Chronic Granulomatous Disease

Indications for Ordering
- Confirm a clinical or laboratory diagnosis of chronic granulomatous disease (CGD)
- Assess carrier status for CGD
- Predictive testing for unaffected at-risk relatives

Test Description
Semiquantitative flow cytometry

Tests to Consider

Typical testing strategy
- A provisional diagnosis of CGD is made using functional tests to detect the absence or reduction of oxidase activity in activated neutrophils (eg, respiratory burst test)
  - Individuals with CGD demonstrate decreased or absent NADPH oxidase activity on functional analysis
- If abnormal oxidase function is noted, molecular testing to confirm the causative mutation(s) is necessary for
  - Diagnostic confirmation
  - Genetic counseling
  - Prenatal diagnosis

Primary tests
- Neutrophil Oxidative Burst Assay (DHR) 0096657
  - Aid in screening for CGD
- Chronic Granulomatous Disease (CYBB Gene Scanning and NCF1 Exon 2 GT Deletion) with Reflex to CYBB Sequencing 2006356
  - Preferred test to assess common molecular causes of CGD

Related tests
- Chronic Granulomatous Disease, X-Linked (CYBB) Gene Scanning with Reflex to Sequencing 2006361
  - Molecular test to confirm a diagnosis or assess carrier status for X-linked CGD
- Chronic Granulomatous Disease (NCF1) Exon 2 GT Deletion 2006366
  - Tests for a common NCF1 mutation associated with autosomal recessive CGD

Familial Mutation, Targeted Sequencing 2001961
- Useful when a pathogenic familial variant identifiable by sequencing is known

Disease Overview

Incidence – 1/250,000 births in the U.S.
- X-linked CGD
  - CYBB – 60-70% of all cases
- Autosomal recessive CGD
  - NCF1 – 25% of cases
  - CYBA – <5% of cases
  - NCF2 – <5% of cases
  - NCF4 – very rare

Pathophysiology
- Primary immunodeficiency disorder that results from changes within genes encoding the essential subunits of the nicotinamide adenine dinucleotide phosphate (NADPH) oxidase complex
  - NADPH complex produces reactive oxygen species necessary to kill bacterial and fungal microorganisms
  - Mutations cause defective function of NADPH complex in the leukocytes
  - CGD leukocytes are unable to produce the superoxide, hydrogen peroxide, hydroxyl ion, and hypochlorous acid necessary for intracellular destruction of phagocytized pathogens and results in
    - Recurrent, severe bacterial and fungal infections
    - Dysregulated inflammatory responses leading to granulomas at infection sites
- Common infectious agents include
  - Staphylococcus aureus
  - Burkholderia cepacia
  - Serratia marcescens
  - Nocardia spp
  - Aspergillus spp

Symptoms
- Recurrent severe bacterial and fungal infections of various organs
  - Lymph nodes
  - Liver
  - Lungs
  - Bones
  - Visceral organs
- Granulomas form at infection sites
Other findings
- Poor wound healing
- Hypergammaglobulinemia
- Splenomegaly
- Chorioretinitis
- Colitis/enteritis
- Obstructions of urinary tract or gastric outlet
- Males with classic X-linked CGD are typically diagnosed before 3 years of age
- Less severe phenotypes have been observed and may be diagnosed later in life
- Carrier females of X-linked disease (~50%) may have mild symptoms, including
  - Photosensitivity
  - Recurrent mouth ulcers
- Females with skewed X-chromosome inactivation
  - Rare
  - Severe disease presentation
- Individuals with X-linked CGD typically have earlier onset and more severe disease than individuals with variant X-linked or autosomal recessive CGD

Diagnostic issues
- Early diagnosis is essential – disease management relies on lifelong antibiotic and antifungal prophylaxis
- Disease severity can be estimated by the level of NADPH oxidase activity associated with a particular CYBB gene mutation
  - Genetic or environmental modifiers may result in variable clinical outcomes

Genetics

Genes
- CYBB; NCF1 GT deletion in exon 2

Inheritance
- CYBB – X-linked
- NCF1 – autosomal recessive

De novo mutations
- 10-20% of CYBB mutations

Mutations
- >600 pathogenic mutations
  - ~90% of CYBB mutations are small nucleotide insertions, deletions, or substitutions
  - ~10% are large deletions
- Identical CYBB mutations in different individuals can result in variable clinical outcomes

Other non-CYBB mutations associated with CGD
- NCF1 – encodes p47-phox
  - GT deletion in exon 2 accounts for majority of mutations
- CYBA – encodes p22-phox
- NCF2 – encodes p67-phox
- NCF4 – encodes p40-phox

Test Interpretation

Chronic Granulomatous Disease (CYBB Gene Scanning and NCF1 Exon 2 GT Deletion) with Reflex to CYBB Sequencing

Sensitivity/specificity
- Clinical sensitivity – 86% for CGD
- Analytical sensitivity – 99% for CYBB or homozygous NCF1 GT deletion; 90% for heterozygous NCF1 GT deletion
- Analytical specificity – 99%

Results
- Positive – pathogenic mutation was detected
  - CYBB mutation
    - In symptomatic male – confirms X-linked CGD
    - In asymptomatic female – confirms carrier status for X-linked CGD
  - NCF1 GT deletion
    - 2 copies confirm autosomal recessive CGD
    - 1 copy confirms carrier status for autosomal recessive CGD
- Negative – CYBB gene mutation or the common NCF1 GT deletion not detected
  - Reduces, but does not eliminate, the possibility of CGD
- Inconclusive – gene scanning/sequencing may detect novel variants of unknown clinical significance

Limitations
- Diagnostic errors can occur due to rare sequence variations
- Deep intronic mutations in CYBB, mutations in NCF1 other than the GT deletion in exon 2, and mutations in additional genes associated with CGD are not evaluated
- Large CYBB gene deletions/duplications will not be detected in females
- Breakpoints of large CYBB deletions/duplications will not be determined in males
- Lack of GT deletion in exon 2 does not rule out carrier status
  - Due to potential recombination between NCF1 and its pseudogenes