causative variant are typically unaffected. When associated with an autosomal dominant disorder, the individual has one normal and one mutated copy of the gene and may be affected by the disorder, may be unaffected but at high-risk of developing the disorder later in life, or the carrier may remain unaffected because of the sex-limited nature of the disorder. Homozygous-affected offspring (those who inherit the variant from both parents) manifest the disorder.

Compound Heterozygous

The presence of 2 different mutant alleles at a particular gene locus, one on each chromosome of a pair.

Expressivity/Expression
The degree to which a penetrant gene is expressed within an individual.

Genetic Testing
Genetic testing involves the analysis of chromosomes, DNA, RNA, genes, or gene products to detect inherited (germline) or noninherited (somatic) genetic variants related to disease or health.

Homozygous
Having the same alleles at a particular gene locus on homologous chromosomes (chromosome pairs).

Penetrance
The proportion of individuals with a variant that causes a disorder who exhibit clinical symptoms of that disorder.

Residual Risk
The risk that an individual is a carrier of a disease, but testing for carrier status of the disease is negative (e.g., if the individual carries a pathogenic variant not included in the test assay).

Appendix 2. Resources
A list of selected higher volume tests and associated laboratories, CPT, and ICD-10 codes is provided below in Appendix Table 1.

Appendix Table 1. Common Carrier Screening Tests

Coverage Criteria Sections	Example Tests (Labs)	Common CPT Codes	Common ICD-10 Codes
Expanded Carrier Screening Panels	Foresight, Myriad Horizon, Natera Inheritest, LabCorp Preparent Standard/Global, Progenity GeneSeq, LabCorp	81443	O09, Z13, Z31, Z34, Z36, Z84
α-Thalassemia Carrier Screening	HBA1 Sequencing HBA2 Sequencing	81257, 81258, 81259, 81269	Z31
Ashkenazi Jewish Carrier Panel Testing	Foresight: AJ Panel, Counsyl Inheritest: AJ Panel, LabCorp Horizon 106 (Comprehensive Jewish Panel), Natera	81412	O09, Z13, Z31, Z34, Z36, Z84
Cystic Fibrosis Carrier Screening	CFTR Common Mutation Panel	81220	O09, Z13, Z31, Z34, Z36, Z84
Duchenne and Becker Muscular Dystrophy Carrier Screening	DMD Deletion/Duplication Analysis	81161	Z31
Fragile X Syndrome Carrier Screening	FMR1 Repeat Analysis	81243, 81244	O09, Z13, Z31, Z34, Z36, Z84
Hereditary Hearing Loss Carrier Screening	GJB2 Sequencing GJB6 Sequencing	81252, 81253, 81254, 81430, 81431, S3844	O09, Z13, Z31, Z84
Mitochondrial Disorder Carrier Screening	MT-TL1 Targeted Mutation Analysis, Mitochondrial DNA Point Mutations and Deletions Screening Panel	81401, 81403, 81404, 81405, 81406, 81445, 81460, 81465	E88.4, O09, Z13, Z31, Z84
Spinal Muscular Atrophy Carrier Screening	SMN1 Deletion/Duplication Analysis SMN2 Deletion/Duplication Analysis	81329, 81336, 81337	O09, Z13, Z31, Z34, Z36, Z84
Tay-Sachs Carrier Screening	HEXA Targeted Mutation Analysis	81255	O09, Z13, Z31, Z34, Z36, Z84

Coverage Criteria Sections	Example Tests (Labs)	Common CPT Codes	Common ICD-10 Codes
General Criteria for Targeted Carrier Testing			O09, Z13, Z31, Z34, Z36, Z84

A list of 22 conditions deemed reasonable to include in a carrier screening panel were published by ACOG in Committee Opinion No. 690: Carrier Screening in the Age of Genomic Medicine.[1] These conditions are summarized below in Appendix Table 2.

Appendix Table 2. Example of an Expanded Carrier Screening Panel (ACOG 2017; Reaffirmed 2020)[a]

Condition	Carrier Frequency in General Population	Carrier Frequency in Specific Ethnic Groups
α-thalassemia	Unknown	African (particularly sub-Saharan): 1 in 3 Mediterranean: 1 in 30 Southeast Asian and Middle Eastern: 1 in 20
β-thalassemia	Unknown	African American: <1 in 8 Ashkenazi Jewish: Varied Asian: 1 in 20 Mediterranean: 1 in 7
Bloom syndrome	<1 in 500	Ashkenazi Jewish: 1 in 100
Canavan disease	<1 in 150	Ashkenazi Jewish: 1 in 41
Cystic fibrosis	Unknown	African American: 1 in 61 Asian: 1 in 94 Ashkenazi Jewish: 1 in 24 Caucasian: 1 in 25 Hispanic: 1 in 58
Familial dysautonomia	<1 in 500	Ashkenazi Jewish: 1 in 31
Familial hyperinsulinism	<1 in 150	Ashkenazi Jewish: 1 in 52
Fanconi anemia C	<1 in 790	Ashkenazi Jewish: 1 in 89
Fragile X syndrome[b]	1 in 259	
Galactosemia	1 in 87	Ashkenazi Jewish: 1 in 127
Gaucher disease	<1 in 100	Ashkenazi Jewish: 1 in 15
Glycogen storage disease type 1A	<1 in 150	Ashkenazi Jewish: 1 in 71
Joubert syndrome	<1 in 500	Ashkenazi Jewish: 1 in 92
Medium-chain acyl-CoA dehydrogenase deficiency	Unknown	Caucasian: 1 in 50
Maple syrup urine disease types 1A and 1B	1 in 240	Ashkenazi Jewish: 1 in 81 (type 1B) Mennonite: 1 in 10 (type 1A-*BCKDHA* p.Y438N)
Mucolipidosis IV	<1 in 500	Ashkenazi Jewish: 1 in 96
Niemann-Pick disease type A	<1 in 500	Ashkenazi Jewish: 1 in 90
Phenylketonuria	Unknown	Caucasian: 1 in 50 Irish: 1 in 34
Sickle cell anemia	Unknown	African American: 1 in 10
Smith-Lemli-Opitz syndrome	Unknown	Caucasian: 1 in 70
Spinal muscular atrophy	Unknown	African American: 1 in 66 Asian: 1 in 53 Ashkenazi Jewish: 1 in 41 Caucasian: 1 in 35 Hispanic: 1 in 117
Tay-Sachs disease[c]	1 in 300	Ashkenazi Jewish: 1 in 30 French Canadian and Cajun: 1 in 30

ACOG: American College of Obstetricians and Gynecologists.
[a] Adapted from ACOG Committee Opinion 690.[1]
[b] Recommended despite a carrier frequency lower than 1 in 100 because fragile X syndrome is more prevalent than other X-linked syndromes.

[c] DNA testing alone will miss up to 10% of carriers, especially in low risk groups. Therefore, enzyme-based testing may be a more appropriate choice for some patients.

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Documentation for Clinical Review

Please provide the following documentation:

- Physician order for genetic test
- Name and description of genetic test
- Name of laboratory performing the test
- CPT code(s) billed for the particular genetic test(s)
- History and physical and/or consultation notes including:
  - Reason for performing test
  - Signs/symptoms/test results related to reason for genetic testing
  - Family history if applicable

Post Service (in addition to the above, please include the following):

- Results/reports of tests performed

Coding

This Policy relates only to the services or supplies described herein. Benefits may vary according to product design; therefore, contract language should be reviewed before applying the terms of the Policy.

The following codes are included below for informational purposes. Inclusion or exclusion of a code(s) does not constitute or imply member coverage or provider reimbursement policy. Policy Statements are intended to provide member coverage information and may include the use of some codes for clarity. The Policy Guidelines section may also provide additional information for how to interpret the Policy Statements and to provide coding guidance in some cases.

Type	Code	Description
CPT®	81220	CFTR (cystic fibrosis transmembrane conductance regulator) (e.g., cystic fibrosis) gene analysis; common variants (e.g., ACMG/ACOG guidelines)
	81243	FMR1 (fragile X mental retardation 1) (e.g., fragile X mental retardation) gene analysis; evaluation to detect abnormal (e.g., expanded) alleles
	81401	Molecular pathology procedure level 2
	81412	Ashkenazi Jewish associated disorders (e.g., Bloom syndrome, Canavan disease, cystic fibrosis, familial dysautonomia, Fanconi anemia group C, Gaucher disease, Tay-Sachs disease), genomic sequence analysis panel, must include sequencing of at least 9 genes, including ASPA, BLM, CFTR, FANCC, GBA, HEXA, IKBKAP, MCOLN1, and SMPD1
	81443	Genetic testing for severe inherited conditions (e.g., cystic fibrosis, Ashkenazi Jewish-associated disorders [e.g., Bloom syndrome, Canavan disease, Fanconi anemia type C, mucolipidosis type VI, Gaucher disease, Tay-Sachs disease], beta hemoglobinopathies, phenylketonuria, galactosemia), genomic sequence analysis panel, must include sequencing of at least 15 genes (e.g., ACADM, ARSA, ASPA, ATP7B, BCKDHA, BCKDHB, BLM, CFTR, DHCR7, FANCC, G6PC, GAA, GALT, GBA, GBE1, HBB, HEXA, IKBKAP, MCOLN1, PAH)
	81479	Unlisted molecular pathology procedure
HCPCS	G0452	Molecular pathology procedure; physician interpretation and report

Policy History

This section provides a chronological history of the activities, updates and changes that have occurred with this Medical Policy.

Effective Date	Action
02/01/2017	BCBSA Medical Policy adoption
06/01/2017	Policy title change from Carrier Testing for Genetic Diseases Policy revision with position change
10/01/2018	Policy revision without position change
02/01/2019	Policy revision without position change Coding update
03/01/2019	Administrative Update - Policy statement clarification Coding update
08/01/2019	Administrative Update
01/01/2020	Annual review. No change to policy statement. Literature review updated.

Effective Date	Action
11/01/2020	Policy reactivated. Previously archived from 9/1/2020 to 10/31/2020. Policy statement, guidelines and literature updated.
01/01/2021	Coding Update
11/01/2021	Annual review. Policy statement and guidelines updated.
02/01/2022	Annual review. Policy statement, guidelines and literature updated.

Definitions of Decision Determinations

Medically Necessary: Services that are Medically Necessary include only those which have been established as safe and effective, are furnished under generally accepted professional standards to treat illness, injury or medical condition, and which, as determined by Blue Shield, are: (a) consistent with Blue Shield medical policy; (b) consistent with the symptoms or diagnosis; (c) not furnished primarily for the convenience of the patient, the attending Physician or other provider; (d) furnished at the most appropriate level which can be provided safely and effectively to the patient; and (e) not more costly than an alternative service or sequence of services at least as likely to produce equivalent therapeutic or diagnostic results as to the diagnosis or treatment of the Member's illness, injury, or disease.

Investigational/Experimental: A treatment, procedure, or drug is investigational when it has not been recognized as safe and effective for use in treating the particular condition in accordance with generally accepted professional medical standards. This includes services where approval by the federal or state governmental is required prior to use, but has not yet been granted.

Split Evaluation: Blue Shield of California/Blue Shield of California Life & Health Insurance Company (Blue Shield) policy review can result in a split evaluation, where a treatment, procedure, or drug will be considered to be investigational for certain indications or conditions, but will be deemed safe and effective for other indications or conditions, and therefore potentially medically necessary in those instances.

Prior Authorization Requirements (as applicable to your plan)

Within five days before the actual date of service, the provider must confirm with Blue Shield that the member's health plan coverage is still in effect. Blue Shield reserves the right to revoke an authorization prior to services being rendered based on cancellation of the member's eligibility. Final determination of benefits will be made after review of the claim for limitations or exclusions.

Questions regarding the applicability of this policy should be directed to the Prior Authorization Department at (800) 541-6652, or the Transplant Case Management Department at (800) 637-2066 ext. 3507708 or visit the provider portal at www.blueshieldca.com/provider.

Disclaimer: This medical policy is a guide in evaluating the medical necessity of a particular service or treatment. Blue Shield of California may consider published peer-reviewed scientific literature, national guidelines, and local standards of practice in developing its medical policy. Federal and state law, as well as contract language, including definitions and specific contract provisions/exclusions, take precedence over medical policy and must be considered first in determining covered services. Member contracts may differ in their benefits. Blue Shield reserves the right to review and update policies as appropriate.

Appendix A

POLICY STATEMENT	
BEFORE **Red font: Verbiage removed**	**AFTER** **Blue font: Verbiage Changes/Additions**
Carrier Screening for Genetic Diseases 2.04.107 **Policy Statement:** Targeted carrier screening of individual genes not included in carrier panels meeting criteria for 81443 with the addition of SNM1 (related to pregnancy or planned pregnancy) for genetic diseases in biological parents may be considered **medically necessary** when **one or more** of the following criteria is met: I. One or both individuals have a first- or second-degree relative who is affected II. One individual is known to be a carrier III. One or both individuals are members of a population known to have a carrier rate that exceeds a threshold considered appropriate for testing for a particular condition AND **all** of the following are met: A. The natural history of the disease is well understood and there is a reasonable likelihood that the disease is one with high morbidity in the homozygous or compound heterozygous state B. Alternative biochemical or other clinical tests to definitively diagnose carrier status are not available, or, if available, provide an indeterminate result or are individually less efficacious than genetic testing C. The genetic test has adequate clinical validity to guide clinical decision making and residual risk is understood D. An association of the marker with the disorder has been established All targeted screening not meeting any of the above criteria is considered **not medically necessary**. Expanded pan-ethnic or similar carrier screening panels for autosomal recessive and X-linked genetic disorders that meet the criteria listed above may be considered **medically necessary** as an alternative to testing of individual genes (e.g., SMN1 gene and CFTR gene) for	**Carrier Screening for Genetic Diseases 2.04.107** **Policy Statement:** ***Targeted Risk-Based Carrier Screening*** Targeted carrier screening for X-linked and autosomal recessive genetic diseases for members who are pregnant or are considering pregnancy and are at increased risk of having offspring with an X-linked or autosomal recessive disease may be considered **medically necessary** when **one or more** of the following criteria is met: I. One or both individuals have a first- or second-degree relative who is affected II. One individual is known to be a carrier III. One or both individuals are members of a population known to have a carrier rate that exceeds a threshold considered appropriate for testing for a particular condition **Note:** Known autosomal dominant genetic diseases can usually be predicted for inheritance without testing, but may be needed when the situation is unclear. AND **all** of the following are met: A. The natural history of the disease is well understood and there is a reasonable likelihood that the disease is one with high morbidity or early mortality in the homozygous or compound heterozygous state (see Policy Guidelines) B. Alternative biochemical or other clinical tests to definitively diagnose carrier status are not available, or, if available, provide an indeterminate result or are individually less efficacious than genetic testing C. The genetic test has adequate clinical validity to guide clinical decision-making and residual risk is understood D. An association of the marker with the disorder has been established E. If targeted testing is performed by a panel, the panel should also either meet the criteria for non-targeted testing, or be limited to a single gene or small panel in addition to a non-targeted panel in unusual circumstances (see Policy

POLICY STATEMENT	
BEFORE **Red font: Verbiage removed**	**AFTER** **Blue font: Verbiage Changes/Additions**
members who are pregnant or are considering pregnancy (see Policy Guidelines). Expanded carrier screening panels other than meeting the criteria for and billed as 81443 (see Policy Guidelines and Coding Sections) are considered **investigational** in all other situations.	Guidelines). Non-targeted panels can be used instead of targeted testing when the genes of interest are included in the non-targeted panel (see below) F. Previous carrier screening or individual targeted gene testing for the gene variant(s) of interest has not been performed (see Policy Guidelines) All targeted carrier screening not meeting any of the above criteria is considered **not medically necessary**. ***Non-Targeted Carrier Screening*** Expanded non-targeted or similar carrier screening panels for autosomal recessive and X-linked genetic disorders may be considered **medically necessary** as an alternative to testing of individual genes (e.g., *SMN1* gene and *CFTR* gene) for members who are pregnant or are considering pregnancy when **all** of the following criteria are met: I. The natural history of each disease is well understood and there is reasonable likelihood that the disease is one with high morbidity or early mortality in the homozygous or compound homozygous state (see Policy Guidelines) II. Alternative biochemical or other clinical tests to definitively diagnose carrier status are not available, or, if available, provide an indeterminate result or are individually less efficacious than genetic testing III. The genetic test has adequate clinical validity to guide clinical decision-making and residual risk is understood IV. An association of the markers with the disorders has been established V. Previous carrier screening has not been performed (see Policy Guidelines) VI. All testing must include CFTR and SMN1 genes Non-targeted carrier screening panels other than meeting the criteria for and billed as 81443 (see Policy Guidelines and Coding Sections) are considered **investigational** in all other situations when above criteria are not met (see Policy Guidelines).