

# Laboratory Procedure Manual

*Analyte:*      **Iron (Frozen)**

*Matrix:*      **Serum**

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

*Method No.:*

*Revised:*

*As performed by:*    **University of Minnesota  
Advanced Research and Diagnostic Laboratory (ARDL)  
1200 Washington Ave S, Suite 175  
Minneapolis, MN 55415**

*Contact:*      **Anthony Killeen, MD, PhD, Laboratory Director  
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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:

<b>Data File Name</b>	<b>Variable Name</b>	<b>SAS Label</b>
FETIB_J	LBXIRN	Iron frozen, Serum (ug/dL)

## **1. SUMMARY OF TEST PRINCIPLE AND CLINICAL RELEVANCE**

Ingested iron is primarily absorbed in the form of  $\text{Fe}^{2+}$  in the small intestine. Dietary iron in the form of  $\text{Fe}^{3+}$  must be reduced by vitamin C in order to be absorbed. Approximately 1 mg of iron is assimilated daily. In the body  $\text{Fe}^{2+}$  is converted to  $\text{Fe}^{3+}$  by ceruloplasmin, and it is bound to transferrin. Transferrin can bind one or two molecules of iron, and nearly all circulating iron is carried in this manner.

This method measures total iron concentration in serum. Iron levels are useful in the diagnosis and management of iron deficiency anemia, hemochromatosis, chronic renal disease, microcytic anemia, macrocytic anemia and other normocytic anemias.

The Roche method of iron measurement is a three step process using FerroZine reagent:  $\text{Fe}^{3+}$  is liberated from transferrin by acid/detergent,  $\text{Fe}^{3+}$  is reduced to  $\text{Fe}^{2+}$  by ascorbate, and the reduced iron then reacts with the FerroZine reagent to form a colored complex. The intensity of this final product is directly proportional to the iron concentration in the sample.

Cobas 6000 Application Code: 661

## **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:** Serum, or lithium heparin plasma. The specimen must be free of visible hemolysis. EDTA, citrate, or oxalate are not acceptable anticoagulants as they will bind iron and interfere with the assay. All will reduce the apparent iron concentration in the specimen. The concentration of iron in serum/plasma is dependent upon ingestion of iron and is subject to circadian variations. The NHANES Biochem study uses refrigerated or frozen serum. This test is analyzed from NHANES Vial 018 or Vial 011.

b. **Specimen Volume:** Optimum/Minimum volume: 100 µL in a sample cup or 2 mL microtube (8.5 µL 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 as they will bind iron and interfere with the assay. All will reduce the apparent iron concentration in the specimen. Other anticoagulants are not acceptable. The specimen must be free of hemolysis.

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 3 weeks at 4°-8 °C, seven days at 20-25°C, several years at -20°C, and longer at -70°C. Specimens must be at room temperature prior to assay. Specimens containing precipitate must be centrifuged prior to analysis.

##### e. **Interferences or limitations:**

- Icteric index < 60: no interference.
- Hemolysis index <200: no interference. Hemoglobin-bound iron released from damaged red blood cells will cause falsely elevated results.
- Lipemic index < 1500: no interference.

- Drugs: No interference was found at therapeutic concentrations using common drug panels.
- In patients treated with iron supplements or metal-binding drugs, the drug-bound iron may not react properly in the test, resulting in artificially low results.
- If the ferritin concentration exceeds 1200 ug/L the assumption that serum iron is bound exclusively to transferrin is no longer valid. Total Iron Binding Capacity and Per Cent Transferrin Saturation should not be calculated in this circumstance.
- 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 0.1 mL. Store sample in refrigerator (vial 018) or freezer (011) until shipment. Ship at corresponding temperature. Use dry ice for frozen specimen shipment.

## **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 #03183696122, Iron2 reagent kit (200 tests):

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

- R1 reagent (cassette position A). Citric acid (200 mmol/L), thiourea (115 mmol/L), detergent
- R3 reagent (cassette position B). Sodium ascorbate (150 mmol/L), FerroZine (6 mmol/L) preservatives.

Storage and stability. Reagent is stable until expiration date on cassette when stored at 2-8°C. The reagent is stable for 6 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 Calibrator for Automated Systems (C.F.A.S.), catalog #10759350190. The calibrator is stable until the expiration date on the bottle when stored at 4°C. The lyophilized calibrator is prepared with 3.0 mL of deionized water. Pipette the water into the bottle, and then dissolve by gentle swirling within 30 minutes. Avoid formation of foam while mixing. The prepared calibrator is stable for eight hours at room temperature, two days at 4°C, and one month at -20°C (frozen once). Traceability: This method has been standardized against a primary reference material (SRM 937). Calibration frequency: A two-point calibration (H<sub>2</sub>O + C.F.A.S.) must be performed daily and as required following control procedures. Reagent lot change also necessitates re-calibration. 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.

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: FE

Manual entry

- Results are reported to a whole number, as in x ug/dL.
- Report low serum results as <5 ug/dL.
- Check results for error flags and take appropriate corrective action.
- Investigate alert values and delta checks.

## 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 <5 ug/dL.

a. Reportable Range of Test Results: Reportable Range 5-1063 ug/dL

Intra-assay %CV (10 within-day replicates at a concentration of 108 ug/dL) 0.8%

Intra-assay %CV (10 within-day replicates at a concentration of 247 ug/dL) 0.3%

Inter-assay %CV (between day replicates at a concentration of 77 ug/dL) 2.7%

Inter-assay %CV (between day replicates at a concentration of 251 ug/dL) 1.7%

Dilutions: The confirmed analytical measurement range of the assay is 5-500 ug/dL.

Specimens exceeding the high limit are automatically sampled at a lesser volume (4 uL vs. 8.5 uL) by the instrument. Results from samples measured at the lesser sample volume are automatically multiplied by a factor of 2.125. If a manual dilution is required, dilute the specimen in normal saline, and multiply the result by the dilution factor. For example, to perform a 1:5 dilution, pipette 50 µL of the patient sample into 200 µL of normal saline. Mix



thoroughly, perform the assay, and multiply the result by a factor of 5. The maximum allowable manual dilution is 1:5.

Reference Range: Serum, adult male: 59-158 ug/dL; Serum, adult female: 37-145 ug/dL

Critical Results: None

Analytical Measurement Range: 5-500 ug/dL

Reportable Range: 5-1063 ug/dL

Limit of Detection (standard 1 + 3 SD): 5 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. The laboratory enrolls in the College of American Pathologist (CAP) linearity program. Iron is included in the LN2 kit that is shipped twice per year. Follow kit instructions for preparation. Analyze samples in duplicate. Results are due within two to four weeks of receipt of kit. Results are submitted online to the CAP website by the lead or supervisor. The linearity report is available online at the CAP website shortly after the due date. Confirm reported

values are within acceptability limits. Place instrument printouts, worksheets and CAP results in the CAP three ring binder.

- 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): 5 ug/dL
- b. Analytical Measurement Range: 5-500 ug/dL
- c. Icteric index < 60: no interference. Hemolytic index < 200: no interference.  
Hemoglobin-bound iron released from damaged red blood cells will cause falsely elevated results. Lipemic index < 1500: no interference. Drugs: No interference was found at therapeutic concentrations using common drug panels. In patients treated with iron supplements or metal-binding drugs, the drug-bound iron may not react properly in the test, resulting in artificially low results. If the ferritin concentration exceeds 1200 ug/L the assumption that serum iron is bound exclusively to transferrin is no longer valid. Total Iron Binding Capacity and Per Cent Transferrin Saturation should not be calculated in this circumstance. In very rare cases,

gammopathy, in particular type IgM (Waldenström's macroglobulinemia), may cause unreliable results.

### **13. REFERENCE RANGES (NORMAL VALUES)**

Serum, adult male: 59-158 ug/dL; Serum, adult female: 37-145 ug/dL

### **14. CRITICAL CALL RESULTS ("PANIC VALUES")**

Not applicable.

### **15. SPECIMEN STORAGE AND HANDLING DURING TESTING**

Specimens are stored at refrigerated (vial 018) or frozen (vial 011) temperature 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		
NHANES	NHANES			receive	and transmitted		
shipper	container		date	spec.		2.5%	
I.D.	I.D. #	vial #	rec'd	cond.	spec.	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								
		date	# days		return to	# days	1 year	NHANES
21-day	analyzed	result	results	thaw	freezer	at frig	discard	Quarterly
due date	date	sent	return	date	date	temp	or return	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:**

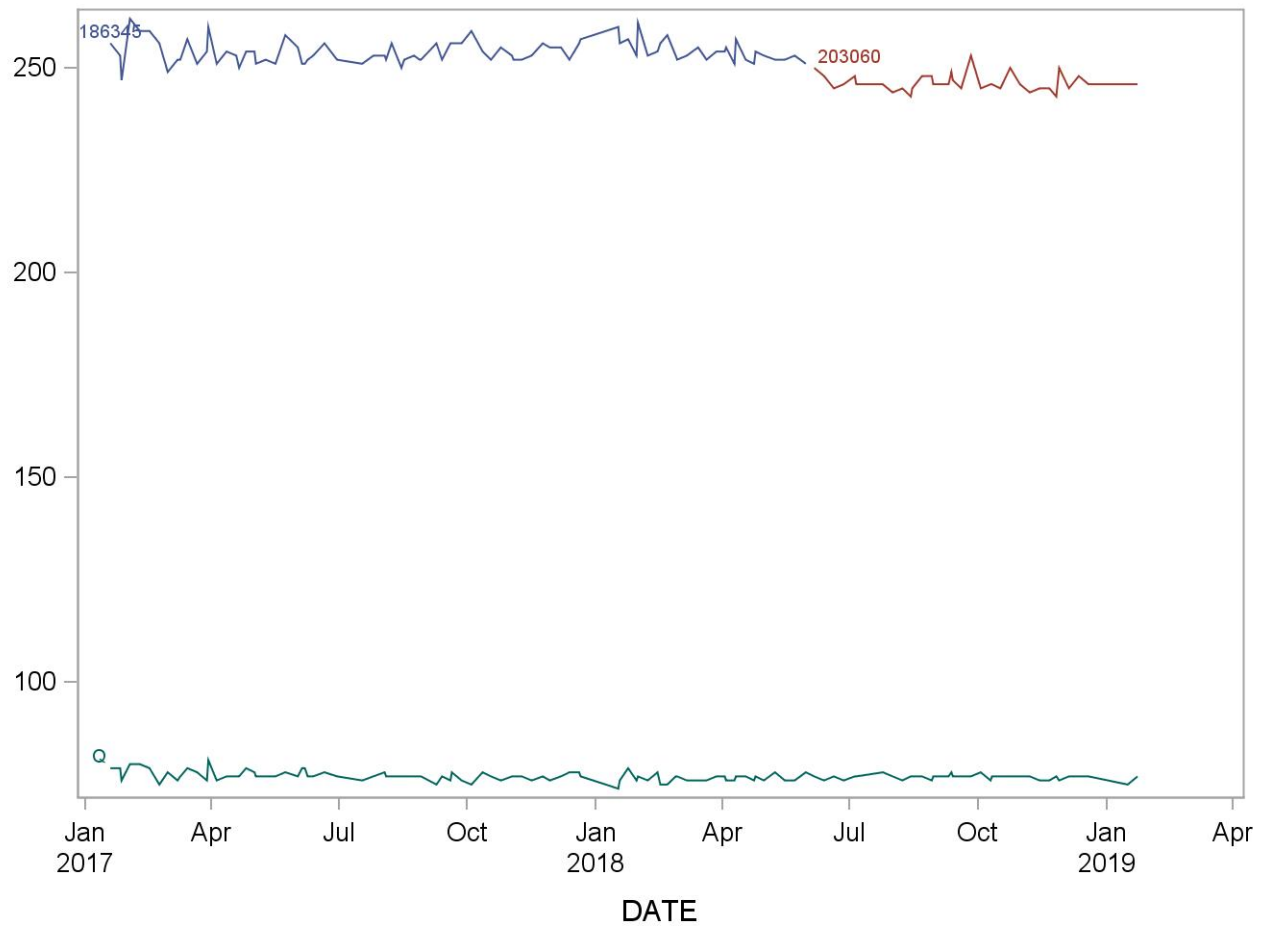
Prior to analysis, the specimens are stored in the designated -70°C freezer or 2-8°C refrigerator. On the day of analysis, the specimens are selected and thawed by the technician operating the COBAS. After analysis and the QC repeats have been run, the specimens are refrozen. After 1 year, the specimen 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.

## 2017-2018 Summary Statistics and QC Chart for Iron frozen, Serum (ug/dL)

Lot	N	Start Date	End Date	Mean	Standard Deviation	Coefficient of Variation
186345	87	19JAN17	31MAY18	253.9	2.8	1.1
Q	122	19JAN17	23JAN19	77.0	1.1	1.4
203060	35	06JUN18	23JAN19	246.4	2.1	0.9



## REFERENCES

1. Cobas 6000 Analyzer Operator's Manual. Roche Diagnostics Inc., 9115 Hague Road Indianapolis, IN 46250-0457. Version 5.0.
2. Roche Calibrator for Automated Systems (C.F.A.S.) package insert. Version 2011-08, V6. Roche Diagnostics Inc., 9115 Hague Road Indianapolis, IN 46250-0457.
3. Roche IRON2 reagent package insert. Version 2015-08, V12.0. Roche Diagnostics Inc., 9115 Hague Road Indianapolis, IN 46250-0457.
4. Roche Precipath U Plus package insert, Version 2015-11, V5.0. Roche Diagnostics Inc., 9115 Hague Road Indianapolis, IN 46250-0457.