For questions concerning laboratory protocols, assay development and validation, quality control, sample handling and assay results, please contact:

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INTRODUCTION

The intention of this manual is to provide guidelines for specimen collection and handling, as well as provide a guide of services currently offered by the Sterol Analysis Laboratory. The Sterol Analysis Laboratory primarily performs quantification of stanols/sterols and intermediates in the bile acid pathway. To request lab tests, see section for specimen collection, handling, and storage.

The tests listed in this Sterol Analysis Laboratory Service Guide are only those which are currently performed or have been performed in the past. It is likely that new assays will be developed. Please contact the Laboratory Director or Supervisor for test availability and scheduling.

STEROL ANALYSIS LABORATORY MISSION

The mission of the Sterol Analysis Laboratory is to:
1. Perform analyses of stanols/sterols and intermediates in the bile acid pathway that are not routinely available in general hospital clinical laboratories or elsewhere in Oregon. We are currently the only laboratory on the West Coast to offer this type of testing.
2. Make laboratory services to measure stanols/sterols and intermediates in the bile acid pathway for diagnostic testing available to all clinicians practicing at OHSU and to those in the surrounding area.
3. Develop new assays for clinical research, which have the potential for wider applicability in diagnosis and patient care.

STEROL ANALYSIS LABORATORY HOURS OF OPERATION

The hours of operation of the Sterol Analysis Laboratory are 9:00 a.m. to 5:00 p.m. Tuesday through Friday. **For blood drawn at night or on weekends, it is important to read the sections entitled “Specimen Collection" and “Specimen Labeling, Ordering Tests and Shipping”.

SPECIMEN COLLECTION

**PLEASE READ CAREFULLY** Blood samples drawn locally after hours should be refrigerated at 4°C and delivered the next working day to Richard Jones Hall, Room 3360 or shipped to the Sterol Analysis Laboratory using overnight delivery. Whole blood specimens should be shipped on ice packs (insulate sample and include one ice-pack, do not freeze). Plasma should be shipped on ice packs or frozen. Urine should be shipped on ice-packs or frozen. Whole blood samples received by the Sterol Analysis Laboratory will be spun and separated. Plasma will be analyzed immediately or frozen prior to analysis.

**NOTE:** All blood, plasma and urine samples should be transported in appropriate biohazard sealed containers that are leak proof.
UNACCEPTABLE SPECIMENS (Including, but not limited to, the following):

1. Specimens consisting of citrate, oxalate, or fluoride plasma (blue, gray, or black topped tubes).
2. Specimens without at least two identifiers (i.e. patient name, DOB and/or MRN).
3. Blood/plasma specimens of less than 0.5 mL volume.
4. Specimens that include broken tubes.
5. Specimens not refrigerated or frozen as required.
6. Whole blood specimens drawn more than one day before receipt by the laboratory and/or that are grossly hemolyzed.

This is not intended to imply that all "unacceptable" specimens will be discarded or not analyzed. Requesting physicians who send unacceptable specimens will be notified no later than the next working day. The phlebotomist, if known, will be notified of the problem.

SPECIMEN LABELING, ORDERING TESTS AND SHIPPING

Samples must be labeled with at least two identifiers, i.e. patient name, DOB and/or MRN.

NOTE: ordering using EPIC (OHSU Out-Patient & In-Patient). Currently, we are a reference lab to OHSU Clinical Pathology. Tests performed by the Sterol Analysis Laboratory for OHSU include: plasma 7-dehydrocholesterol, plasma 5α-cholestanol, plasma beta-sitosterol, plasma sterols, misc. and urine bile alcohol (5β-cholestan-3α,7α,12 α,23S,25-pentol).

The Laboratory Sample Requisition Form (or EPIC order) associated with the sample must provide the following information:

- Patient Name
- Ordering Physician’s name
- Medical Record Number (MRN)
- DOB, Sex
- Date of specimen collection
- Test to be performed

For samples shipped directly to the Sterol Analysis Laboratory from outside OHSU, please include:

- A paper Sample Requisition Form, completed and signed by Ordering Physician
- We will need to invoice the referring laboratory or bill the patient directly – if patient is responsible, please provide patient address, phone number and email.

NOTE: Specimens should be shipped by overnight express carrier Monday through Thursday. Saturday delivery may be available upon request. Call Laboratory at (503) 494-4593 or email tracking number to debarber@ohsu.edu to notify lab of shipment.
**SHIPPING ADDRESS:**
Attention: Andrea DeBarber (503-494-4593)
Richard Jones Hall Room 3340/3360, Dock 4, Oregon Health & Science University
3181 SW Sam Jackson Park Road
Portland, OR 97239-3098

**ASSAY TIMING AND RELEASE OF RESULTS**

Assays performed by the Sterol Analysis Laboratory are analyzed on a batch basis whenever possible. Therefore, turnaround times will vary depending on which assay is requested. Turnaround time for each assay is provided in the Laboratory Services Guide. The Sterol Analysis Director or Technical Supervisor/Laboratory Supervisor reviews all results.

If samples are referred to our Laboratory by Clinical Pathology, the final reports are sent to Clinical Pathology to be scanned into Beaker and reported in EPIC. For samples submitted directly to the Sterol Analysis Laboratory reports are emailed and/or Fax ed to the requesting physician and/or referring laboratory. Research results are sent to the PI or study coordinator.

**SAMPLE DISPOSAL**

The Sterol Analysis Laboratory is faced with space limitations. Therefore, samples are generally not stored for longer than 2 years.

**ASSAY BATCHING**

The following tests are batched and analyzed by the Sterol Analysis Laboratory or are referred to the OHSU Lipid-Atherosclerosis Laboratory for analysis*:

- Plasma/serum cholesterol, total*
- Plasma/serum sterols (includes 7-dehydrocholesterol, 5α-cholestanol; Beta-sitosterol)
- Plasma/serum bile acid pathway intermediates (7α,12α-dihydroxy-4-cholesten-3-one and 7α-hydroxy-4-cholesten-3-one)
- Plasma/serum bile alcohol (5β-cholestane-3α,7α,12α,25-tetrol-3-O-β-D-glucuronide)
- Urinary bile alcohol (5β-cholestane-3α,7α,12α,23S,25-pentol)

**REFERRAL SERVICE** The Sterol Analysis Laboratory sends out samples for total cholesterol testing to the OHSU Lipid Atherosclerosis Laboratory. The Sterol Analysis may also refer samples for analysis to other lipid research laboratories in the United States. This is generally for research purposes. Please contact Laboratory Director for more information.
COLOR CODING OF BLOOD COLLECTION TUBES

<table>
<thead>
<tr>
<th>TUBE</th>
<th>ADDITIVE</th>
<th>GENERAL USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lavender top</td>
<td>EDTA(K2) Spray Dried/2 or 3 mL</td>
<td>Plasma</td>
</tr>
<tr>
<td>Green top</td>
<td>143 IU Sodium Heparin/2 or 3 mL</td>
<td>Plasma</td>
</tr>
<tr>
<td>Red top</td>
<td>None</td>
<td>Serum</td>
</tr>
</tbody>
</table>

SPECIMEN REQUIREMENTS FOR COMMON TESTS REQUESTED
(Please read also "Specimen Collection" on page 3)

<table>
<thead>
<tr>
<th>TEST</th>
<th>MEASURE</th>
<th>TUBE REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Plasma/serum Cholesterol*</td>
<td>Cholesterol, total</td>
<td>3 mL lavender or green top (plasma) or 3 mL red top (serum)</td>
</tr>
<tr>
<td>2. Plasma/serum sterol*</td>
<td>7-Dehydrocholesterol, total</td>
<td>3 mL lavender or green top (plasma) or 3 mL red top (serum)</td>
</tr>
<tr>
<td>3. Plasma/serum sterol*</td>
<td>5α-Cholestanol, total</td>
<td>3 mL lavender or green top (plasma) or 3 mL red top (serum)</td>
</tr>
<tr>
<td>4. Plasma/serum sterol*</td>
<td>Beta-sitosterol, total</td>
<td>3 mL lavender or green top (plasma) or 3 mL red top (serum)</td>
</tr>
<tr>
<td>5. Plasma/serum bile acid pathway intermediate*</td>
<td>7α,12α-Dihydroxy-4-cholesten-3-one, free</td>
<td>3 mL lavender or green top (plasma) or 3 mL red top (serum)</td>
</tr>
<tr>
<td>6. Plasma/serum bile acid pathway intermediate*</td>
<td>7α-Hydroxy-4-cholesten-3-one, free</td>
<td>3 mL lavender or green top (plasma) or 3 mL red top (serum)</td>
</tr>
<tr>
<td>7. Plasma/serum bile alcohol*</td>
<td>5β-cholestane-3α,7α,12α,25-tetrol-3-O-β-D-glucuronide</td>
<td>3 mL lavender or green top (plasma) or 3 mL red top (serum)</td>
</tr>
<tr>
<td>9. Urinary bile alcohol</td>
<td>5β-Cholestane-3α,7α,12α, 23S,25-pentol, total</td>
<td>10 mL random urine</td>
</tr>
</tbody>
</table>

*Note: Whole blood can be shipped on ice-packs (not frozen). Whole blood specimens must reach laboratory within 2-4 days of collection.
### LIST OF AVAILABLE TESTS AND METHODOLOGY

#### OFFERED THROUGH THE OHSU LIPID-ATHEROSCLEROSIS LABORATORY:

<table>
<thead>
<tr>
<th>PLASMA/SERUM CHOLESTEROL, TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma preferred/serum</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>3 mL lavender or green top (plasma)</td>
</tr>
<tr>
<td>3 mL red top (serum)</td>
</tr>
</tbody>
</table>

**Method:** The cholesterol assay uses an enzymatic, colorimetric process. Cholesterol esters are cleaved by the action of cholesterol esterase to yield free cholesterol and fatty acids. Cholesterol oxidase then catalyzes the oxidation of cholesterol to 4-cholesten-3-one and hydrogen peroxide. In the presence of peroxidase, the hydrogen peroxide formed affects the oxidative coupling of phenol and 4-aminophenazone to form a red quinone-imine dye. The color intensity of the dye formed is directly proportional to the cholesterol concentration. It is determined by measuring the increase in absorbance. Linear up to 800 mg/dL without dilution. No significant interference from hemolysis up to 700 mg/dL. Cholesterol is stable up to 7 days at 2-8°C.

**Precision:** In-house inter-assay CV < 2.0%

**Sample Stability:** Plasma/serum is stable up to 7 days refrigerated or can be frozen for long-term storage. Plasma can be shipped on ice-packs or frozen. Whole blood can be shipped on ice-packs (not frozen). Refrigerated whole blood specimens must reach laboratory within 2-4 days of collection.

**Reference Ranges:**

<table>
<thead>
<tr>
<th>Age</th>
<th>Cholesterol</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-18 years</td>
<td>&lt; 180 mg/dL</td>
</tr>
<tr>
<td>18-45 years</td>
<td>&lt; 200 mg/dL</td>
</tr>
<tr>
<td>&gt; 45 years</td>
<td>&lt; 200 mg/dL</td>
</tr>
</tbody>
</table>

Note – For adults, the NHLBI ATP III recommends the following:

- **Desirable**  
  Cholesterol < 200 mg/dL
- **Borderline High**  
  Cholesterol 200-239 mg/dL
- **High**  
  Cholesterol > 240 mg/dL

**NOTE:** Reference ranges listed are based on NHLBI Guidelines; Surgeon General of USA. Certain drugs may alter the lipid profile.

Assay is analyzed every day by the Lipid Laboratory Tuesday through Friday (except holidays).
OFCRED THROUGH THE STEROL ANALYSIS CLINICAL LABORATORY:

<table>
<thead>
<tr>
<th>PLASMA/SERUM STEROLS, TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma (preferred)/serum</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

**Method:** Hexane extraction of saponified plasma lipids followed by derivatization. Gas chromatography for quantitative determination of elevated cholestanol (for CTX); 7-dehydrocholesterol (for diagnosis of Smith-Lemli-Opitz Syndrome), beta-sitosterol (for Sitosterolemia). Quantification is by flame ionization detection or selected-ion monitoring, ion-ratio fragmentometry in the electron impact mode using epicoprostanol as internal standard. Linear up to 4.8 mg/dL without dilution.


**Precision:** In-house inter-assay CV < 15%

**Sample Stability:** Plasma/serum is stable up to 17 hours at ambient temperature or refrigerated. Samples can be frozen for long-term storage. Plasma can be shipped overnight on ice-packs or frozen. Whole blood can be shipped overnight on ice-packs (not frozen). Protect samples from light for 7-dehydrocholesterol measurement.

**Reference Ranges:**

- Normal cholestanol concentration in unaffected individuals age range 4.0-70.3 years old, n=14
  
  \[
  0.32 \pm 0.10 \text{ mg/dL} \\
  \text{mean} \pm \text{SD}
  \]

- Cholestanol concentration in CTX-affected untreated individuals age range 5.2-33.0 years old, n=14
  
  \[
  3.01 \pm 1.40 \text{ mg/dL} \\
  [1.31-7.10] \\
  \text{mean} \pm \text{SD} \ [\text{range}]
  \]

- Normal concentration in children age range 0.1-16 years old, n=153
  
  - 7-Dehydrocholesterol < 0.1 mg/dL
  - Sitosterol < 0.26 \pm 0.13 \text{ mg/dL}

Assay is batched by the Sterol Analysis Laboratory with a resultant turn-around time for reporting of 20 business days.
### PLASMA/SERUM BILE ACID PATHWAY INTERMEDIATE

**7α,12α-DIHYDROXY-4-CHOLESTEN-3-ONE, FREE**

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma (preferred)/serum</td>
<td>3 mL lavender or green top (plasma)</td>
</tr>
<tr>
<td></td>
<td>3 mL red top (serum)</td>
</tr>
<tr>
<td></td>
<td>(minimum volume 0.5 mL)</td>
</tr>
</tbody>
</table>

**Method:** Addition of 7α,12α-dihydroxy-4-cholesten-3-one-d7 method internal standard in methanol to sample and extracted as previously described. Isotope-dilution quantification is performed using positive-mode LC-ESI-MS/MS multiple reaction monitoring of 7α12αC4 (m/z 417.3>253.1 and 417.3>381.2) and internal standard (m/z 424.3>253.1) with a reversed-phase gradient utilizing a 150 x 4.6 mm Biphenyl (2.6 µm) column. Linear up to 1,000 ng/mL without dilution. No significant interference from common over the counter and prescription medications. Carry over response in blanks is < 6% of the LLOQ for the analyte and < 1% for the internal standard.


**Precision:** In-house intra-assay CV < 7% for low QC n=20 samples and < 7% for high QC n=20 samples

**Accuracy:** In-house intra-assay within ± 10% of nominal value for low and high QC, n=20 samples

**Sample Stability:** Plasma is stable for up to 8 hours at ambient temperature (66 hours refrigerated) or can be frozen for long-term storage. Plasma can be shipped overnight on ice-packs or frozen. Do not keep plasma at room temperature for more than 8 hours.

**Reportable Range:**

<table>
<thead>
<tr>
<th>Component</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>7α,12α-DIHYDROXY-4-CHOLESTEN-3-ONE</td>
<td>10 ng/mL to 10,000 ng/mL</td>
</tr>
</tbody>
</table>

**Reference Ranges:**

- Normal concentration in unaffected individuals age range 4.0-70.3 years old, n=14: < 10 ng/mL (< 0.024 nmol/mL)
- Concentrations in CTX-affected untreated individuals age range 5.2-33.0 years old, n=14: 3,561 ± 1,181 ng/mL [1,549-5,632] (8.548 ± 2.835 nmol/mL [3.719-13.519]) mean ± SD [range]

Assay is batched by the Sterol Analysis Laboratory with a resultant turn-around time for reporting of 20 business days.
**Title:** Sterol Analysis Clinical Laboratory Services Guide

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**PLASMA/SERUM BILE ACID PATHWAY INTERMEDIATE, 7α-DIHYDROXY-4-CHOLESTEN-3-ONE, FREE**

| Method: | Addition of 7α-hydroxy-4-cholesten-3-one-d7 method internal standard in methanol to sample and extracted as previously described. Isotope-dilution quantification is performed using positive-mode LC-ESI-MS/MS multiple reaction monitoring of 7αC4 (m/z 401.2>177.1 and 401.2>97.0) and internal standard (m/z 408.3>177.1) with a reversed-phase gradient utilizing a 150 x 4.6 mm Biphenyl (2.6 µm) column. Linear up to 1,000 ng/mL without dilution. No significant interference from common over the counter and prescription medications. Carry over response in blanks is < 10% of the LLOQ for the analyte and < 1% for the internal standard. |
| Precision: | In-house intra-assay CV < 8% for low QC n=20 samples and < 8% for high QC n=20 samples |
| Accuracy: | In-house intra-assay within ± 10% of nominal value for low and high QC, n=20 samples |
| Sample Stability: | Plasma is stable for up to 8 hours at ambient temperature (66 hours refrigerated) or can be frozen for long-term storage. Plasma can be shipped overnight on ice-packs or frozen. Do not keep plasma at room temperature for more than 8 hours. |
| Reportable Range: | Plasm (preferred)/serum 3 mL lavender or green top (plasma) 3 mL red top (serum) (minimum volume 0.5 mL) |
| Concentrations in CTX-affected untreated individuals | age range 5.2-33.0 years old, n=14 | 2,628 ± 1,244 ng/mL [1,215-4,863] (6.560 ± 3.104 nmol/mL [3.033-12.139]) mean ± SD [range] |
| Normal concentration in unaffected individuals | age range 4.0-70.3 years old, n=14 | 16.3 ±19.5 ng/mL 1 (0.041 ± 0.049 nmol/mL) mean ± SD |

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1. 7α-hydroxy-4-cholesten-3-one normal reference range calculated including concentrations <LLOQ. Note that reported normal reference ranges are 22 ± 20 ng/mL (Mignarri A et al (2016) J Inherit Metab Dis 39(1):75-83) and 15 ± 4 ng/mL (Matysik S et al (2011) Chem Phys Lipids 164(6):530-4)

Assay is batched by the Sterol Analysis Laboratory with a resultant turn-around time for reporting of 20 business days.

38-FRM-002.09 (Effective 05-APR-2024)
**PLASMA/SERUM BILE ALCOHOL**

5β-CHOLESTANE-3α,7α,12α,25-TETROL GLUCURONIDE

| Method: | Addition of 5β-cholestane-3α,7α,12α,25-tetrol-3-O-β-D-glucuronide-d₆ method internal standard in methanol to sample and extracted as previously described. Isotope-dilution quantification is performed using positive-mode LC-ESI-MS/MS multiple reaction monitoring of 5β-cholestane-3α,7α,12α,25-tetrol-3-O-β-D-glucuronide (m/z 611.4>75.0 and 611.4>85.0) and internal standard (m/z 617.4>75.0) with reversed-phase gradient utilizing a 150 x 4.6 mm Biphenyl (2.6 µm) column. Linear up to 5,000 ng/mL without dilution. No significant interference from common over the counter and prescription medications. Carry over response in blanks is < 2% of the LLOQ for the analyte and < 1% for the internal standard. |
| Precision: | In-house intra-assay CV < 4% for low QC n=20 samples and < 5% for high QC n=20 samples |
| Accuracy: | In-house intra-assay within ± 10% of nominal value for low and high QC n=20 samples |
| Sample Stability: | Plasma is stable for up to 8 hours at ambient temperature (66 hours refrigerated) or can be frozen for long-term storage. Plasma can be shipped overnight on ice-packs or frozen. Do not keep plasma at room temperature for more than 8 hours. |
| Reportable Range: | 200 ng/mL to 50,000 ng/mL |
| Reference Ranges: | Normal concentration in unaffected individuals age range 4.0-70.3 years old, n=14 < 200 ng/mL < 0.326 nmol/mL | Concentrations in CTX-affected untreated individuals age range 5.2-33.0 years old, n=14 10,536 ± 6,119 ng/mL [3,245-20,541] (17.193 ± 9.985 nmol/mL [5.296-33.520]) mean ± SD [range] |


Assay is batched by the Sterol Analysis Laboratory with a resultant turn-around time for reporting of 20 business days.
**Title:** Sterol Analysis Clinical Laboratory Services Guide

**URINARY BILE ALCOHOL**

**5β-CHOLESTANE-3α,7α,12α,23S,25-PENTOL, TOTAL**

| Method | Addition of 23S-pentol-d6 method internal standard followed by incubation of urine with β-glucuronidase enzyme. Isotope-dilution quantification performed using positive-mode LC-ESI-MS/MS multiple reaction monitoring of 23S-pentol (m/z 453.3>361.4) and internal standard (m/z 459.3>343.5) with a reversed-phase gradient utilizing a 4.6x50mm Biphenyl (2.6 µm) column. Linear up to 5,000 ng/mL without dilution. No significant interference from common over the counter and prescription medications. Carry over response in blanks is < 1% of the LLOQ for the analyte and < 0.5% for the internal standard. References: Shimazu K et al (1986) J Biochem 99: 477, Batta AK et al (1985) J Lipid Res 26: 690. |
|---|
| Precision | In-house intra-assay CV < 4% for low QC n=20 samples and < 3% for high QC n=20 samples |
| Accuracy | In-house intra-assay within ± 10% of nominal value for low and high QC, n=20 |
| Sample Stability | Urine is stable up to 5 days at ambient temperature or refrigerated. Samples can be frozen for long-term storage. Urine can be shipped over-night on ice-packs or frozen. |
| Reportable Range | **5β-CHOLESTANE-3α,7α,12α,23S,25-PENTOL** 200 ng/mL to 250,000 ng/mL |
| Reference Ranges | Normal concentration in unaffected individuals, n=20 < 200 ng/mL |
| Concentrations in CTX-affected untreated individuals age range 5.2-45.8 years old, n=14 | 58,941 ± 42,524 ng/mL [12,541-177,506] mean ± SD [range] |

Assay is batched by the Sterol Analysis Laboratory with a resultant turn-around time for reporting of 20 business days.