MAYO CLINIC LABORATORIES

Test Definition: DHR

Dihydrorhodamine Flow Cytometric Test, Blood

Overview

Useful For

Evaluation of chronic granulomatous disease (CGD), X-linked and autosomal recessive forms, Rac2 deficiency, complete myeloperoxidase deficiency

Monitoring chimerism and nicotinamide adenine dinucleotide phosphate oxidase (NOX) function post-hematopoietic cell transplantation

Assessing residual NOX activity pretransplant

Identifying female carriers for X-linked CGD

Assessing changes in lyonization with age in female carriers

Genetics Test Information

Approximately 70% of chronic granulomatous disease cases are X-linked and are due to disease-causing variants in the *CYBB* gene, encoding the gp91phox protein. The following genes may have genetic variants inherited in an autosomal recessive pattern: *NCF1* (p47phox), *NCF2* (p67phox), *CYBA* (p22phox), and *NCF4* (p40phox). Disease-causing variants in *NCF1* account for 25% of cases, while variants in *NCF2* and *CYBA* account for 5% of cases each. Disease-causing variants in the *NCF4* and *CYBC1* genes have been described but are rare.

Method Name

Flow Cytometry

NY State Available

Yes

Specimen

Specimen Type

WB Sodium Heparin

Shipping Instructions

Testing is not performed on Saturday, Sunday, or observed holidays. Only collect and ship specimens for arrival on days when testing is performed.

Specimens received on days when testing is not performed or after 5 p.m. Central on Friday will be canceled if specimen is outside of stability when testing is next performed.

Collect and package specimen as close to shipping time as possible. Ship specimen overnight in an Ambient Shipping Box-Critical Specimens Only (T668) following the instructions in the box. It is recommended that specimens arrive within 24 hours of collection.

Necessary Information

Ordering healthcare professional name and phone number are required.

Specimen Required

Two whole-blood sodium heparin specimens are required, one from the testing patient and the other from an unrelated healthy donor as a control.

Supplies: Ambient Shipping Box-Critical Specimens Only (T668)

Patient:
Container/Tube: Green top (sodium heparin)
Specimen Volume: 5 mL
Collection Instructions: Send whole blood specimen in original tube. **Do not aliquot.**

Normal Control:
Container/Tube: Green top (sodium heparin)
Specimen Volume: 5 mL
Collection Instructions:
1. Collect a control specimen from the unrelated healthy donor within an hour of the patient's specimen collection time.
2. Clearly label as **Normal Control** on the outermost label.
3. Send the whole blood specimen in the original tube. **Do not aliquot.**
4. Rubber band patient specimen and control vial together.

Specimen Minimum Volume

1 mL

Reject Due To

Gross hemolysis	Reject
Gross lipemia	Reject

Specimen Stability Information

Specimen Type	Temperature	Time	Special Container
WB Sodium Heparin	Ambient	48 hours	GREEN TOP/HEP

Clinical & Interpretive

Clinical Information

Chronic granulomatous disease (CGD) is caused by genetic alterations in the gene components that encode the nicotinamide adenine dinucleotide phosphate (NADPH) oxidase (NOX) enzyme complex. These alterations result in an inability to produce superoxide anions required for killing bacterial and fungal organisms. Other clinical features include a predisposition to systemic granulomatous complications and autoimmunity.(1) There are 6 known genes associated with the clinical phenotype of CGD.(2) The gene defects include disease-causing variants in the *CYBB* gene, encoding the gp91phox protein, which is X-linked and accounts for approximately 70% of CGD cases. Other genetic causes are autosomal recessive in inheritance and occur in one of the following genes: *NCF1* (p47phox), *NCF2* (p67phox), *CYBA* (p22phox), *NCF4* (p40phox) and *CYBC1*.(3) Typically, patients with X-linked CGD have the most severe disease, while patients with p47phox defects tend to have the best outcomes. Disease-causing variants in *NCF4* and *CYBC1* have been the most recently described rare causes of disease.(3,4) There is significant clinical variability even among individuals with similar variants, in terms of NOX function, indicating that there can be several modulating factors including the genetic alteration, infection history, and granulomatous and autoimmune complications. There appears to be a correlation between very low NADPH superoxide production and worse outcomes. CGD can be treated with hematopoietic cell transplantation, which can be effective for the inflammatory and autoimmune manifestations.

It has been shown that survival of patients with CGD was strongly associated with residual reactive oxygen intermediate (ROI) production, independent of the specific gene alteration.(5) Measurement of NOX activity through the dihydrorhodamine (DHR) flow cytometry assay contributed to the assessment of ROI. The diagnostic laboratory assessment for CGD includes evaluation of NOX function in neutrophils, using historically the nitroblue tetrazolium test or currently the more analytically sensitive DHR test as described here. Activation of neutrophils with phorbol myristate acetate (PMA) results in oxidation of DHR to a fluorescent compound, rhodamine 123, which can be measured by flow cytometry. Flow cytometry can distinguish between the some genetic forms of CGD.(6,7) DHR test may be normal or mildly impaired in patients who are NCF4 (p40phox) deficient.(4) Complete myeloperoxidase (MPO) deficiency can cause a false-positive result for CGD in the DHR flow cytometric assay (8); however, there is a difference between the percent of DHR positive neutrophils and the mean fluorescence intensity after PMA stimulation that allows discrimination between true X-linked CGD and complete MPO deficiency. Further, the addition of recombinant human MPO enhances the DHR signal in MPO-deficient neutrophils but not in CGD neutrophils.(8)

It is important to have quantitative measures in the DHR flow cytometry assay to effectively use the test for diagnosis of the different forms of CGD as well as for monitoring chimerism and NOX activity post-hematopoietic cell transplantation. These quantitative measures include assessment of the relative proportion (%) of neutrophils that are positive for DHR fluorescence after PMA stimulation and the relative fluorescence intensity of DHR on neutrophils after activation.

This assay can also be used for the diagnostic evaluation of Rac2 deficiency, which is a neutrophil defect that causes profound neutrophil dysfunction with decreased chemotaxis, polarization, superoxide anion production, azurophilic granule secretion. This disease is caused by inhibitory variants in the *RAC2* gene, which encodes a Rho family GTPase essential to neutrophil activation and NOX function.(9) Patients with Rac2 deficiency have been shown to have normal neutrophil oxidative burst when stimulated with PMA, indicating normal NOX activity but abnormal neutrophil responses to N-formyl-methionyl-leucyl-phenylalanine (fMLP), which is a physiological activator of neutrophils. The defective oxidative burst to fMLP, but not to PMA, is consistent with RAC2 deficiency.(10,11) By contrast, gain of function variants in *RAC2* would lead to an exaggerated response to fMLP.(11,12)

Female carriers of X-linked CGD can become symptomatic for CGD due to skewed lyonization (X chromosome

inactivation).(13) Age-related acquired skewing of lyonization can also cause increased susceptibility to infections in carriers of X-linked CGD.(14) While inherited disease-causing variants are more common in CGD, there have been reports of *de novo* variants in the *CYBB* gene, causing X-linked CGD in male patients whose mothers are not carriers for the affected allele. Additionally, somatic mosaicism has been reported in patients with X-linked CGD who have small populations of normal cells.(15) There are also reports of triple somatic mosaicism in female carriers (16,17) as well as late-onset disease in an adult female who was a somatic mosaic for a novel variant in the *CYBB* gene.(18)

Therefore, the clinical, genetic, and age spectrum of CGD is varied and laboratory assessment of NOX activity after neutrophil stimulation, coupled with appropriate interpretation, is critical to achieving an accurate diagnosis or for monitoring patients posttransplant.

Reference Values

Result name	Unit	Cutoff for defining normal
% PMA ox-DHR+	%	> or =95%
MFI PMA ox-DHR+	MFI	> or =60
% fMLP ox-DHR+	%	> or =10%
MFI fMLP ox-DHR+	MFI	> or =2
Control % PMA ox-DHR+	%	> or =95%
Control MFI PMA ox-DHR+	MFI	> or =60
Control % fMLP ox-DHR+	%	> or =10%
Control MFI fMLP ox-DHR+	MFI	> or =2

PMA = phorbol myristate acetate
DHR = dihydrorhodamine
MFI = mean fluorescence intensity
fMLP = N-formyl-methionyl-leucyl-phenylalanine

The appropriate age-related reference values for Absolute Neutrophil Count will be provided on the report.

Interpretation

An interpretive report will be provided, in addition to the quantitative values.

Interpretation of the results of the quantitative dihydrorhodamine (DHR) flow cytometric assay must include both the proportion of positive neutrophils for DHR after phorbol myristate acetate and/or N-formyl-methionyl-leucyl-phenylalanine stimulation and the mean fluorescence intensity. Additionally, visual assessment of the pattern of DHR fluorescence is helpful in discriminating between the various genetic defects associated with chronic granulomatous disease and complete myeloperoxidase deficiency.

Cautions

Specimens are optimally tested within 24 hours of blood draw, though the stability of the assay is within 48 hours of collection. Specimens should be collected in sodium heparin and transported under strict ambient conditions. Use of the Ambient Mailer-Critical Specimens Only box (T668) is encouraged to ensure appropriate transportation of the specimen.

Some disease-causing variants in *NCF4* cause only a mild atypical form of chronic granulomatous disease (CGD) and may not be detected by this assay. The DHR test may be normal or mildly impaired in patients who are NCF4 (p40phox) deficient.

Severe glucose-6-phosphate dehydrogenase deficiency can be a phenocopy of CGD both in cellular and clinical terms and can be the underlying reason for an abnormal DHR response.(19)

Hemolyzed specimens may interfere with the assay (ie, high background).

Specimens with an absolute neutrophil count less than 200 will not be accepted for this assay.

Complete myeloperoxidase deficiency can yield a false-positive result.

Supportive Data

Dihydrorhodamine analysis was performed to assess neutrophil oxidative burst in 157 healthy donors, 74 children and 83 adults.

Clinical Reference

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Performance

Method Description

A sodium heparin whole blood specimen is incubated at 37 degrees C in the presence of DHR123. Phorbol myristate acetate (PMA) or N-formyl-methionyl-leucyl-phenylalanine (fMLP) stimulant is added and mixed with the whole blood specimen for additional incubation at 37 degrees C. The specimen is then centrifuged, and the cell pellet is subsequently lysed with ammonium chloride at ambient temperature. Lysed specimens are then washed with azide-free phosphate buffered saline prior to staining with LIVE/DEAD viability marker and CD15 at ambient temperature. Finally, cells are washed, centrifuged, and resuspended in 1% paraformaldehyde prior to analysis. Viable neutrophils are identified by the use of the viability dye and further confirmed by the presence of CD15. Approximately 20,000 viable neutrophil events in the unstimulated specimen are used to set the limits for number of events collected for flow cytometry. The results are derived as delta % DHR-positive neutrophils after PMA or fMLP stimulation and mean fluorescence intensity for each stimulant for DHR flow cytometry.(O'Gorman MR, Corrochano V. Rapid whole-blood flow cytometry assay for diagnosis of chronic granulomatous disease. Clin Diagn Lab Immunol. 1995;2[2]:227-232; Kuhns DB. Diagnostic testing for chronic granulomatous disease. Methods Mol Biol. 2019;1982:543-571)

PDF Report

No

Day(s) Performed

Monday through Friday

Report Available
3 to 4 days

Specimen Retention Time
4 days

Performing Laboratory Location
Mayo Clinic Laboratories - Rochester Superior Drive

Fees & Codes

Fees
- Authorized users can sign in to Test Prices for detailed fee information.
- Clients without access to Test Prices can contact Customer Service 24 hours a day, seven days a week.
- Prospective clients should contact their account representative. For assistance, contact Customer Service.

Test Classification
This test was developed using an analyte specific reagent. Its performance characteristics were determined by Mayo Clinic in a manner consistent with CLIA requirements. This test has not been cleared or approved by the US Food and Drug Administration.

CPT Code Information
86352 x2

LOINC® Information

Test ID	Test Order Name	Order LOINC® Value
DHR	DHR Flow, B	98122-5

Result ID	Test Result Name	Result LOINC® Value
ANC	Absolute Neutrophil Count	751-8
PMAP	% PMA ox-DHR+	85376-2
PMAM	MFI PMA ox-DHR+	85374-7
FMPPP	% FMLP ox-DHR+	85373-9
FMPM	MFI fMLP ox-DHR+	85370-5
ANCC	Control Absolute Neutrophil Count	85369-7
PMAPC	Control % PMA ox-DHR+	85377-0
PMAMC	Control MFI PMA ox-DHR+	85375-4
FMPPC	Control % fMLP ox-DHR+	85372-1
FMPMC	Control MFI fMLP ox-DHR+	85371-3
DHRI	Interpretation	69052-9