

Laboratory Procedure Manual

Analyte: Total Cholesterol

Matrix: **Serum**

Method: **Roche/Hitachi Modular P Chemistry Analyzer**

as performed by: Collaborative Studies Clinical Laboratory

University of Minnesota Medical Center

Fairview-University Medical Center

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Important Information for Users

The Fairview -University Medical Center periodically refines these laboratory methods. It is the responsibility of the user to contact the person listed on the title page of each write-up before using the analytical method to find out whether any changes have been made and what revisions, if any, have been incorporated.

Public Release Data Set Information

This document details the Lab Protocol for testing the items listed in the following table:

File Name	Variable Name	SAS Label
TCHOL_E	LBXTC	Total cholesterol (mg/dL)
	LBDTCSI	Total cholesterol (mmol/L)

1. SUMMARY OF TEST PRINCIPLE AND CLINICAL RELEVANCE

In this enzymatic method esterified cholesterol is converted to cholesterol by cholesterol esterase. The resulting cholesterol is then acted upon by cholesterol oxidase to produce cholest-4-en-3-one and hydrogen peroxide. The hydrogen peroxide then reacts with 4-aminophenazone in the presence of peroxidase to produce a colored product that is measured at 505 nm (secondary wavelength = 700 nm). The final step is also known the Trinder reaction. This method is a single reagent, endpoint reaction that is specific for cholesterol.

Cholesterol, a steroid molecule with a hydroxyl group in the C3 position, is synthesized in many types of tissue, but mainly in the liver and intestinal wall. About 75 per cent of cholesterol is newly synthesized, with the remainder originating from dietary intake. Cholesterol measurement is performed to screen for atherosclerotic risk and in the diagnosis and treatment of disorders involving elevated cholesterol as well as lipid and lipoprotein metabolic disorders. This is a completely enzymatic method; much less labor-intensive than the reference method of Abell and Kendall.

2. SAFETY PRECAUTIONS

A. Daily Safety Precautions.

All personnel working in the laboratory must wear gloves and laboratory coats. Laboratory coats are to be kept snapped. Lab coats must meet OSHA compliance CPL2-2.44D. Splash and spray resistant fabric that is also antistatic is required. Gloves are removed when leaving the immediate work area or when entering offices within the immediate work area. All used gloves, vials, pipettes and other items that come in contact with specimens are disposed of in a Biohazard box lined with a red plastic bag. Work benches are cleaned at the end of each day with a solution of sodium hypochlorite (bleach:water, 10:100, v/v) and then covered with plastic-backed white paper.

B. Blood Handling.

The improper handling of blood samples from patients with infectious diseases, e.g., hepatitis or HIV, can lead to infection of staff that draw, handle, analyze or store such samples. Transmission can occur by ingestion, inhalation or direct contact, and staff must exercise care when handling blood samples. Always wear liquid impermeable gloves (e.g., nitrile or plastic) when handling biological samples. The use of latex gloves is not allowed due to concerns for personnel having or developing latex sensitivities. Never pipet samples by mouth. Avoid contact with serum. Cover any scratches or cuts on fingers and hands and wear gloves before handling serum. Store all samples in sealed containers. In order to minimize the formation of aerosols, do not leave samples open to the atmosphere longer than necessary.

It is about 30 times easier to become infected with hepatitis than with HIV through sample mishandling, and it has been recommended that the usual precautions for handling blood specimens to prevent hepatitis infection serve as a guide to prevent AIDS infection as well. Handle all specimens as if you know them to be infectious. All staff should adhere to the CDC Guidelines for Prevention of HIV Infection in Health Care Workers.

C. Spills.

The contaminated area is cleaned with a solution of sodium hypochlorite (bleach:water, 10 :100, v/v) and the wipes are disposed of in a red biohazard box.

3. COMPUTERIZATION; DATA SYSTEM MANAGEMENT

NHANES results are entered into a spreadsheet provided electronically by WESTAT, Inc for NHANES.

To access the spreadsheet click on My Computer → Z drive → User → Dep Labs → Collab Studies → NHANES → Glyhb 004.

Choose the file named with the corresponding box number.

Enter the analysis date, run number, technologist's initials, result, and result comment code.

The spreadsheet will be sent electronically by the contact person.

4. SPECIMEN COLLECTION, STORAGE, AND HANDLING PROCEDURES; CRITERIA FOR SPECIMEN REJECTION

A. Specimen handling

Use serum or plasma (EDTA and heparin anticoagulants are acceptable) for the procedure. Other anticoagulants are unacceptable. Serum or plasma is stable for 5-7 days at 4°C, and longer at -70°C.

Serum or plasma specimens that have been frozen are sometimes prone to excessive precipitate formation. These specimens should not be centrifuged as that could cause layering of the lipids in the specimen. Since lipids tend to rise during centrifugation, this could lead to falsely elevated results. This is because the sample probe on the ModP aspirates as soon as it contacts the liquid surface. Excessive particulate matter may be removed by inserting a wooden stick into the

specimen to pick up the particles, or by drawing the serum or plasma through a coarse pipet-tip filter.

Bilirubin does not interfere up to an I index of 25. Hemolysis does not interfere up to an H index of 700. Lipemia does not interfere up to an L index 1250.

Minimum volume: 100 uL (includes dead volume)

5. PROCEDURES FOR MICROSCOPIC EXAMINATIONS; CRITERIA FOR REJECTION OF INADEQUATELY PREPARED SLIDES-

Not applicable for this procedure.

6. EQUIPMENT AND INSTRUMENTATION, MATERIALS, REAGENT PREPARATION, CALIBRATORS (STANDARDS), AND CONTROLS

A. Instrumentation

1. Roche Modular P chemistry analyzer. Roche Diagnostics, 9115 Hague Road, Indianapolis, IN 46250.
2. Cell Wash Solution II/Acid Wash. Roche product #4880307 (2L bottle). No preparation required. Solution of formic acid, citric acid and nikkol BT-9. Store at room temperature. Stable until expiration date on bottle. No stability time window after opening. This solution is automatically drawn by the Mod P while cleaning reaction cuvettes during analysis.
3. Cell Wash Solution I/NaOH-D. Roche product #1551540 (1800 mL bottle). No preparation required. Solution of sodium hydroxide (1N). Store at room temperature. Stable until expiration date on bottle. After opening a bottle it is stable for 14 days on the instrument. This solution is automatically drawn by the Mod P while cleaning reaction cuvettes during analysis.
4. Reaction cell cuvette segments. Roche product #714-0650 (Four sets of eight segments. Eight segments complete the entire rotor). Soak cuvettes overnight in a solution of 2% Hitergent before installing on the instrument. Perform cell wash and cell blank functions after installation. Change cuvettes quarterly.
5. Hitergent. Roche product #409149 (1L bottle). No preparation required. Solution of ethanamine, hexahydro-1,3,5-tris (Betahydroxyethyl) triazine and nonidet P-40. Store at room temperature. Stable until expiration date on bottle. Hitergent is an on-board reagent automatically drawn by the Mod P during the daily incubator bath exchange. Hitergent is transferred, as needed, from the 1L bottle to the 66 mL bottle located in position 2D3.
6. Sample cups (micro). Roche product #11406680001.
7. Sample cups (standard). Roche product #729177.

B. Other Materials

Serum mixer, transfer pipettes, sample cups, quality control normal and high serum from Solomon Park, SL2 and SL3 series.

C. Reagent Preparation

1. Roche product #1491458, CHOL reagent kit:

-R1 reagent (12 x 65 mL). PIPES buffer, pH 6.8, Mg²⁺, sodium cholate, 4-aminophenazone, phenol, fatty alcohol polyglycol ether, cholesterol esterase, cholesterol oxidase, peroxidase, stabilizers, preservative. See insert for concentrations. No preparation required. There are approximately 350 tests per bottle.

-Storage and stability. Keep reagents stored in refrigerator until use. R1 is stable for 28 days refrigerated on the analyzer.

-When loading the reagents onto the Mod P, make sure R1 is placed in the R1 rotor. Remove any bubbles in the reagent prior to loading.

2. Milli-Q water. Milli-Q is the trade name of the water system purchase from the Millipore Corporation. Milli-Q is deionized water treated with activated carbon and deionization cartridges and filtered to remove microorganisms larger than 0.22 micrometers. This meets CAP class I water requirements.

D. Preparation of Quality Control Materials

Two levels of control are assayed each time the cholesterol method is performed. It is acceptable to run each control at the start of the day, and again at the end of the day. The operator may run them more frequently, if desired. One control is prepared from pooled, normal human serum. The other is an elevated, abnormal commercial control. Consult quality control charts for current ranges and lots in use.

Aliquot thawed, mixed, and transferred to two sample cups for duplicate analysis per run.

E. Standards Preparation

The calibrator used for this assay is obtained from a unit of whole blood collected from a single donor. The unit of blood is collected at the UMMC donor center, and then it is allowed to clot overnight at room temperature. There are no additives in the collection bag. Cholesterol concentration will vary with each donor selected. The calibrator is stored at -70°C. The new calibrator is first assayed in duplicate for 20 consecutive days. The new calibrator is also

assayed in duplicate on two consecutive days using the reference Abell-Kendall method. The values obtained from the two different methods should agree within two percent of each other.

7. CALIBRATION AND CALIBRATION VERIFICATION PROCEDURES

There is a variety of calibration models used on the Mod P. There are factored methods, blank calibrations, two-point calibrations and multi-point calibrations. The type of calibration is dictated by the Roche chemistry parameters for each method. The calibrator material may be a Roche product, an in-house preparation, or a product from another company. When the lot number of Roche's calibrator changes, Roche provides a barcode document to automatically install the new setpoints. This update (and other parameter edits) may also be performed manually.

Frequency of calibration is dictated by an automatic, time-dependent re-calibration built into the chemistry parameter profile for each test, and by observing the quality control data. All methods do not have the automatic time-out calibration feature. Details for each assay may be found in specific procedures and in the application parameters on the Mod P. Acceptable accuracy and precision limits are defined in each chemistry parameter file.

Calibration frequency: The Mod P will automatically perform a two-point calibration when there is a reagent lot number change. No other auto-calibrations are defined for the direct HDL-C assay. The Mod P will not allow testing to proceed until a successful calibration has been completed. Monitor control values to determine stability of the current calibration.

The ModP will automatically calibrate (2-point) cholesterol when there is a reagent lot number change, and it will perform a blank (1-point) calibration when there is a bottle change. There is no automatic time-dependent calibration. Monitor control values to determine stability of the current calibration.

B. Verification

All reagent and calibrator lots are validated with both the old calibrator reagent run values vs. the newly calibrated channel or new reagent lot. All values must be within 5% of the older lot analysis. If the values are greater than 5% the lot is rejected for use.

8. PROCEDURE OPERATING INSTRUCTIONS; CALCULATIONS; INTERPRETATION OF RESULTS

The Roche/Hitachi Modular P Chemistry Analyzer (Mod P) is used to measure a wide variety of analytes on various body fluid specimens. It uses an ion specific

electrode (ISE) measuring system as well as a photometric measuring system. The ISE system is used in the quantitation of sodium, potassium and chloride. The photometric system can measure colorimetric or nephelometric reactions utilizing end point or kinetic (rate) absorbance measurements. Test ordering on the Mod P and resulting in the Misys host computer system may be done manually or these tasks may be executed by use of a barcode-based bi-directional interface. The Mod P can utilize both of these two systems simultaneously.

A. Theory of Operation

Whether directed by the user or by an interfaced order, each specimen is aspirated and delivered to the two different measuring systems. ISE specimens (sodium, potassium, chloride) pass through the electrode measuring system, while photometric specimens are delivered to one of 160 reaction cells, along with up to four reagents. Endpoint or rate reactions occur in the reaction cell with absorbance changes measured using discrete wavelength settings. Following completion of the reaction, the cell rinse unit washes the reaction cell, and the cell is re-used. All analyses occur at 37°C.

B. Specimens

Follow all usual precautions for obtaining a specimen by venipuncture. To determine the correct specimen type, refer to the specific assay procedure. Follow UMMC's Clinical Laboratory Safety Manual isolation and standard precautions for blood and body substances.

The approximate dead volume for the Mod P microsample cups is 50 uL. It is 50-75 uL for the macro cups.

Specimens may also be direct-sampled in the original storage vial. These vials are typically prepared by field center laboratories after collection of specimens at their site. Because they are frequently very small with small volumes of specimen, care must be taken that these vials are very thoroughly mixed prior to sampling. Since mixing or vortexing can cause bubble formation (which interferes with the Mod P sample detection system), care must be taken to remove these bubbles before analysis begins. This can be done by poking the bubbles with a wooden stick, or by a short (5 minute) centrifugation at 1,500 x g. However, if lipids are being measured centrifugation is not an option because the triglycerides could layer out into the surface of the specimen, resulting in an artifactual increase in their concentration. Storage vials come in a variety of shapes and sizes, and the clip design of the Mod P sample racks accommodates most of them.

C. Instrument Overview:

A general description of the instrument and its components is found in Section A of the Modular Analytics Operator's Manual, Book 1.

The Mod P has spectrophotometric and ion specific electrode measuring systems. The instrument utilizes reusable optically pure plastic reaction cells that are changed on a quarterly basis. The reaction cells are automatically washed by the instrument after completion of the test cycle. Sample and reagents are added to the reaction cells at specific timed intervals, varying by the program parameters defined for each test. Most methods utilize two reagents, but a few use one. All reagent bottles have a barcoded ID label on them so they can be placed in any position in the appropriate reagent rotor. The Mod P measures the reagent volume in the bottle as it is withdrawn, so the instrument provides a real time update on the number of tests available in each of the bottles.

Tests can be ordered manually or they can be executed by use of the bi-directional interface connected to the Misys host computer. Similarly, reporting can be achieved through the interface, or by manually keying the results into Misys from the instrument's hard copy printout.

The Misys Method Code for the Mod P when using the OEM (Online Entry Management) function

D. Instrument Setup

1. Log into the Mod P using assigned username and password.
2. Reagents. All reagents used on the Mod P are stored in a refrigerated reagent compartment. Cholesterol is a one-reagent system. Reagent 1 must be placed in the outer (R1) rotor. All reagents have a unique barcoded identifier. Before starting the analysis sequence check the reagent status on the Mod P to confirm there is adequate reagent to complete the anticipated test volume for the day. Discard any bottles that have gone empty. Check the volume of the two wash reagents.
3. Maintenance. Complete the scheduled daily maintenance as described in the Mod P general operations protocol.
4. Order calibration, if indicated (see Mod P general operations protocol).
5. Order controls. If a calibration was requested, the controls should not be ordered until the calibration report has printed. If the controls are ordered and executed before the calibration prints out, the controls will be measured on the previously stored calibration line.

E. Loading Calibrators and Controls

Each calibrator and control has a defined location on the black calibrator sample racks. A complete posting of all of these assigned locations is available on the Mod P computer. The assigned locations are also marked on the calibrator racks. A micro- or standard sample cup may be used to hold the calibrators. Fill the sample cup with enough volume to complete the full calibration sequence (this will vary by method; some multi-point calibrations will sample the standard several times, while in a simple two-point calibration, the standard is only sampled in duplicate). Most calibrations require saline as the “zero” standard. Make sure it is loaded. The sample cups are loaded into the calibrator sample racks like the controls and specimens will be later: seated down into the rack until the flange of the cup is level to the top surface of the rack. If the cup is not seated down far enough, the Mod P may not be able to detect it through the window in the rack’s mid-section. Additionally, if the sample cup is not fully seated, it could be jarred from the rack during transport on the Mod P.

See specific protocols for the assigned calibrators and controls to be used for each test.

F. Requesting a Calibration: (Operator’s Manual Section B, Book 1)

1. At the home screen, click or touch screen on <Calibration> tab.
2. Click or touch screen on <Status>. A list of all the Mod P tests appears. If more than one bottle set of reagents is on-board, a separate listing will appear for each set.
3. Click or touch screen on the tests to be calibrated.
4. In the “Method” box on the right side of the screen, select (click) the appropriate type of calibration to be performed on the selected test. The correct type of calibration for each method can be found in the specific test protocols located in the Mod P Applications folder. Most methods utilize a two-point calibration. Generally on the Mod P, if a screen button is white, that means it is active/available. Yellow indicates completion, gray indicates inactive/unavailable. Make sure that the Method box is white before clicking on Save below.
5. If a calibration has timed out, or if there has been a reagent lot change, this information appears in the Cause column. In these cases just highlight the test, skip the Method box, and touch or click on <Save>.
6. Click or touch screen on <Save>.
7. Failed calibrations will generate an error message by the Mod P. The two most common flags found in a failed calibration are SENS and DUP.
 - a. SENS (sensitivity error) occurs when the difference in absorbance between the zero standard and measuring standard does not fall within a method-specific, defined range. Typically, the absorbance difference is too small, and this usually indicates a deteriorated reagent. Replace both reagent bottles, and repeat the calibration.
 - b. All calibration lines are assayed in duplicate. DUP (duplication error) occurs when the pair of measurements at the zero or measuring point does

not agree satisfactorily with each other. In this case simply repeat the calibration. If the error occurs again, consider sources of imprecision (sample probe, syringe leakage, bubbles in reagent, etc.).

- c. Other calibration topics are found in the Operator's Manual, Section B, Book

G. Loading Reagents: (Operator's Manual Section B, Book 1)

Review available reagents by <Reagents>, <Status>. Sort the reagents by clicking on Available Tests. This lists the reagents in ascending order of the number of tests performable with the reagents currently on the Mod P. When a test is highlighted on this list, its reagent bottle locations are shown in the window on the right side of the screen.

There are two concentric reagent carousels: R1 and R2. R1 is the outer ring; R2 is the inner. Most test methods use two reagents, though some use only one. Generally, R1 is a buffered reagent that establishes the optimum pH and reaction conditions for the test, and R2 has the enzymes and/or chromogenic components that complete the reaction. The two reagent carousel chambers are refrigerated, with a locking lid to ensure constant temperature. There are 48 positions in each rotor. Forty-four of these are available for test reagents, three are reserved for system wash reagents, and one is left open to allow barcode scanning of the inner rotor. All reagent containers have a barcoded ID on their side. This barcode contains lot number, test code, expiration date and available test count information. If a test volume greater than the capacity of one reagent container is anticipated, additional bottles may be placed on the instrument. If an automatic calibration is not required on bottle change, or if the new bottle set was calibrated when it was placed on the instrument, then the Mod P will automatically begin pipetting a new bottle once the previous bottle is empty. If the reagents are placed in incorrect rotors, or if the barcode is illegible, the Mod P will not allow performance of the assay. Reagents may be placed in any position of the appropriate rotor since the barcode directs the Mod P to the correct rotor location for pipetting. The Mod P automatically reads the barcodes each time a lid is removed and replaced over the reagent chamber.

H. Loading Specimens: (Operator's Manual Section B, Book 1)

These instructions are provided under the assumption that all sample IDs and test codes will be manually entered by the Mod P user. The instructions for specimen loading utilizing the bi-directional interface and barcode reader can be found in the separate Mod P: interface protocol.

1. Transfer the specimen from its original labeled container to a Mod P sample cup.
2. Place the cup into the next available sample position in a gray, 5-place sample rack.

3. With the original container still in hand, enter the desired demographics for the specimen:
 - a. <Workplace>
 - b. <Test Selection>
 - c. In <Type> field select the specimen type (Ser/Pl or Urine) from the dropdown menu.
 - d. Enter the specimen ID number in the Sample ID field. <Enter>
 - e. Click or touch screen on the desired tests. Most individual tests are on the Sheet 1 tab. Test panels are on Sheet 2.
 - f. To assign a testing position for the vial, click <Barcode Read Error>.
 - g. Enter Rack No. and Position in the corresponding fields. Note that position 1 on each rack is on the right end of the rack. The gray racks are defined for serum testing; the yellow racks are defined for urine testing.
 - h. <Add>.
 - i. <OK>.
 - j. <Save>.
4. Continue this process until 10 specimens (two racks) have been ordered. Additional specimen loading can occur while the instrument is running.
5. If the reagent status is acceptable and the necessary calibrations have been ordered, load the sample racks on to the Mod P. Lift the lid of the sample loading compartment, and place the racks onto track. Since the track (and the slot in the racks) is offset, there is only one way to load them onto the instrument.
6. After the racks are loaded close the lid and click <Start>
8. The Start Conditions window appears. Click the big <Start> to begin the run.
9. The other options on this screen have uses described in the Operator's Manual. The primary field of interest is the Masking field. If any tests are to be turned off, click on Masking, then highlight the tests. Click on Mask to turn the test off. Test masking is primarily done with the HDL (precipitate) method so that it is not executed when the other tests are executed through communication with the host computer system.
10. The instrument will go through its homing checks, wash several reaction cells, then begin delivering the calibrators, controls, specimens and reagents to the reaction cells.
11. After this process has begun, additional tests may be ordered by returning to the Test Selection screen. Tests may be added at anytime, but the Mod P will not allow the Start button to be activated if it is flashing. This delay occurs after the last sample rack has entered the sampling chamber. It usually lasts ~ 1 minute.

I. Operation of Assay Procedure

After calibration and controls have been measured and evaluated, the test specimens may be loaded onto the Mod P. An abbreviated description of the

measurement procedure follows. A more thorough description may be found in the Mod P general operations protocol.

1. If specimens have been frozen, allow them to thaw completely, and then mix well. Serum specimens should not require centrifugation unless they have large amounts of suspended material.
2. To order non-barcoded tests on the Mod P:
 - a. <Workplace>
 - b. <Test Selection>
 - c. Enter specimen ID in the Sample ID field, then <Enter>
 - d. Select test GLU by touching the screen or clicking on it with the mouse.
 - e. <Barcode Read Error>
 - f. Enter the rack number and rack position in the Rack No.-Pos. fields.
 - g. <Add>
 - h. <OK>
 - i. <Save>
3. Note the order of positions 1-5 in the sample rack: position 1 is on the right and position 5 is on the left. Place the specimen in the rack so that $\frac{1}{4}$ to 1 inch of the vial is above the sample rack. This allows the Mod P to detect the presence of the vial in the rack. Orient the vial in the rack so that any barcodes are turned inward, and therefore unreadable. If the testing vials are to be re-capped, arrange the caps so they can be matched up following analysis.
4. To order barcoded tests on the Mod P: Follow instructions as in step 3 above, except that the barcode now must face outward so the Mod P can read it. The barcode must be oriented vertically. No test ordering is required on the instrument. In this case test ordering has occurred in Misys, and a label has been generated for that purpose, or the specimen has a non-Misys barcode label and a user-defined default battery has been installed on the Mod P.
5. After the specimens are in place, put the racks onto the loading platform. The racks will only load in one orientation, as the center track is offset. Do not prepare more than three racks at a time, as evaporation could occur while the instrument goes through the sampling process.
6. Close the cover on the loading platform.
7. On the Mod P computer terminal, press or click <Start>, then <Start> again.
8. Only calibration and control data automatically print out. Patient data hard copies must be requested in <Workplace>, <Data Review>. Highlight the desired records, then <Print>, and <Print> again.
9. Non-barcoded records must be manually entered into Misys, a designated spreadsheet, or website.
10. Barcoded records are accepted using the OEM program in Misys. The method code for the Mod P is UR9.

J. Instrument shutdown

After the patient specimens and final controls have been evaluated and accepted, load the green rack (W999) and run it through the instrument. Place three standard sample cups in positions 1, 2 and 3. Fill cup 1 with 1N sodium hydroxide, fill cup 2 with 4N sodium hydroxide, and fill cup 3 with leftover serum. Place it onto the loading platform and press <Start>, and <Start> again. After 18 minutes, the Mod P comes to Stand-by status. If the green rack is not run, the Mod P will take at least one hour to come to Stand-by status.

After coming to Stand-by status the data from each day's run is downloaded from the Mod P computer to a diskette, then to the network folder. Consult the procedure describing this process for details.

Print all Mod P test results, and file in chronological order with the other daily printouts.

The Mod P is turned off each day after all work is complete. The steps are as follows:

<Utility>, <Maintenance>, <Nightly Pipe>, <Select>, <Execute>. This shutdown process requires approximately five minutes. The instrument and its computer are automatically turned off. The reagent compartment remains refrigerated.

An automatic timer has been set so that the Mod P turns on each weekday morning at 0630, automatically performing an air purge, photometer check, and incubator bath exchange during the process. The automatic timer has been set so that the Mod P remains off during weekends.

Return all leftover controls and calibrators to the refrigerator at the end of the day.

K. Recording of Data

Control and calibration results will automatically print out on the remote printer connected to the Mod P. Patient result printouts must be requested on the Mod P: <Workplace>, <Data Review>, highlight desired records, <Print>, <Print>. Make sure the ribbon is in satisfactory condition prior to beginning the day's batch. After evaluating all controls and calibrations, take the hard copy printout to a Misys terminal, and create a worksheet (function MWS) by entering all of the specimen accession numbers in their printout order. Within a given battery of specimens there may be multiple worksheets that have to be created. Enter the results into these worksheets, then print out the hard copy to check against the instrument printout. The worksheets to be created are defined within the Misys protocols developed for each study. After checking the worksheet result printout, initial the report and place it in the box in room L271.

Treatment of interfaced results is discussed in the separate Mod P interface protocol.

9. REPORTABLE RANGE OF RESULTS

Linear range of the method: 0-800 mg/dL (serum). Specimens exceeding the high limit are automatically diluted (1:5.5) by the instrument, and reported accordingly. If a manual dilution is required, dilute the specimen in normal saline, and multiply the result by the dilution factor.

The Roche cholesterol assay meets the 1992 National Institutes of Health (NIH) goal of less than or equal to 3 per cent for both precision and bias.

Analytical Measurement Range: 0-800 mg/dL

Clinically Reportable Range: 10-1000 mg/dL

10. QUALITY CONTROL (QC) PROCEDURES

A. Control limits

The control limits for each pool are calculated from the overall mean and standard deviation of the run means, and ranges for the pool. Continuity between the current and replacement pool is maintained from at least 20 overlapping runs in which both pools are analyzed in parallel. It is from this period of overlap that the 20 run temporary limits are established for the replacement pool. During this period the acceptability of the measurements is based on the current pool. Furthermore, the analyses must be "in control" before the data are accepted for use to establish control limits for the replacement pool. The mean chart monitors the deviation of individual run means \bar{X} from the overall laboratory mean \bar{X} . Any shift, drift, or among day variability is assessed from the mean chart.

B. Quality Control Pools

Two levels of control are assayed each time the triglycerides method is performed. It is acceptable to run each control at the start of the day, and again at the end of the day. The operator may run them more frequently, if desired. One control is prepared from pooled, normal human serum. The other is an elevated, abnormal commercial control. Consult quality control charts for current ranges and lots in use.

C. Calculation of Control Limits

The Laboratory uses statistical control charts to evaluate performance and make quality control decisions. Control limits are calculated from the means, standard deviations and ranges as described in this section. It is important that the data

used to calculate control limits be collected during a stable analytical period when they are representative of overall laboratory performance.

The daily mean, \bar{X} , for a control pool is calculated for each run by averaging the replicate values for the pool:

$$\bar{X} = \text{sum of control values}/\text{number of replicates} = x/n$$

For NHANES 2007-2008, $n = 2$.

The overall mean for the pool, \bar{X} , is calculated by summing the individual run means and dividing by the number of runs, N :

$$\bar{X} = \text{sum of run means}/\text{number of runs} = X/N$$

The overall mean is rounded to the nearest whole number.

$N = 20$ run days for temporary limits

$N = 50$ run days for permanent limits

The standard deviation of the run means, $S_{\bar{X}}$, is also calculated for the control pool. The basic equation for calculating standard deviation is as follows:

$$S_{\bar{X}} = \sqrt{\sum (x - \bar{x})^2 / (N - 1)}$$

The control limits (99%) for the \bar{X} chart are calculated as follows:

$$\text{Upper control limit} = \bar{X} + 3S_{\bar{X}}$$

$$\text{Lower control limit} = \bar{X} - 3S_{\bar{X}}$$

Control limits are rounded to the nearest whole number.

The warning (95%) limits for the \bar{X} chart are calculated as follows:

$$\text{Upper warning limit} = \bar{X} + 2S_{\bar{X}}$$

$$\text{Lower warning limit} = \bar{X} - 2S_{\bar{X}}$$

Warning limits are rounded to nearest whole number.

The limits on \bar{X} are evaluated as described below.

E. Evaluation of Control Limits

Before the control chart can be used for quality control, it is reviewed to determine that the data have been collected during a stable analytical period. The chart is examined for outliers, for periods of questionable or unstable performance, and for evidence of excessive bias. An outlier will distort the control limits if incorporated into the final calculations. An outlier is considered to be any value of \bar{X} which falls outside the control limits ($\bar{X} \pm 3S_{\bar{X}}$) or any value of R which exceeds the control limit for R . These values are eliminated as are values from any questionable period of performance. The values of \bar{X} , $S_{\bar{X}}$, and the control limits are recalculated and the charts are evaluated again.

The criteria used in the Laboratory were those designed to minimize both bias and variability.

F. Construction of Control Charts

A separate control chart is constructed for each analyte in each control pool. Construct each chart so that plots for \bar{X} are arranged one above the other on the same sheet of graph paper. Draw the \bar{X} line across the entire sheet; draw the warning- and control limits parallel to the \bar{X} line.

Plot the run mean and range values. The chart should be kept current; the values should be plotted after each run. Make liberal use of annotations indicating events that might affect the analyses (personnel changes, reagent problems, changes in instrument components, etc.).

G. Use and Interpretation of Control Charts

Values for \bar{X} which exceed the $3S_{\bar{X}}$ limit indicate the run is 'out-of-control'. The run must be repeated. Statistically, one in 100 runs can be expected to be 'out-of-control during normal stable operation. A value exceeding the warning limit, but not the control limit, is interpreted as an indication of possible trouble, but does not necessarily require action. Statistically, about one in 20 values will exceed the warning limits.

11. REMEDIAL ACTION IF CALIBRATION OR QC SYSTEMS FAIL TO MEET ACCEPTABLE CRITERIA

If control values are out of the acceptable range, recalibration is required. Reanalyze any patient samples after recalibration.

12. LIMITATIONS OF CHOLESTEROL METHOD; INTERFERING SUBSTANCES AND CONDITIONS

The following information applies to cholesterol

- A. Icterus: No significant interference up to an I index of 25 (approximate conjugated bilirubin concentration: 25 mg/dL or 428 $\mu\text{mol/L}$) and an I index of 10 (approximate unconjugated bilirubin concentration: 10 mg/dL or 171 $\mu\text{mol/L}$).
- B. Hemolysis: No significant interference up to an H index of 700 (approximate hemoglobin concentration: 700 mg/dL or 435 $\mu\text{mol/L}$).

- C. Lipemia (Intralipid): No significant interference up to an L index of 1250. There is poor correlation between the L index (corresponds to turbidity) and triglycerides concentration.
- D. In very rare cases gammopathy, in particular type IgM (Waldenström's macroglobulinemia), may cause unreliable results.

For diagnostic purposes, the results should always be assessed in conjunction with the patient's medical history, clinical examination and other findings.

The color reactions used to measure cholesterol and triglyceride (Section 1 A. and B., above) are unaffected by common interfering substances such as uric acid, creatinine, and glutathione.

- E. Drug Interference.

The following information was taken from package insert. No further details were provided by the manufacturer:

Therapeutic amounts of 38 drugs showed no interference with this procedure.

A two-fold toxic dose of a-methyldopa lowered recovery by 50%.
Noramidopyrine showed a 20% lowered recovery.

A ten-fold therapeutic concentration of ascorbic acid led to 5% lower recovery of cholesterol.

13. REFERENCE RANGES (NORMAL VALUES)

Roche range: Serum, adult: <200 mg/dL is considered "desirable"

Collaborative Studies Clinical Laboratory ranges:

Misys test code CHR: Serum, adult: 0-200 mg/dL

Misys test code FHSC: Serum, adult: 100-200 mg/dL

14. CRITICAL CALL RESULTS ("PANIC VALUES")

Early Reporting Results for NHANES:

Notify the NHANES Medical Officer of any critical result. The contact person will report these results as soon as possible.

15. SPECIMEN STORAGE AND HANDLING DURING TESTING

Samples are received frozen and stored at -80°C until testing is performed. Upon completion of analysis, specimens are stored for 1 week. NHANES specimens are frozen at -70°C and discarded after 1 year.

16. ALTERNATIVE METHODS FOR PERFORMING TEST OR STORING SPECIMENS IF TEST SYSTEM FAILS

Samples are held at -80°C in the freezer. Samples are held at -80°C in the freezer. If a problem occurs and this freezer begins to warm samples are transferred to the research freezers. A service call is placed to repair the freezer.

The laboratory has 2 instruments for performing glycohemoglobins. If neither instrument is available for use, the specimens are stored at 4°C until testing can be performed.

17. TEST RESULT REPORTING SYSTEM; PROTOCOL FOR REPORTING CRITICAL CALLS (IF APPLICABLE)

18. TRANSFER OR REFERRAL OF SPECIMENS; PROCEDURES FOR SPECIMEN ACCOUNTABILITY AND TRACKING

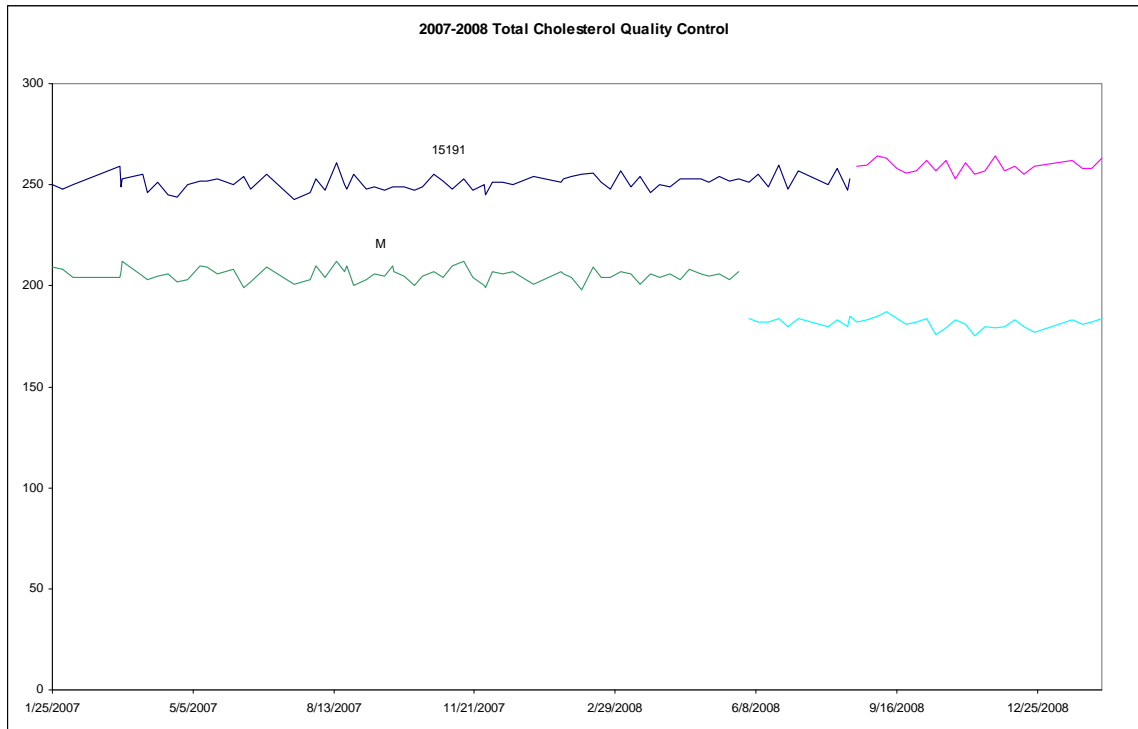
All shipments are recorded on the NHANES Shipping Log upon receipt. Actions taken during the course of analysis, result reporting, and specimen retention are also recorded on the log

Total Cholesterol in Serum
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19. SUMMARY STATISTICS and QC GRAPHS

Summary Statistics for Total Cholesterol by Lot

Lot	N	Start Date	End Date	Mean	Standard Deviation	Coefficient of Variation
M	66	1/25/2007	5/27/2008	205.394	3.267	1.6
15191	76	1/25/2007	8/14/2008	251.053	3.695	1.5
N	33	6/3/2008	2/9/2009	181.667	2.642	1.5
15231	23	8/19/2008	2/9/2009	259.087	3.088	1.2



REFERENCES

1. Roche/Hitachi System Application Sheet for HDL-C plus 3rd generation, 2007.
2. Roche/Hitachi System Application Sheet for HDL-C plus 2rd generation, 2005.
3. Package insert for C.F.A.S. Lipids, 2005.
4. Roche/Hitachi Modular Analytics Operator's Manual, version 2.0, October 2006.