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Assessment of Analytical Quality through Sigma Metrics & its Application for Selection of Westgard Rule

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Abstract:- Background: In today's world, the clinical laboratory is a rapidly expanding area under constant demand to give speedy and reliable results. A clinical laboratory's performance is measured using IQC and EQAS. However, these approaches cannot quantify the number of errors. A new tool called sigma metric quantifies the approximate amount of analytical errors, and assesses and directs the development of better quality control procedures. In order to minimizing error rates Six Sigma were utilized to quantify the analytical quality of automated clinical chemistry.
Objective: This study was conducted to estimate Sigma metrics and Quality Goal Index of various biochemical analytes in order to evaluate quality control performance and execute the best quality control approach for each analyte.
Material and method: IQC and EQA data were examined using a chemistry auto analyzer (Architect C 8000) at the Biochemistry laboratory, Sir T Hospital, Bhavnagar, from January 2022 to October 2022. Mean, standard deviation, coefficient of variation %, bias % and sigma metrics and Quality Goal Index were calculated for Plasma Glucose, serum Urea, Creatinine, alanine ALT, AST, Total protein, Albumin, ALP, Total Cholesterol, Triglyceride, HDL, LDL, Uric acid and LDH.
Results: Excellent sigma values were elicited for SGOT (Level 2), ALP, Triglycerides, HDL, and Uric acid. Satisfactory sigma values were elicited for, Creatinine (both the levels) TP, LDH (Level 1), SGPT, LDL (Level 2), while Glucose, Albumin, Cholesterol, (both the levels) SGPT, LDL (Level 1), TP (Level 2) having sigma value <3.
Conclusion: Sigma metrics is useful for addressing poor performance in assessments, improves laboratory performance and aids in the evaluation of analytical techniques. It serves as a roadmap for developing a quality control strategy. It can be used as a self-evaluation tool for clinical laboratories.

Keywords:- *IQC, EQAS, Six Sigma, Quality Goal Index*

I. INTRODUCTION

In the Healthcare Laboratory, "quality" is defined as adherence to the needs and expectations of users (nurses and physicians) or customers (patients or other parties who pay the bills), as well as satisfaction of those needs and expectations.(1) A high-quality laboratory's performance is evident in both the test reports it produces and the Quality Controls it conducts as performance checks. (2)

Clinical laboratories use a variety of procedures to ensure quality, including Internal Quality Control and External Quality Control.(3) IQC is a sample material with a matrix that is identical to that of the patient's sample and a concentration range that is available in two or three levels to cover the medical decision points. The IQC is performed according to NABL guidelines and interpreted using Levy Jennings' control charts and Westgard rules. IQC keeps a constant eye on the analytical system to see if the results are trustworthy enough to be released.(4)(5) External quality control entails analyzing and reporting control samples provided by a third party at a predetermined time interval, which in clinical chemistry is once a month. The Z score or the standard deviation indexes are used to interpret external quality control. A Z score is a calculated value that indicates how many standard deviations a control result has deviated from the expected mean value for that material.(4)(5)While running internal and external QCs, it is difficult to quantify the exact amount of errors that occur in the system and to provide a direct and integrated evaluation of the analytical system's performance, Sigma metrics can.(6)

Six Sigma is a management approach that helps to enhance process output quality by identifying and eliminating the causes of defects (errors) and limiting variability in manufacturing and business processes.(7) Six is the number of standard deviations from the mean, which is a statistical measure of distribution. It is a data-driven and statistically driven strategy to eliminating manufacturing faults. (2) Concept of six sigma began at Motorola in 1982 with the goal of lowering costs, enhancing manufacturing techniques, reducing variation, and promoting quality improvement.(8) In the year 2000, laboratory medicine adopted the "Six Sigma" technique.(2) The first study utilizing sigma metrics in the clinical lab was published by Nevalainen et al., in the year 2000 and since then many similar studies have been done throughout the world. (9) The Sigma scale, which is used to categories performance, ranges from sigma level 1 to 6, with 6 being the target for world-class quality and 3 being the least allowed sigma for routine performance.(11) Although achievement of sigma metrics value 6 or more is not easy, but with appropriate precautions to minimize the errors associated with sample processing; this goal can be approached.

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DMAIC was the methodology used in our Central Laboratory to deploy Lean Six Sigma. TQM and the Six Sigma model are comparable. In comparison with TQM's PDCA, we can say that define corresponds to the plan step, measure to the do step, analyze to the check step, and improve to the act step. Control is an additional step in the Six Sigma model that is critical in modern quality management. With this step, We can avoid defects returning to the process with this step.(7)(10)(9) It means "identifying" the issue that is causing our results to deviate from a set of accepted criteria. It also entails identifying the resources that may be required to tackle the issue. (1)(4) After that, in order to tackle the problem, its extent was "measured" by collecting relevant data and storing it in a more presentable format, such as collecting IQC and EQC data and computing CV percent and Bias percent from it. (11)Subsequently the information was "analyzed" to work out the basis explanation for problems. During this phase, we estimate the disparities between our results and also the goal values, yet as determine their likely reasons. (12) After that, the foundation causes were eliminated by implementing certain corrective measures in accordance with Westgard sigma rules to "improve" the method performance. Following the correction of the problem, specific preventive measures were implemented to "control" or "check" that the matter wouldn't recur within the future. Every step of sample processing was meticulously checked and monitored so as to eliminate any errors or inefficient operations. To minimize TAT and enhance sample processing quality, many remedial procedures were performed to cut back mistakes at the pre-analytical, analytical, and post-analytical phases.(11)

II. MATERIALS &METHODS

From January to October 2022, an extensive investigation of sample processing and quality control methods was conducted in the Clinical Biochemistry Laboratory at Sir T Hospital in Bhavnagar, Gujarat. The parameters which were analyzed include Glucose, Urea, Creatinine, AST, ALT, ALP, total protein, albumin, cholesterol, triglyceride, high Density Lipoprotein (HDL), Low Density Lipoprotein (LDL), Uric acid, LDH. Both levels of IQC were done using Architect C 8000 clinical chemistry analyzer and all data were analyzed on each day. Only if the IQC was within the permissible range according to Westgard guidelines were the patients' samples conducted and reported. The IQC material (both level I & level II) were obtained from Randox Laboratories India (lyphochek assayed chemistry control). EQAS sample was run once in every month which was obtained from Randox Laboratories, UK.

Calculation of CV%

By using IQC data; Mean & S.D. were determined from which CV% was calculated for each month.(2) The test method's analytical coefficient of variation is represented by CV percent. It is a indicator of random error. CV has no dimensions and is unaffected by changes in measuring units. If CV is less than 5%, then the particular method used for determination of an analytes concentration is said to have a very good performance& precise. Precision is the degree of agreement between independent, repeatable results obtained from the same sample under certain conditions.(5)

CV% = SD x 100 / Lab Mean

Calculation of Bias: Bias is the systematic discrepancy between the results that would be achieved using a recognised reference technique and the predicted results obtained by the laboratory's test method. Bias is used to describe the inaccuracy of the method. Lower the bias more is the accuracy.(5) The following formula was used to determine bias using RIQAS:

Bias (%) = (Mean of all laboratories using same instrument & method – Our Laboratory Mean) / (Mean of all laboratories using same instrument & method) x 100

The total permissible error: The total permissible error (TEa) values were derived from CLIA-88 (Clinical Laboratories Improvement Act) recommendations. (8)

Calculation of sigma metrics: Sigma metrics (σ) were calculated using the equation:

Sigma metrics (σ) = (TEa – Bias) / CV

Calculation of Quality Goal Index: The quality goal index (QGI) ratio indicates how well bias and precision meet their respective quality goals. This was used to investigate the cause of the lower sigma in analytes, i.e., whether the issue is due to imprecision, inaccuracy, or both. (4)(11)

QGI = Bias/1.5 × CV%.

Table 1: Sigma level and ppm defects or errors per Million Opportunities (DPMO)

Sigma Level	Accuracy	Long-Term ppm* Defects
1	30.85%	691,462
2	69.1%	308,538
3	99.33%	66,807
4	99.38%	6,210
5	99.977%	233
6	99.99966%	3.4

Table 2: Criteria for interpreting Quality Goal Index: (4)

QGI	Problem

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<0.8	Imprecision
0.8-1.2	Imprecision and inaccuracy
>1.2	inaccuracy

Table 3: CV% calculated from Internal Quality Control L1 from January 2022 To October 2022

L1											
Parameter	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**AVG**
Glucose	3.29	6.00	3.03	2.79	3.68	3.16	-	3.68	2.59	3.58	3.18
Urea	3.57	3.59	0.54	3.75	2.75	4.54	4.59	4.03	3.76	2.62	3.374
Creatinine	4.17	3.53	4.05	3.58	3.45	1.82	-	3.15	5.72	4.46	3.77
SGPT	6.62	4.89	5.20	5.36	6.98	5.29	5.35	6.14	5.25	6.67	5.775
SGOT	3.59	3.37	3.25	3.03	3.45	3.17	3.94	3.27	3.13	3.11	3.331
ALP	6.00	4.31	3.27	4.38	4.06	3.34	3.24	5.52	5.04	5.54	4.47
TP	2.68	2.02	2.36	3.61	2.43	2.17	1.8	2.15	2.44	1.83	2.349
ALB	2.80	2.02	2.30	3.02	3.11	3.30	2.76	0.92	3.36	2.44	2.603
Cholesterol	2.60	2.79	3.31	2.92	2.81	1.30	1.24	3.03	3.20	2.20	2.54
TG	3.16	3.80	2.6	2.03	3.56	1.91	1.93	2.89	2.39	1.67	2.594
HDL	4.56	4.18	3.81	3.56	4.48	3.0	4.86	3.43	3.57	3.05	3.85
LDL	5.26	4.94	2.96	4.03	4.27	3.70	3.16	3.98	RNS	2.71	3.89
UA	3.74	2.28	2.32	9.0	2.52	1.33	1.55	2.36	2.51	1.73	2.934
LDH	5.0	4.85	4.32	4.98	6.01	4.18	6.64	3.91	3.63	3.96	4.748
LIPASE	5.39	6.62	3.12	12.7	3.15	3.30	3.68	4.01	2.22	2.81	4.7

Table 4: CV% calculated from Internal Quality Control L2 from January 2022 to October 2022

L2											
Parameter	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**AVG**
Glu	2.86	2.69	3.17	3.40	3.73	1.88	-	3.55	2.50	3.31	3.01
Urea	3.56	2.50	3.61	3.67	2.42	3.32	2.49	4.14	2.49	2.57	3.07
Creat	3.04	2.63	3.31	2.26	2.16	1.70	-	2.89	3.13	5.42	2.94
SGPT	3.19	2.67	4.51	2.19	3.06	3.93	3.58	4.27	2.81	3.62	3.38
SGOT	3.23	2.53	3.15	3.19	2.72	2.11	2.57	3.96	1.79	2.72	2.79
ALP	3.25	2.80	2.82	2.53	3.34	1.89	2.25	4.67	4.52	5.47	3.35
TP	3.11	2.61	2.91	2.44	3.18	3.57	3.68	2.96	2.05	2.83	2.93
ALB	3.0	2.98	3.61	3.28	2.67	5.69	2.92	1.92	2.07	2.22	3.03
CHOLE	3.02	2.84	2.48	3.13	2.74	3.36	1.59	2.91	1.43	2.78	2.62
TG	3.65	4.38	3.29	2.85	2.96	2.53	2.33	5.18	1.87	2.83	3.18
HDL	5.15	4.58	3.32	3.16	3.52	3.37	5.13	4.09	2.99	4.25	3.95
LDL	4.39	5.55	4.37	2.60	2.81	2.61	2.89	2.72	RNS	3.42	3.48
UA	3.76	2.86	2.0	2.10	2.02	1.91	1.95	2.33	1.77	1.49	2.21
LDH	2.65	2.89	2.99	4.35	4.55	3.92	3.83	3.52	3.29	2.60	3.45
LIPASE	4.19	6.64	4.20	10.85	3.09	4.36	3.15	4.18	3.50	2.42	4.65

Table5. Bias % calculated from RIQAS from January 2022 to October 2022

Paramter	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Avg**
GLU	1.3	9.9	1.4	1.6	0.4	1.2	0.1	1.6	5.9	1.0	2.44
UREA	7.3	11.4	8.5	4.0	5.1	10.3	10.2	7.0	5.8	7.9	7.75
CREAT	4.9	7.2	7.4	0.5	4.0	3.7	0.1	1.8	5.3	1.6	3.65
SGPT	1.5	7.1	5.2	12.3	9.6	8.4	8.9	6.2	11.4	5.0	7.56
SGOT	2.9	0.4	1.0	8.1	5.2	6.6	4.4	5.7	0.9	5.4	4.06
ALP	8.6	16.32	0.9	3.8	4.5	3.9	2.7	7.9	13.9	12.4	7.49
TP	1.6	0.8	1.1	3.5	6.3	1.6	3.5	1.7	6.6	1.6	2.83
ALB	3.7	1.9	1.8	1.3	1.9	3.5	6.3	0.6	4.6	0.0	2.56
CHOLE	1.6	4.6	7.6	3.1	7.3	0.5	0.0	1.9	2.2	3.7	3.25
TG	0.5	6.0	0.8	5.9	3.2	2.0	3.9	0.8	4.8	3.1	3.1
HDL	4.4	2.2	0.0	0.2	1.8	0.2	9.3	0.7	2.5	0.5	2.18
LDL	1	4.7	9.5	11.6	10.9	14.3	16.8	9.6	-	4.3	9.18
UA	0.3	0.7	0.1	1.1	2.2	0.1	3.1	3.7	5.1	0.6	1.7

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LDH	5.7	1.8	1.7	12.7	8.3	6.0	5.8	4.4	2.0	4.0	5.24

Table 6. Average Bias, Average CV% & sigma metrics calculated for 10 months for both levels of IQC (L1 & L2).

Paramter	TAE	BIAS	CV 1	Sigma 1	CV2	Sigma 2
GLU	10	2.44	3.18	2.38	3.01	2.51
UREA	9	7.75	3.37	0.37	3.077	0.40
CREAT	15	3.65	3.77	3.01	2.95	3.85
SGPT	20	7.56	5.77	2.15	3.38	3.68
SGOT	20	4.06	3.33	4.78	2.80	5.70
ALP	30	7.49	4.47	5.03	3.35	6.71
TP	10	2.83	2.35	3.05	2.93	2.44
ALB	10	2.56	2.60	2.86	3.04	2.45
CHOLE	10	3.25	2.54	2.66	2.63	2.57
TG	25	3.1	2.59	8.44	3.19	6.87
HDL	30	2.18	3.85	7.23	3.96	7.03
LDL	20	9.18	3.89	2.78	3.48	3.10
UA	17	1.7	2.93	5.22	2.22	6.89
LDH	20	5.24	4.74	3.11	3.46	4.27

Table-7: Sigma metrics of various parameters

Sigma metrics	L1	L2
<2 (Unacceptable)	Urea	Urea
2-3 (Poor)	Glucose, SGPT, Albumin, Cholesterol, LDL	Glucose, TP, Albumin, Cholesterol
3-4 (Acceptable)	Creatinine, TP, LDH	Creatinine, SGPT, LDL
4-5 (Good)	SGOT,	LDH
5-6 (Excellent)	Uric acid, ALP,	SGOT,
>6 (world class performance)	Triglyceride, HDL	ALP, Triglyceride, HDL, Uric acid

Table-8: QGI

Parameter	QGI (L1)	Problem	QGI (L2)	Problem
Glucose	0.5	Imprecision	0.5	Imprecision
Urea	1.5	inaccuracy	1.7	inaccuracy
SGPT	0.9	Imprecision and inaccuracy	1.5	inaccuracy
Total protein	0.8	Imprecision and inaccuracy	0.6	Imprecision
Albumin	0.6	Imprecision	0.6	Imprecision
Cholesterol	0.8	Imprecision and inaccuracy	0.8	Imprecision and inaccuracy
LDL	1.6	inaccuracy	1.8	inaccuracy

III. DISCUSSION

The present study was undertaken to evaluate the quality of the analytical performance of clinical chemistry laboratory of Sir T Hospital, Bhavnagar, Gujarat, India on sigma scale. In clinical laboratories, evaluating the quality of laboratory testing is an important research topic. Six Sigma quality standards consider bias (system error) and CV (random error) to guide quality management in clinical laboratories while analyzing possible causes of error, identifying solutions, improving testing quality, and optimizing the QC schedule. However, the optimal TEa, bias, CV, and other indicators to calculate 6σ are unknown, especially when the sources of bias and CV differ between laboratories. As a result, we compared two new methods for calculating metrics as a future reference for the implementation of 6σ quality management in clinical laboratories. (14)

Selection of westgard rules Based on the sigma values obtained from the QC: (16)

>6σ –excellent tests =evaluate with 1 QC/day.(alternating levels between days) and follow 1-3 s Westgard rule.

4 σ - 6 σ =suited for purpose –evaluate with two levels of QC /day, follow 1-3 s, 2-2 s, R4 s Westgard multirules.

3 σ - 4 σ =poor performers-use a combination of rules with 2 levels of qc/day, follow 1-3 s, 2-2 s, R4s, and 4-1 s Westgard's multirules

< 3 σ = max QC, 3 levels, 3 times a day. Root cause analysis should be performed; method performance must be improved before the method can be routinely used (10)(11)(13)

It can be visualized from Table1 & Table 2 that except for SGPT (CV%>5 in L1) all parameters depicted CV<5%. This clearly indicates that our lab has achieved high level of precision in remaining 13 analytes.

Another important calculated index in the present study is bias% by using the EQC data. Bias shows high degree of accuracy in our lab results. Out of all the parameters

measured in the present study Urea, SGPT, ALP, LDL, LDH had Bias >5%. Rest all parameters depicted Bias <5%. This indicates that our lab has achieved high level of accuracy in remaining 9 analytes.

In the present study; σ>5 for Triglyceride, HDL, ALP, Uric acid, SGOT(Level 2) was observed (Table 4). Hence it required only 13s, 22s, and R4s to be followed.

σ>3-5 for both the level of IQC was observed for Creatinine, LDH, TP, SGOT, SGPT, LDL. It implies Westgard sigma multirole application is needed for such parameters.

Those parameters having σ<3 requires extensive evaluation in terms of reducing analytical bias & imprecision.

Mahmood, Bushra, et al.have similar result for the Glucose, Creatinine and Urea(<3 sigma) and SGPT(>3).(17)(18) has similar results for Total protein and Albumin and Total Bilirubin(<3 sigma) and for triglyceride sigma value is >3.(19) However 20 number study does not coincide with our study result which shows sigma value > 6 for the Glucose, Creatinine and Total Bilirubin.(20)

IV. CONCLUSION

Sigma metrics in clinical laboratories is a crucial methodology to detect and rectify any lab results that deviate from the established criteria. It can assist us in determining poor assay performance and in evaluating the effectiveness of the current laboratory procedures. The idea of sigma metrics allows for the elimination of time-consuming and costly additional stages. This will shorten the turnaround time and facilitate the delivery of high-quality reports for improved patient care. Additionally, sigma metrics can aid in developing suitable plans for the prudent application of IQC & EQC in a larger clinical laboratory.(8) The goal of six sigma is to ensure that important specifications are met by reducing both variance and quality control procedures. It is also imperative to implement appropriate QC strategies in order to augment the judicious use of QC.(6)

REFERENCES

[1]. Garg M, Sharma N, Das S. SIGMA METRICS ASSESSMENT AS QUALITY IMPROVEMENT METHODOLOGY IN A CLINICAL CHEMISTRY LABORATORY. medRxiv. 2021 Jan 1.
[2]. Klee GG, Westgard JO. Quality Management. In: Burtis AC, Ashwood ER, Brurns DE, editors. Tietz Textbook of Clinical Chemistry and Molecular Diagnostics. Saunders: Philadelphia; 2012. p. 163–204.
[3]. Koshy JS, Raza A. Sigma metrics in quality control-An innovative tool.
[4]. Westgard JO. Six Sigma quality design and control. Westgard QC. Inc, Madison. 2006.
[5]. Kumar BV, Mohan T. Sigma metrics as a tool for evaluating the performance of internal quality control in a clinical chemistry laboratory. Journal of laboratory physicians. 2018 Apr;10(02):194-9.
[6]. Angmo D, Kant S. Six sigma implementation in healthcare industry: Past, present and future. Int J Eng Res Technol. 2015;4(6):1078-82.
[7]. Adiga US, Preethika A, Swathi K. Sigma metrics in clinical chemistry laboratory-A guide to quality control. Al Ameen J Med Sci. 2015;8(4):281-7.
[8]. Westgard S, Bayat H, Westgard JO. Analytical Sigma metrics. A review of Six Sigma implementation tools for medical laboratories. Biochem Med (Zagreb). 2018;28(2):020502.
[9]. Nevalainen D, Berte L, Kraft C, Leigh E, Picaso L, Morgan T. Evaluating laboratory performance on quality indicators with the six sigma scale. Archives of Pathology & Laboratory Medicine. 2000;124(4):516–519.
[10]. Coskun A, Inal TC, Serteser M. Six Sigma Projects and Personal Experiences. Croatia: InTech; 2011.
[11]. Smętkowska M, Mrugalska B. Using Six Sigma DMAIC to improve the quality of the production process: a case study. Procedia-Social and Behavioral Sciences. 2018 Jan 1;238:590-6.
[12]. Heher YK. A brief guide to root cause analysis. Cancer Cytopathology. 2017 Feb;125(2):79-82.
[13]. Singh B, Goswami B, Gupta VK, Chawla R, Mallika V. Application of sigma metrics for the assessment of quality assurance in clinical biochemistry laboratory in India: a pilot study. Indian journal of clinical biochemistry. 2011 Apr;26(2):131-5.
[14]. Westgard JO, Westgard SA. The quality of laboratory testing today: an assessment of σ metrics for analytic quality using performance data from proficiency testing surveys and the CLIA criteria for acceptable performance. American journal of clinical pathology. 2006 Mar 1;125(3):343-54.
[15]. Kinns H, Pitkin S, Housley D, Freedman DB. Internal quality control: best practice. Journal of Clinical Pathology. 2013 Dec 1;66(12):1027-32.
[16]. Mahmood B, Rasheed MK, Khazal A, Rasheed MK. Assessment of sigma metric results of serum parameters of liver and kidney function tested by automated chemistry analyzer in Medical City Hospital. Iraqi Postgrad Med J. 2018;17(3):307-14.
[17]. Kaftan AN, Yaseen AK, Hasan Z. Assessment of sigma metrics results of serum glucose and lipid profile tested by automated chemistry analyzer in medical city hospitals in Iraq. Int J Res Med Sci. 2017;5(11):4690–6
[18]. Iqbal S, Mustansar T. Application of sigma metrics analysis for the assessment and modification of quality control program in the clinical chemistry laboratory of a tertiary care hospital. Indian Journal of Clinical Biochemistry. 2017 Mar;32(1):106-9.
[19]. Hamza MM. Assessment of Quality Control in a Clinical Chemistry Laboratory using Six Sigma Metrics (Doctoral dissertation, University of Gezira).
[20]. Al-Hassan M. Assessment of Quality Control in a Clinical Chemistry Laboratory using Six Sigma Metrics; 2017. Available from: http:// repo.uofg.edu.sd/handle/123456789/2979.