theranos	LDT Validation Report	Theranos Magnesium Assay	Rev:
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Description	Validation Report for Modified Siemens Assay of Magnesium in Lithium Heparin Plasma		
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Validation of Modified Siemens Magnesium Assay

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Magnesium Plasma Assay

Overview

Magnesium along with potassium is a major intracellular cation. Magnesium is a cofactor of many enzyme systems. All adenosine triphosphate (ATP)-dependent enzymatic reactions require magnesium as a cofactor. Approximately 70% of magnesium ions are stored in bone. The remainder is involved in intermediary metabolic processes; about 70% is present in free form while the other 30% is bound to proteins (especially albumin), citrates, phosphate, and other complex formers. The serum magnesium level is kept constant within very narrow limits. Regulation takes place mainly via the kidneys, primarily via the ascending loop of Henle.

Conditions that interfere with glomerular filtration result in retention of magnesium and hence elevation of serum concentrations. Hypermagnesemia is found in acute and chronic renal failure, magnesium overload, and magnesium release from the intracellular space. Mild-to-moderate hypermagnesemia may prolong atrioventricular conduction time. Magnesium toxicity may result in central nervous system (CNS) depression, cardiac arrest, and respiratory arrest.

Numerous studies have shown a correlation between magnesium deficiency and changes in calcium-, potassium-, and phosphate-homeostasis which are associated with cardiac disorders such as ventricular arrhythmias that cannot be treated by conventional therapy, increased sensitivity to digoxin, coronary artery spasms, and sudden death. Additional concurrent symptoms include neuromuscular and neuropsychiatric disorders. Conditions that have been associated with hypomagnesemia include chronic alcoholism, childhood malnutrition, lactation, malabsorption, acute pancreatitis, hypothyroidism, chronic glomerulonephritis, aldosteronism, and prolonged intravenous feeding.

I. Method Principle

Magnesium ions react with xylidyl blue in an alkaline medium to form a water-soluble purple-red complex. The increase in absorbance of xylidyl blue at 505/695 nm is proportional to the concentration of magnesium in the sample. Calcium is excluded from the reaction by complexing with EGTA.

Reaction Equation

$$\text{Xylidyl Blue} + Mg^{2+} \xrightarrow{OH^-} \text{Xylidyl Blue } (Mg^{2+}) \text{ Complex}$$

II. Definitions and Abbreviations

The following definitions and abbreviations are used in this document and related documents and attachments:

a. **Accuracy:** Accuracy is defined by CLSI as the closeness of agreement between a test result and an accepted reference value. Method accuracy is used in a different sense by the American Association of Pharmaceutical Scientists where it is expressed as percent relative error (%RE). Trueness, a related CLSI term, is the closeness of agreement between the average of a number of replicate measured quantity values and a reference quantity value.

b. **Analyte:** Component represented in the name of a measurable quantity. The closely related term measureand is defined as the particular quantity subject to measurement.

c. **Analytical sensitivity:** There are several alternative uses of this term. Most commonly, and for the purposes of this Validation Plan, it is used interchangeably with limit of detection. It is also used to describe the ability of an analytical method to assess small variations of the concentration of an analyte, such as the slope of the calibration curve (IUPAC).

d. **Analytical specificity:** Ability of a test or procedure to correctly identify or quantify an entity, including in the presence of interfering substance(s) or phenomena.

e. **Calibration:** Set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards. Under CLIA, calibration refers to the process of testing and adjusting an instrument, kit, or test system, to provide a known relationship between the measurement response and the value of the substance being measured by the test procedure (42 CFR 493.1217).

f. **Calibrator:** A substance, material, or article intended to be used to establish the measurement relationships of a diagnostic medical device.

g. **CLIA:** Clinical Laboratory Improvement Amendments of 1988. Congressional legislation that defined and requires specific quality assurance practices in clinical laboratories.

h. **CLSI:** Clinical and Laboratory Standards Institute.

i. **Coefficient of Variation:** The ratio of the standard deviation to the average, often multiplied by 100 and expressed as a percentage, abbreviated as %CV .

j. **Colorimetry:** A technique used to determine the concentration of colored compound(s) in solution.

k. **Interfering substance:** A substance or quantity thereof that is not the measurand but that affects the result of the measurement.

l. **IUPAC:** International Union of Pure and Applied Chemistry

m. **LDT:** Laboratory –developed Test.

n. **Linearity:** Linearity is the ability of a quantitative analytical method to provide results that are directly proportional to the concentrations of an analyte in test samples, within a given measuring interval. It is an important parameter to confirm when evaluating an analytical method because it verifies correct interpolation of results between points.

o. **LMR:** Lower end of the measuring range is the lowest level at which defined conditions, including all stated characteristic of the method, are met.

p. **LoB:** Limit of Blank is the highest value in a series of results on a sample that contains no analyte.

q. **LoD:** Limit of Detection is the lowest amount of analyte in a sample that can be detected with stated probability, although perhaps not quantified as an exact value.

r. **LoQ:** When used without a prefix, the Limit of Quantitation is the lowest actual concentration at which an analyte is reliably detected and at which uncertainty of the test result is less than or equal to the goal set by the manufacturer or laboratory. The term may also be used with prefixes L for lower (LLOQ) and U for upper (ULOQ), respectively. Note: LoB < LoD ≤ LoQ.

s. **Matrix:** All components of a material system, except the analyte. A specimen matrix is the biological milieu in which an analyte exists (e.g., plasma, serum, urine, or other body fluids).

t. **Measuring Interval (reportable range; analytical measurement range or AMR):** A measuring interval consists of all numeric values between the lower and upper numeric values for which a method can produce quantitative results suitable for clinical use. Where applicable, a linearity study is frequently used to establish or verify the measuring interval that can be reported for a measurement method. Alternatively, the lower limit of the measuring interval may be assigned as the LoQ (LLOQ).

u. **Precision:** Precision is the closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions. It is usually expressed numerically in terms of standard deviation (SD) or percent Coefficient of Variation (%CV).

v. **Reference interval:** The interval between and including two reference limits. It is common practice to define a reference limit so a stated fraction of the reference values is less than or equal, or greater than or equal, to the respective upper or lower limit.

w. **SOP:** Standard Operating Procedure.

x. **Spectrophotometry:** The quantitative measurement of the transmission (or reflection) properties of a material as a function of wavelength.

y. **Testing System:** The entirety of the testing process, including instrument, sample, reagents, supplies, and procedures. Personnel are sometimes included in the definition.

III. Pre-clinical Validation

a. Analytical Measurement Range

i. Limits of Blank, Detection and Quantitation

The limits of blank, detection, and quantitation were determined to be 0.0 mg/dL, 0.2 mg/dL and 0.4 mg/dL respectively.

Limit of blank

CLSI guideline EP17-A section 4.3.1

Level	Number of samples	N	Mean	SD
Blank	1	20	0.000	0.000

Alpha	5%
Parametric LoB	0.000

Limit of detection

CLSI guideline EP17-A section 4.3.2

Level	Number of samples	N	Pooled SD
Low	1	20	0.093

Beta	5%
Parametric LoD	0.154

Limit of quantitation

CLSI guideline EP17-A section 5.1

Level	Number of samples	N
Low	1	20

Bias	0.077
Pooled imprecision	0.093
95% total error	0.259
Allowable error	0.08

The lower limit of quantitation has been established at 0.4 mg/dL (19.4% CV and 119 % recovery)

ii. Linearity

The Analytical Measurement Range (AMR) including linear measurement interval has been determined by Siemens. Refer to the Analytical Range section of the manufacturer product information insert for additional details.

b. Analytical Specificity

The analytical specificity for this assay was determined by testing the effect of hemoglobin (100 mg/dL), bilirubin (10 mg/dL) and triglycerides (400 mg/dL) on plasma samples spiked with the interferents and then compared with un-spiked controls. Magnesium concentration at which the interference testing was performed was at 2 mg/dL. Non-interference was defined as the mean result from testing of spiked samples within 10% of the mean of the un-spiked samples. Recoveries were within 98.5% to 102.7% (see table below).

Table 1. Interference Testing For Magnesium

Analyte (mg/dL)	% Recovery		
	Interferent		
	Bilirubin (10 mg/dL)	Hemoglobin (100 mg/dL)	Triglycerides (400 mg/dL)
Magnesium	98.5	101.6	102.7

No significant interference was observed.

c. Precision

Level = Level 1

Number of observations	80
Number of runs	40
Number of days	20
Runs per day	2
Replicates per run	2
Mean	1.218

	SD	95% CI	CV	Allowable Total SD
Repeatability	0.155	0.127 to 0.198	12.7%	-
Between-run	0.000		0.0%	-
Between-day	0.170		14.0%	-
Within-laboratory	0.230	0.188 to 0.298	18.9%	0.304

Imprecision is less than allowable total imprecision: 25% upto 3mg/dL then 15%.

Level = Level 2

Number of observations	80
Number of runs	40
Number of days	20
Runs per day	2
Replicates per run	2
Mean	2.875

	SD	95% CI	CV	Allowable Total SD
Repeatability	0.120	0.099 to 0.154	4.2%	-
Between-run	0.048		1.7%	-
Between-day	0.155		5.4%	-
Within-laboratory	0.201	0.164 to 0.262	7.0%	0.719

Imprecision is less than allowable total imprecision: 25% upto 3mg/dL then 15%.

Level = Level 3

Number of observations	80
Number of runs	40
Number of days	20
Runs per day	2
Replicates per run	2
Mean	4.188

	SD	95% CI	CV	Allowable Total SD
Repeatability	0.080	0.066 to 0.103	1.9%	-
Between-run	0.000		0.0%	-
Between-day	0.145		3.5%	-
Within-laboratory	0.166	0.132 to 0.226	4.0%	0.628

Imprecision is less than allowable total imprecision: 25% upto 3mg/dL then 15%.

IV. Clinical Validation

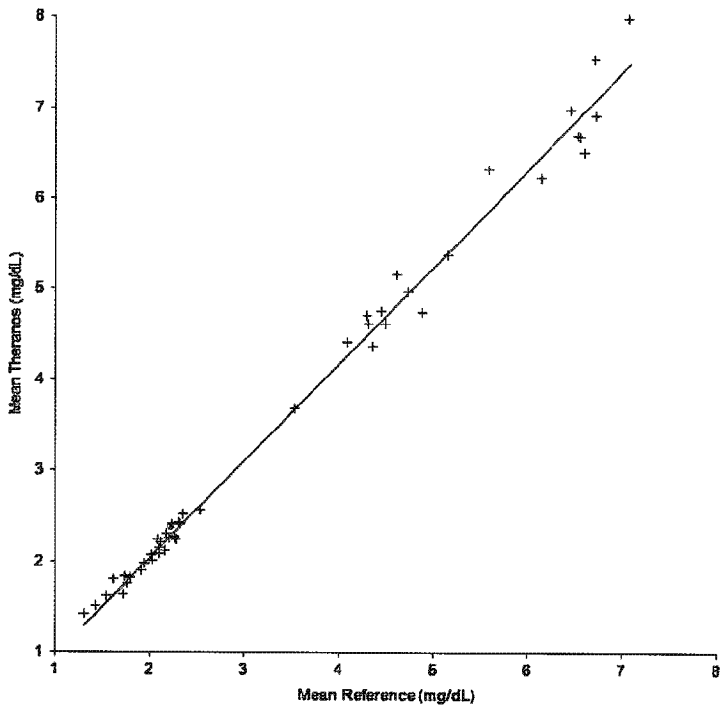
a. Method Comparison with Predicate (Accuracy/Comparability)

To test the accuracy of the assay on the Theranos System, Forty nine unique patient samples were screened on the predicate method (Siemens, Advia) and on the Theranos method. Using the predicate method twenty nine (29) values were within the reference range (1.3 – 2.7 mg/dL), none (0) were below the reference range, and twenty (20) were above the reference range. Based on the results of the data examination, either a simple linear regression or alternative procedures were used to estimate expected (average) bias and the confidence interval of expected bias at the desired medical decision level(s) as per CLSI guidance EP09-A2. StatisPro was used for bias calculations. These estimates were compared with internal criteria to judge the acceptability of the Theranos method. Each sample was run in duplicate on the predicate, and the average used for comparison to the Theranos method. Some samples were stored before analysis on both methods. If the confidence interval for the predicted bias includes the defined acceptable bias or if the acceptable bias is greater than the higher limit of the confidence interval of the predicted bias, then the data do not show that the bias of the Theranos method is different from the acceptable bias or there is a high probability (97%) that the predicated bias is acceptable, respectively. The acceptable bias at each medical decision level was determined based on the total allowable error (TEa) minus the measured precision at the level closest to that decision level. Total allowable error (TEa) was taken from American Proficiency Institute (API) peer proficiency testing criteria or CLIA proficiency

testing criteria for acceptable analytical performance, as printed in the Federal Register February 28, 1992;57(40):7002-186, when available. The TEa for Magnesium is 25%. The table below shows the allowable bias and precision at 3 levels (values shown in parentheses) and the corresponding closest medical decision limits.

Table 2. Allowable Bias and Precision at the Medical Decision Levels

Medical Decision Levels (mg/dL)	**1.2 (1.2)**	**2.0 (2.9)**	**5.0(4.2)**
Precision (%)	**14.0**	**5.4**	**3.5**
Allowable Bias (%)	**11.0**	**19.6**	**21.5**



Observation comments

1. Detected outliers greater than 4 mean absolute difference and 4 * mean relative absolute difference.*

Figure 1. Graph showing Theranos method versus Predicate Method (Siemens Advia).

Simple linear regression was used to establish a slope, intercept and an r^2. The slope, intercept and clinical correlation were determined to be 1.07, -0.09 and 0.99 respectively.

Comparability

CLSI guideline EP09-A2-IR section 7

Level ID	Value	Difference	SE	95% CI	Allowable difference
	1.200000	-0.0110670	0.04321620	-0.0980567 to 0.0759227	0.2400000
	2.000000	0.0445268	0.03470148	-0.0253236 to 0.1143773	0.4000000
	5.000000	0.2530036	0.03617740	0.1801823 to 0.3258250	1.0000000

Difference is less than allowable bias: 11% upto 1.2mg/dL then 20%.

The difference between the two methods is not greater than the allowable difference. The performance requirement is verified.

b. Transference and Verification of Reference Interval (Venous)

Reference ranges were modified by applying the regression equation to the lower and upper reference limits of existing reference interval to generate a new reference range. New reference ranges were verified using a minimum of twenty (20) new normal subjects

New reference ranges were verified using a total of fifty three (53) new normal subjects with matched Lithium heparin venous and finger sticks samples. For a reference range to pass verification, 95% of values should fall within the upper and lower reference limits and 5% or fewer values fall outside of the upper and lower reference limits. For venous verification 53 (100%) values fell within the new reference range and 0 (0%) values fell outside the new reference range. See graphs below for venous samples verification.

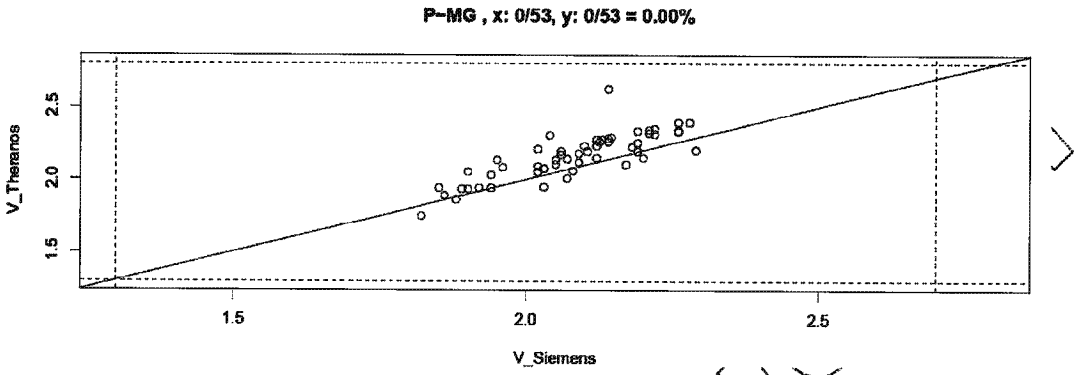


Figure 2. Graph showing venous sample reference range verification.

c. Verification of Reference Interval with Finger Stick Samples

New reference ranges were also verified with venous matched finger sticks (Lithium heparin) samples from a total of forty nine (49) new normal subjects. The finger stick samples were collected in a Theranos blood collection device (BCD) configured with separate Lithium heparin and EDTA vessels. For finger stick verification 48 values (98%) fell within the new reference range and 1 value (2%) fell outside the new reference range. See graphs below for finger stick samples verification.

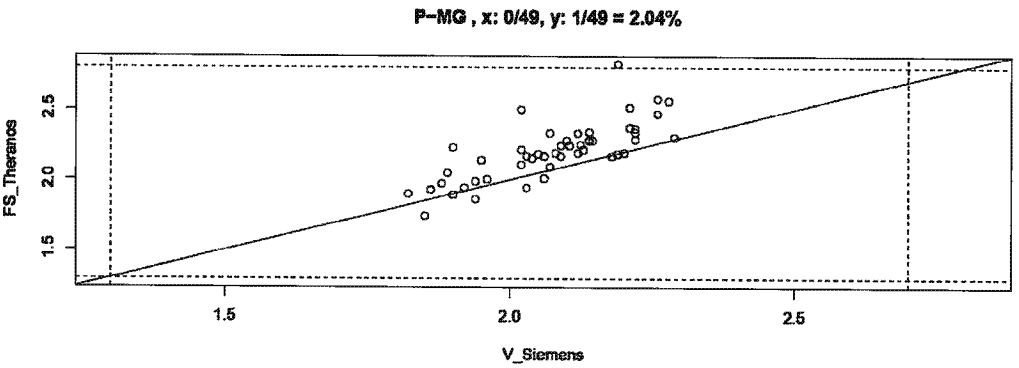


Figure 3. Graph showing Finger stick sample reference range verification.

The new reference range for finger stick Magnesium was determined to be 1.3 – 2.8 mg/dL.

VI. Stability

a. Reagents

On-board Reagent Stability

System	Without Reagent Container Insert	With Reagent Container Insert
ADVIA 1200	4 days	10 days
ADVIA 1650/1800	4 days	21 days
ADVIA 2400	4 days	21 days

For all systems, unopened reagents are stable until the expiration date printed on the product label when stored at 2°C - 8°C. Do not freeze the reagents.

For additional details, refer to the Methods Introduction section of the system-specific Operator's Guide.

b. Sample

Plasma samples for magnesium analysis are stable for 2 weeks at 2-8 °C, or at least 90 days at -20 °C.

c. Calibrators

Siemens Chemistry Calibrators should be stored at 2-8 °C, protected from light, and are stable until the expiration date on the vial label. Opened calibrators are stable for 48 hours, except for total and direct bilirubin, which are stable for 8 hours.

REVISION HISTORY

Revision Level	Effective Date	Initiator	ECO Number
A	11/10/2013	A. Rosendorff	CL ECO-00118

Section Number	Description and Justification of Changes
All	Initial Release