

Laboratory Procedure Manual

Analyte: **Unsaturated Iron-Binding Capacity (UIBC)**

Matrix: **Serum**

Method: **Roche Cobas 6000 (c501 module)**

As performed by: **University of Minnesota
Advanced Research and Diagnostic Laboratory (ARDL)
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Important Information for Users

The Advanced Research and Diagnostic Laboratory (ARDL) periodically refine 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:

Data File Name	Variable Name	SAS Label
FETIB_K	LBXUIB	Unsaturated Iron Binding Capacity (UIBC) (ug/dL)

1. SUMMARY OF TEST PRINCIPLE AND CLINICAL RELEVANCE

The total iron content of the body is approximately 3 to 3.5 g. Of this amount about 2.5 g is contained in red blood cells or their bone marrow precursors. Plasma contains only about 2.5 mg of iron. Iron in the plasma is transported as Fe^{3+} bound to apotransferrin. This complex is referred to as transferrin. In an average person about one-third of transferrin's binding capacity is utilized. The remaining binding capacity is referred to as the unsaturated iron binding capacity (UIBC). The sum of serum iron and UIBC represents the total iron binding capacity (TIBC). In iron deficiency anemia the TIBC is elevated and the transferrin saturation is $<15\%$. Anemia of chronic disorders, malignant tumors and infections is characterized by low serum iron and low TIBC.

In the first step of the measurement process excess Fe^{2+} is added to the specimen. In an alkaline environment it is converted to Fe^{3+} as it binds to the unbound endogenous transferrin. The unbound Fe^{2+} in the reagent then reacts with FerroZine reagent to form a colored compound. This is an inverse outcome: greater color development indicates the transferrin is more highly occupied by iron (low UIBC). Lesser color development indicates that the transferrin has more binding capacity available (high UIBC). Because of this characteristic and the calibration model, all results are multiplied by a factor (-1) to yield a positive result. This is a two-point, endpoint reaction, with measurement occurring at 546 nm (secondary wavelength 700 nm).

Cobas 6000 Application Code: 779

2. SAFETY PRECAUTIONS

Caution: This product is of human and animal origin. Handle as though capable of transmitting infectious disease. Wear appropriate PPE when handling equipment, reagents, and samples.

3. COMPUTERIZATION; DATA SYSTEM MANAGEMENT

ARDL utilizes a highly specialized Laboratory Information System (LIS) (STARLIMS, Abbott Informatics Corporation; Hollywood, FL, 33021-6755) for all lab functions. Major instrument platforms are interfaced directly to the LIS, allowing data to be electronically transferred directly to the main database. The system provides an extensive quality

assurance package and data management tools. Numerous networked computer workstations are used in the laboratory for data management and transmission, and also include software for word and spreadsheet creation and manipulation, statistical analysis, report presentation, and electronic communication. All workstations are user password protected with job specific security access levels and have idle time out functionality. All systems are redundantly backed up on a real time basis.

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

a. **Specimen Type and Requirements:** Use serum that has been separated from the clot within one hour of collection. Heparinized plasma is also acceptable, although lithium heparin plasma specimens yield values that are approximately 6% less than serum values. The specimen must be free of hemolysis. EDTA, citrate, or oxalate are not acceptable anticoagulants. Specimens containing precipitate must be centrifuged prior to analysis. This specimen is received frozen and the test is analyzed from NHANES Vial 011.

b. **Specimen Volume:** Optimum/Minimum volume: 120 μ L in a sample cup or 2 mL microtube (20 μ L serum or plasma; remainder for dead volume).

c. **Acceptable Specimens/Unacceptable Specimens:** Serum, or lithium heparin plasma. EDTA, citrate, or oxalate are not acceptable anticoagulants. All will reduce the apparent iron concentration in the specimen. Other anticoagulants are not acceptable. A fasting morning specimen is preferred because of diurnal variation.

d. **Specimen Stability and Storage:** Separated serum or plasma should be removed from the cells within one hour of collection. Serum or plasma is stable for seven days at 4°C, four days at 18-30°C, and longer at -70°C. Specimens containing precipitate must be centrifuged prior to analysis. Specimens must be at room temperature prior to assay.

e. **Interferences or limitations:**

- Icteric index <60: no interference.

- Hemolytic index <40: no interference. Since iron concentration is greater in red blood cells than in plasma, hemolysis will interfere with the assay.
 - Lipemic index <300: no interference.
 - Drugs: No interference was found at therapeutic concentrations using common drug panels. Exceptions: Oxytetracycline causes artificially high UIBC values at the tested drug level.
 - Exceptionally high levels of albumin (7 g/dL) decreases the apparent UIBC value significantly.
 - If the patient's serum iron exceeds the binding capacity of the transferrin, a negative UIBC value will result.
 - In patients treated with iron supplements or metal-binding drugs, the drug-bound iron may not properly react in the test, resulting in falsely low values.
 - The physiological function of deferoxamine-containing drugs is to bind iron to facilitate its elimination from the body. Therefore any deferoxamine concentration interferes with the UIBC assay.
 - In the presence of high ferritin concentrations (>1200 ug/L) the assumption that serum iron is almost completely bound to transferrin is not valid. Therefore, such iron results should not be used to calculate TIBC or per cent transferrin saturation.
 - In very rare cases, gammopathy, in particular type IgM (Waldenström's macroglobulinemia), may cause unreliable results.
- f. **Specimen Handling and Transport:** Mix specimens well, allow clot to fully form (if serum), and centrifuge 10 minutes at 2000 x g before use. Aliquot a minimum of 0.120 mL. Freeze sample until shipment. Ship frozen on dry ice.

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. Reagents and Supplies

Roche product #04536355190, UIBC reagent kit (100 tests):

b. Reagent Preparation (*Reagents are ready to use; no preparation required)

- R1 reagent. Ferrous chloride: 62 $\mu\text{mol/L}$; sodium hydrogen carbonate: 75 mmol/L ; TRIS buffer: 375 mmol/L , pH 8.4; preservative
- R3 reagent. FerroZine. 20 mmol/L ; hydroxylamine: 160 mmol/L ; pH 2.5
- Storage and stability. Keep reagents stored at refrigerated temperature (2-8°C) until use. Reagent is stable until expiration date on cassette when stored at 2-8°C. The reagents are stable for 8 weeks refrigerated on the analyzer.

c. Equipment/Instrumentation-

Roche Cobas 6000 Chemistry Analyzer (Roche Diagnostics Corporation, Indianapolis, IN 46250)

- The Millipore Elix Gulfstream Clinical 35 System is designed to meet CLSI Clinical Laboratory Reagent Water (CLRW) standards. Water purification is achieved by reverse osmosis, electrodeionization, bactericidal 254 nm UV lamp and 0.22 μm filtration.

d. Specimens are run in singleton

e. Quality Control

- Normal pooled serum control (CQ). Stable at -80°C for up to 4 years, at refrigerated temperature for up to 1 day and at room temperature for up to 4 hours.
- Roche Precipath U Plus Control (catalog #12149443160). Roche Diagnostics 9115 Hague Road Indianapolis, IN 46250-0457). Stable until expiration date on package when unopened and stored at 2-8°C. To prepare, open bottle 1 and pipette in exactly 3.0 mL of diluent (bottle 2). Dissolve by gentle swirling

for 30 minutes. Prepared control is stable for 12 hours at room temperature, 5 days at 2-8°C, and one month at -20°C (when frozen once).

7. CALIBRATION AND CALIBRATION VERIFICATION PROCEDURES

Roche Fe Standard, 1 x 75 mL, 500 ug/dL, catalog #12146401160. The calibrator is stable until the expiration date on the bottle when stored at 15-25°C. The calibrator is a liquid preparation, ready to use.

Calibration frequency: A two-point calibration (H₂O + Fe Standard) must be performed when there is a reagent lot number change. A calibration each day the test is run is also recommended. The Cobas 6000 will not allow testing to proceed until a successful calibration has been completed. Monitor control values to determine stability of the current calibration.

This method has been standardized against a primary reference material (weighed in purified material) through iron.

Manual calibration should be performed if:

- A reagent lot change has not occurred in the past 6 months
- After major service or repairs
- As needed for troubleshooting

If calibration fails perform the following corrective action steps in sequence:

- Check reagent and calibrator for appropriate lot numbers, expiration dates, preparation and storage conditions.
- Repeat calibration with new calibrator.
- Repeat calibration with new reagent and new calibrator
- If successful calibration is not achieved, discontinue testing and notify the supervisor.

8. OPERATING PROCEDURE INSTRUCTIONS; CALCULATIONS; INTERPRETATION OF RESULTS

- a. **Instrument Operation:** The Roche/Hitachi Cobas 6000 analyzer series is a fully automated, random-access, software controlled system for immunoassay and photometric analyses intended for qualitative and quantitative in vitro determinations using a wide variety of tests. The Cobas 6000 analyzer series is optimized for workloads using a combination of photometric and ion-selective electrode (ISE) determinations (c501 module), and electrochemiluminescence (ECL) signal in the immunoassay analysis module (e601 module). The ISE system is used in the quantitation of sodium, potassium and chloride. The photometric system can measure colorimetric or immunoturbidimetric reactions utilizing end point or kinetic (rate) absorbance measurements. Test ordering end execution on the Cobas 6000 and data entry in the STARLIMS host computer system may be done manually or these tasks may be executed via a barcode-based bi-directional interface. The Cobas 6000 can utilize both of these two systems simultaneously.
- b. **Professional Judgement:** Check results for error flags and take appropriate corrective action. Investigate alert values and delta checks.
- c. **Result Entry**

STARLIMS test code: UIBC

Manual entry

- Results are reported to a whole number, as in x ug/dL.
- Report low serum results as <17 ug/dL.
- Check results for error flags and take appropriate corrective action.
- Investigate alert values and delta checks.
- The calculation for TIBC is executed in StarLIMS: $FE + UIBC = TIBC$
- The calculation for iron saturation is executed in StarLIMS: $(FE/(FE+UIBC))*100$

9. REPORTABLE RANGE OF RESULTS

Out of Range results: Certain tests have pre-programmed limits that trigger an automatic re-analysis by the COBAS. These limits may be low-end values or high-end values (but

within technical range). If the duplicate value is in agreement with the initial value, then the initial value is reported.

Results are reported to a whole number, as in x ug/dL. Report low results as <17 ug/dL.

a. Reportable Range of Test Results: Reportable Range 17-700 ug/dL

Intra-assay %CV (10 within-day replicates at a concentration of 137 ug/dL) 2.3%

Intra-assay %CV (10 within-day replicates at a concentration of 207 ug/dL) 1.2%

Inter-assay %CV (between day replicates at a concentration of 238 ug/dL) 3.0%

Inter-assay %CV (between day replicates at a concentration of 199 ug/dL) 4.0%

Dilutions: The confirmed analytical measurement range of the assay is 17-700 ug/dL.

Note: The technical limits for this assay are defined as -700 ug/dL for the lower limit, and -17 for the upper limit due to the instrument factor for UIBC (-1). Results under the lower limit (i.e. more negative than -700 ug/dL) will be flagged ">TEST". Via the rerun function these specimens will be re-sampled at half the original volume (10 uL vs. 20 uL), and result will be automatically multiplied by two. Results above the upper limit (i.e. more positive than -17) of the measuring range will be flagged with "<TEST" and automatically repeated with the same sample volume.

The confirmed analytical measurement range of the assay is 17-700 ug/dL. If a manual dilution is desired, dilute the specimen in normal saline, and multiply the result by the dilution factor. For example, to perform a 1:2 dilution, pipette 75 µL of the patient sample into 75 µL of normal saline. Mix thoroughly, perform the assay, and multiply the result by a factor of 2. The maximum allowable manual dilution is 1:2.

Reference Ranges:

UIBC, Serum, adult : 112-347 ug/dL

TIBC, Serum, adult (calculated): 250-400 ug/dL

Iron saturation, Serum, adult (calculated): 14-50%

Critical Results: None

Analytical Measurement Range: 17-700 ug/dL

Reportable Range: 17-1400 ug/dL

Limit of Detection (standard 1 + 3 SD): 17 ug/dL

10. QUALITY CONTROL (QC) PROCEDURE

- Normal pooled serum control (CQ). Stable at -80°C for up to 4 years, at refrigerated temperature for up to 1 day and at room temperature for up to 4 hours.
- Roche Precipath U Plus Control (catalog #12149443160). Roche Diagnostics 9115 Hague Road Indianapolis, IN 46250-0457). Stable until expiration date on package when unopened and stored at 2-8°C. To prepare, open bottle 1 and pipette in exactly 3.0 mL of diluent (bottle 2). Dissolve by gentle swirling for 30 minutes. Prepared control is stable for 12 hours at room temperature, 5 days at 2-8°C, and one month at -20°C (when frozen once).
- Both levels of quality control are analyzed at the start of the day and results are verified for acceptability prior to testing specimens. Quality control is also analyzed at the end of the shift, with change in reagent, after major maintenance, or as needed for troubleshooting.
- The analytical measurement range (AMR) must be validated every 6 months or after major maintenance or service procedures. Use a patient sample with elevated UIBC concentration to confirm linear range. Make serial dilutions and document appropriately.
- New Lot Verification: Each new reagent lot must be verified for acceptability before being placed into use. Calibration, quality control, and comparison of at least 5 patient samples on the old and new lots must be performed and found to be within acceptable limits before a new lot can be placed into use.

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

ACCEPTABLE CRITERIA

- If QC values are outside of specified ranges, do the following, in order, until QC is acceptable:
 1. Repeat the analysis using fresh QC material.

2. Perform a calibration.
3. Check for system problems.
4. Contact Roche Technical Support for assistance and possible service dispatch.
Phone: 1-800-428-2336; account number: 55042919

12. LIMITATIONS OF METHOD; INTERFERING SUBSTANCES AND CONDITIONS

- a. Limit of Detection (standard 1 + 3 SD): 17 ug/dL
- b. Analytical Measurement Range: 17-700 ug/dL
- c. Interfering Substances and Conditions
 - Icteric index <60: no interference.
 - Hemolytic index <40: no interference. Since iron concentration is greater in red blood cells than in plasma, hemolysis will interfere with the assay.
 - Lipemic index <300: no interference.
 - Drugs: No interference was found at therapeutic concentrations using common drug panels. Exceptions: Oxytetracycline causes artificially high UIBC values at the tested drug level.
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 - In patients treated with iron supplements or metal-binding drugs, the drug-bound iron may not properly react in the test, resulting in falsely low values.
 - The physiological function of deferoxamine-containing drugs is to bind iron to facilitate its elimination from the body. Therefore any deferoxamine concentration interferes with the UIBC assay.
 - In the presence of high ferritin concentrations (>1200 ug/L) the assumption that serum iron is almost completely bound to transferrin is not valid. Therefore, such iron results should not be used to calculate TIBC or per cent transferrin saturation.

- In very rare cases, gammopathy, in particular type IgM (Waldenström's macroglobulinemia), may cause unreliable results.

13. REFERENCE RANGES (NORMAL VALUES)

UIBC, Serum, adult: 112-347ug/dL

TIBC, Serum, adult (calculated): 250-400 ug/dL

Iron saturation, Serum, adult (calculated): 14-50%

14. CRITICAL CALL RESULTS ("PANIC VALUES")

Not applicable.

15. SPECIMEN STORAGE AND HANDLING DURING TESTING

Specimens are frozen at -70°C between sample receipt and analysis on the instrument. Specimens must be at room temperature prior to assay. Specimens are returned to refrigerated or frozen temperature post analysis depending on the study specific requirements.

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

Should the testing system become inoperable, discontinue testing and notify the supervisor. While instrument trouble-shooting or repair occurs; keep specimens at refrigerated or frozen temperature depending on study specific requirements.

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

All data is reported electronically via an eFile that is uploaded to the WESTAT secure website within 21 days of receipt of specimens.

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

Specimen Receipt:

Shipments for NHANES generally will arrive on Tuesdays and/or Wednesdays. These shipments are recorded on the Log of Quality Assurance located in a binder labeled

NHANES Shipping Log in the receiving area. The specimen barcode numbers in the boxes are checked against the manifests. The receipt date is written on top of the boxes. The frozen samples (vial 11-Iron/UIBC & vial 13-CRP) are placed in the designated -70°C freezer and the refrigerated samples (vial 18-Biochem panel) are placed in the designated 2-8°C refrigerator until analysis. The manifests are filed in a binder labeled NHANES Shipping Manifests located in the receiving area. All labels are removed from the shipping box and the provided airbill is attached for return shipment.

Quality Assurance Log:

A Quality Assurance Specimen Receipt and Specimen Return Log is maintained by laboratory staff. The following parameters are tracked: NHANES shipper I.D., NHANES Container I.D., Vial #, Date Received, Specimen Receipt Conditions, Number of Specimens Received, 2.5% QC Repeats, Total Number of Specimens, 21 Day Due Date, Analysis Date, Date Results Sent, Number of Days For Result Return, Thaw Date (if applicable), Return To Freezer Date, Number of Days at Refrigerated Temperature, 1 Year Discard or Return Date, NHANES Quarterly Report Date

QUALITY ASSUR SPECIMEN RECEIPT					# received, analyzed and transmitted		
NHANES shipper I.D.	NHANES container I.D. #	vial #	date rec'd	receive spec. cond.	spec.	2.5% qc rpts	total
778177102370	368009	018	1/17/2017	ok	47	1	48
778204066788	368058	018	1/24/2017	ok	44	1	45
778299222501	368100	018	1/31/2017	ok	41	1	42
778354403016	368143	018	2/7/2017	ok	25	1	26
778355410426	369009	018	2/7/2017	ok	42	1	43
778408602420	369092	018	2/14/2017	ok	54	1	55
778407805716	368181	018	2/14/2017	ok	22	1	23
778454414575	368221	018	2/21/2017	ok	21	1	22
778463664926	369135	018	2/21/2017	ok	44	1	45
778511320887	369176	018	2/28/2017	ok	29	1	30
778517067017	370009	018	2/28/2017	ok	44	1	45
778564705940	370058	018	3/7/2017	ok	64	1	65

QUALITY ASSURANCE OF SPECIMEN RETURN								1 year	
21-day	analyzed	date	# days	thaw	return to	# days	discard	NHANES	
due date	date	result	results	date	freezer	at frig	or return	Quarterly	
date	sent	return	date	date	temp	date	Report		
2/7/2017	1/18/2017	1/30/2017	13	NA	1/20/2017	2			
2/14/2017	1/25/2017	2/6/2017	13	NA	1/27/2017	2			
2/21/2017	2/1/2017	2/6/2017	6	NA	2/2/2017	1			
2/28/2017	2/8/2017	2/10/2017	3	NA	2/10/2017	2			
2/28/2017	2/8/2017	2/10/2017	3	NA	2/10/2017	2			
3/7/2017	2/15/2017	2/17/2017	3	NA	2/16/2017	1			
3/7/2017	2/15/2017	2/17/2017	3	NA	2/16/2017	1			
3/14/2017	2/22/2017	2/27/2017	6	NA	2/24/2017	2			
3/14/2017	2/22/2017	2/27/2017	6	NA	2/24/2017	2			
3/21/2017	3/1/2017	3/3/2017	3	NA	3/3/2017	2			
3/21/2017	3/1/2017	3/3/2017	3	NA	3/3/2017	2			
3/28/2017	3/8/2017	3/10/2017	3	NA	3/10/2017	2			

Specimen Ordering/Labeling:

Electronic files for all NHANES specimens are sent via email from Westat, Inc to the NHANES contact person shortly before they are to be received. These files include the Sample ID, Analyte Type, Slot No, Sample Collection Date, Sample Comment, Age Grouping, Astro ID, Receipt Date, Analysis Date, Run Number, Tech ID, Analyte Result, Result Comment, Adjusted Result, QC Repeat, LOD, Change Reason, and Change Reason Other. The first seven columns are protected and cannot be altered. The files are saved on the laboratory’s common S drive in the NHANES Biochem folder. After analysis, the contact person returns the completed files via their website to Westat, Inc.

The NHANES spreadsheets are used to set up pending batches for batch accession upload in the Laboratory Information system (STARLIMs). New labels are generated out of the Laboratory Information System (STARLIMs). The new bar-coded labels are attached to a carrier tube. The Cobas analyzer reads the bar-coded label for the sample ID and test information.

Specimen Storage:

The temperatures for all freezers and refrigerators are monitored 24 hours a day/ 7 days a week. If the temperature for any unit falls outside the allowable range, action is taken to resolve the problem. If the temperature cannot be corrected, the contents are moved to a different unit.

Specimen Handling/Specimen Return:

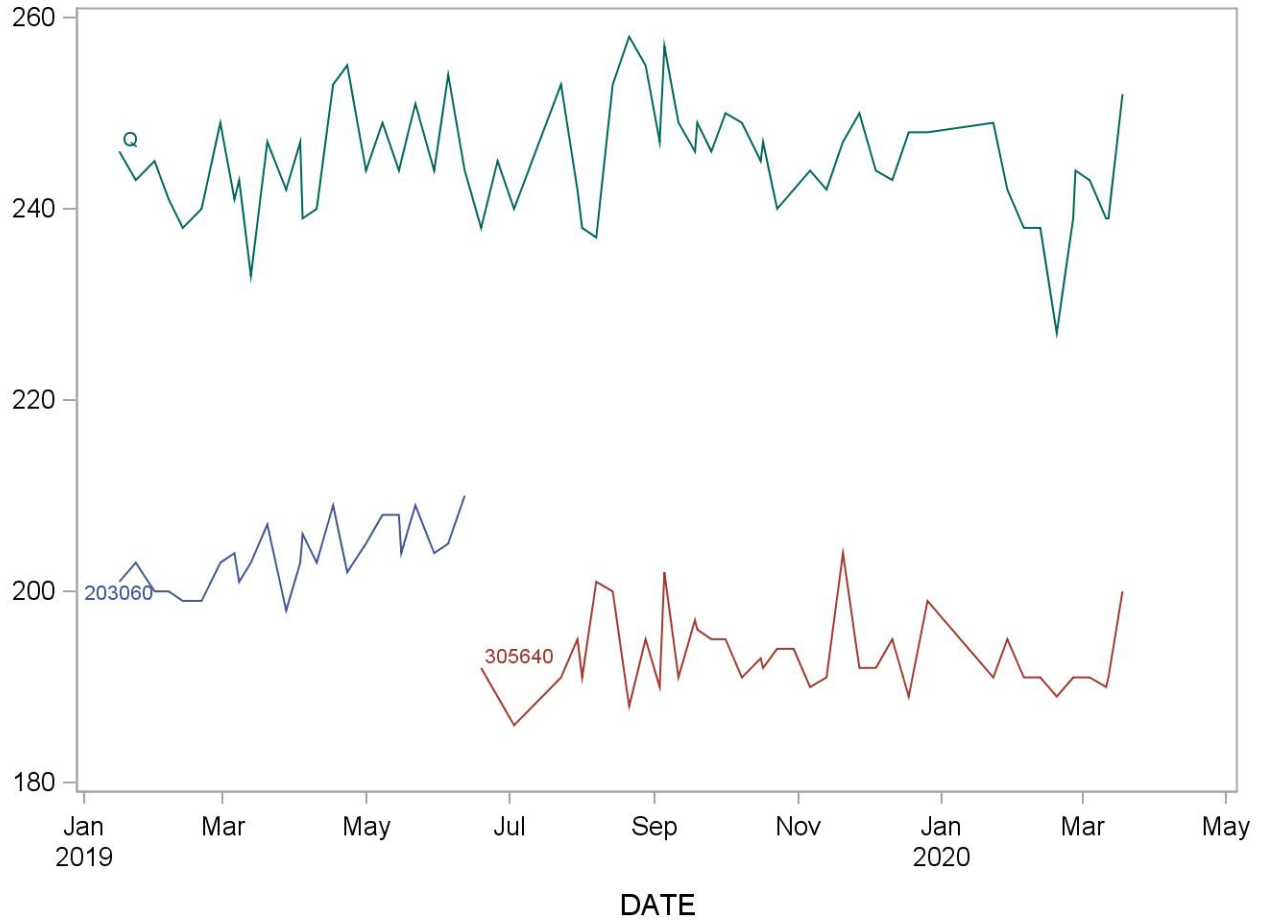
Prior to analysis, the specimens are stored in the designated -70°C freezer. On the day of analysis, the specimens are selected and thawed by the technician operating the COBAS. After analysis and the QC repeats have been run, the specimens are refrozen. After 1 year, the specimen vials that have at least 0.2ml of sample remaining will be shipped to SriSai Biopharmaceuticals in Frederick, MD. These specimens will be shipped on dry ice via Federal Express.

19. SUMMARY STATISTICS AND QC GRAPHS

See following page.

**Summary Statistics and QC Chart
LBXUIB (UIBC, Serum (ug/dL))**

Lot	N	Start Date	End Date	Mean	Standard Deviation	Coefficient of Variation
Q	66	16JAN19	18MAR20	244.8	5.8	2.4
203060	25	16JAN19	12JUN19	203.8	3.4	1.7
305640	41	19JUN19	18MAR20	193.2	4.0	2.1



REFERENCES

1. Cobas 6000 Analyzer Operator's Manual. Roche Diagnostics Inc., 9115 Hague Road Indianapolis, IN 46250-0457. Version 5.0.
2. Roche Fe Standard package insert. Version 2015-01, V1.0. Roche Diagnostics Inc., 9115 Hague Road Indianapolis, IN 46250-0457.
3. Roche Precipath U Plus package insert, Version 2015-11, V5.0. Roche Diagnostics Inc., 9115 Hague Road Indianapolis, IN 46250-0457.
4. Roche UIBC reagent package insert. Version 2016-03, V11.0. Roche Diagnostics Inc., 9115 Hague Road Indianapolis, IN 46250-0457.
5. Website: www.mayomedicallaboratories.com/test-catalog/Clinical+and+Interpretive/34624. Test information for iron and total iron binding capacity.